EPA

United States
Environmental Protection
Agency

The Regional Benefits Assessment for the Proposed Section 316(b) Rule for Phase III Facilities

November 2004

U.S. Environmental Protection Agency
Office of Water (4303T)
1200 Pennsylvania Avenue, NW
Washington, DC 20460

EPA-821-R-04-017

ACKNOWLEDGMENTS AND DISCLAIMER

This document was prepared by the Office of Water staff. The following contractors provided assistance and support in performing the underlying analysis supporting the conclusions detailed in this document.

Stratus Consulting Inc.
Abt Associates Inc.
Tetra Tech
Science Applications International Corporation

The Office of Water has reviewed and approved this document for publication. The Office of Science and Technology directed, managed, and reviewed the work of the contractors in preparing this document. Neither the United States Government nor any of its employees, contractors, subcontractors, or their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use of or the results of such use of any information, apparatus, product, or process discussed in this document, or represents that its use by such party would not infringe on privately owned rights.

Table of Contents

Introduction

Introduction

Contents

EPA is proposing regulations implementing section 316(b) of the Clean Water Act (CWA). This regulation is the third in a series of rulemaking actions under CWA section 316(b), addressing the environmental impacts of cooling water intake structures (CWIS). The Proposed Section 316(b) Rule for Phase III Facilities would establish national performance requirements for the location, design, construction, and capacity of CWIS at facilities subject to this regulation. The proposed national requirements would establish the best technology available (BTA) to minimize the adverse environmental impact (AEI) associated with the use of these structures. CWIS may cause AEI through several means, including impingement (where fish and other aquatic life are trapped on equipment at the entrance to CWIS) and entrainment (where aquatic organisms, eggs, and larvae are taken into the cooling system, passed through the heat exchanger, and then discharged back into the source water body).

Facilities potentially subject to regulation under Phase III consist of the following types of facilities that employ a cooling water intake structure and are designed to withdraw two million gallons per day or more from waters of the United States: (1) existing manufacturing facilities, (2) existing electric power producing facilities with a design intake flow (DIF) of less than 50 million gallons per day (MGD), and (3) new offshore oil and gas extraction facilities. These facilities are referred to as “potential Phase III facilities.” Phase III would not include facilities regulated under Phase I (new facilities other than new offshore oil and gas extraction) or Phase II (existing power producing facilities with a DIF of 50 MGD or greater). More information on the regulated sectors and facilities can be found in *the Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004).

This Regional Benefits Assessment presents the methods used by EPA for the environmental assessment and benefits analysis of regulatory options. EPA's analysis had four main objectives: (1) to develop a national estimate of the magnitude of impingement and entrainment (I&E) at potentially regulated Phase III facilities; (2) to estimate changes in the I&E losses as a result of projected reductions in I&E under the proposed rule options; and (3) to estimate the national economic benefits of reduced I&E. The environmental assessment and benefits analyses presented in this report pertain only to the Manufacturers and Electric Generators segments of the industries subject to the 316(b) Phase III regulation because EPA was unable to assess benefits for facilities in the Oil and Gas industry segment due to the lack of data at the time of proposal. Part A of the document provides details of the methods used. Parts B-G present reports of results for each of six study regions. Finally, Part H presents national estimates. The following sections provide an overview of the study design and a summary of the contents of each part of the document.

1-1 Summary of the Proposed Rule and Other Evaluated Options

In today’s proposal, EPA is proposing three options for existing facilities based on DIF and source waterbody type. These options define which facilities are Phase III existing facilities that would be subject to the proposed national categorical requirements. The three proposed options would regulate:

- (1) facilities with a total design intake flow of **50 MGD or more** and located on **any source waterbody type**;
- (2) facilities with a total design intake flow of **200 MGD or more** and located on **any source waterbody type**;
- (3) facilities with a total design intake flow of **100 MGD or more** and located on **certain waterbody types** (i.e., an ocean, estuary, tidal river/stream or one of the Great Lakes).

The proposed rule would require Phase III existing facilities to meet the same performance standards as those required in the final Phase II rule, including a 80-95% reduction in impingement mortality and a 60-90% reduction in entrainment. The proposed rule also provides for the same five compliance alternatives specified in the final Phase II rule. If a facility is a point source that uses a cooling water intake structure and has, or is required to have, an NPDES permit, but does not meet the definition of Phase III existing facility under the corresponding evaluated option (e.g., the intake is below the specified design intake flow/source waterbody threshold or does not meet the 25% cooling purposes threshold), it would be subject to requirements implementing section 316(b) of the Clean Water Act set by the permit director on a case-by-case basis, using best professional judgment (BPJ).

In developing this proposal, EPA evaluated several additional options based on varying flow regimes and waterbody types. Two of these options (specifically, Options 1 and 6 below) are based on applying the same performance standards and compliance alternatives as those being proposed (i.e., the final Phase II performance standards and requirements including the use of case-by-case permit determinations based on BPJ for facilities below the applicable thresholds) but using different design intake flow (DIF) applicability thresholds. EPA also considered a number of options (specifically Options 2, 3, 4, and 7 below) that would establish different performance standards for certain groups or subcategories of Phase III existing facilities. Under these options, EPA would apply the proposed performance standards and compliance alternatives (i.e., the Phase II requirements) to the higher threshold facilities, apply the less-stringent requirements as specified below to the middle flow threshold category, and would apply BPJ below the lower threshold.

Each of the options evaluated in developing this proposed rule is described in detail below:

Option 1 (“20 MGD for All Waterbodies Option”): Facilities with a DIF of 20 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today’s rule. Under this option, section 316(b) requirements for existing Phase III facilities with a DIF of less than 20 MGD would be established on a case-by-case, BPJ, basis.

Option 2: Facilities with a DIF of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today’s rule (discussed above). Facilities located on estuaries, oceans, tidal rivers or streams, or one of the Great Lakes, and with a DIF between 20 and 50 MGD (20 MGD inclusive) would be subject to the same performance standards and compliance alternatives proposed in today’s rule. Facilities located on freshwater rivers and lakes with a DIF between 20 and 50 MGD (20 MGD inclusive) would have to meet the performance standards for impingement mortality only and not for entrainment. Under this option, section 316(b) requirements for existing Phase III facilities with a DIF of less than 20 MGD would be established on a case-by-case, BPJ, basis.

Option 3: Facilities with a DIF of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today’s rule (discussed above). All facilities with a DIF between 20 and 50 MGD (20 MGD inclusive) would have to meet the performance standards for impingement mortality only and not for entrainment. Under this option, section 316(b) requirements for existing Phase III facilities with a DIF of less than 20 MGD would be established on a case-by-case, BPJ, basis.

Option 4: Facilities with a DIF of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today’s rule (discussed above). Facilities located on estuaries, oceans, tidal rivers or streams, or one of the Great Lakes, and with a DIF between 20 and 50 MGD (20 MGD inclusive) would be subject to the same performance standards and compliance alternatives proposed in today's rule. Under this option, section 316(b) requirements for all existing Phase III facilities on freshwater rivers/streams or lakes/reservoirs and with a DIF between 20 and 50 MGD (20 MGD inclusive), and all existing Phase III facilities with a DIF of less than 20 MGD would be established on a case-by-case, BPJ, basis.

Option 5 (Proposed "50 MGD for All Waterbodies Option"): Facilities with a DIF of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule (discussed above). Under this option, section 316(b) requirements for existing Phase III facilities with a DIF of less than 50 MGD would be established on a case-by-case, BPJ, basis.

Option 6: Facilities with a DIF of 2 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule (discussed above). Under this option, section 316(b) requirements for Phase III facilities with a DIF of less than 2 MGD would be established on a case-by-case, BPJ, basis.

Option 7: Facilities with a DIF of 50 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule (discussed above). Facilities with a DIF between 30 and 50 MGD (30 MGD inclusive) would have to meet the performance standards for impingement mortality only and not for entrainment. Under this option, section 316(b) requirements for Phase III facilities with a DIF of less than 30 MGD would be established on a case-by-case, BPJ, basis.

Option 8 (Proposed "200 MGD for All Waterbodies" Option): Facilities with a DIF of 200 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule (discussed above). Under this option, section 316(b) requirements for existing Phase III facilities with a DIF of less than 200 MGD would be established on a case-by-case, BPJ, basis.

Option 9 (Proposed "100 MGD for Certain Waterbodies" Option): Facilities located on estuaries, oceans, tidal rivers or streams, or one of the Great Lakes, and with a DIF of 100 MGD or greater would be subject to the performance standards and compliance alternatives proposed in today's rule (discussed above). Under this option, section 316(b) requirements for all existing Phase III facilities on freshwater rivers and streams or lakes and reservoirs, and all existing Phase III facilities with a DIF of less than 100 MGD would be established on a case-by-case, BPJ, basis.

Table 1-1 summarizes which facilities would be defined as existing Phase III facilities and which performance standards would apply under each of the options described above.

Table 1-1: Performance Standards for the Evaluated Options for Existing Facilities

<table>
<tr><th rowspan="2">Option</th><th colspan="6">Minimum DIF Defining Facilities as Existing Phase III Facilities</th></tr>
<tr><th>2 MGD</th><th>20 MGD</th><th>30 MGD</th><th>50 MGD</th><th>100 MGD</th><th>200 MGD</th></tr>
<tr><td>1</td><td>BPJ</td><td colspan="5">I&E</td></tr>
<tr><td>2</td><td>BPJ</td><td colspan="2">Estuaries, oceans, tidal waters, or one of the Great Lakes: I&E
All other waterbodies: I only</td><td colspan="3">I&E</td></tr>
<tr><td>3</td><td>BPJ</td><td colspan="2">I only</td><td colspan="3">I&E</td></tr>
<tr><td>4</td><td>BPJ</td><td colspan="2">Estuaries, oceans, tidal waters, or one of the Great Lakes: I&E
All other waterbodies: BPJ</td><td colspan="3">I&E</td></tr>
<tr><td>5</td><td colspan="3">BPJ</td><td colspan="3">I&E</td></tr>
<tr><td>6</td><td colspan="6">I&E</td></tr>
<tr><td>7</td><td colspan="2">BPJ</td><td>I only</td><td colspan="3">I&E</td></tr>
<tr><td>8</td><td colspan="5">BPJ</td><td>I&E</td></tr>
<tr><td>9</td><td colspan="4">BPJ</td><td colspan="2">Estuaries, oceans, tidal waters, or one of the Great Lakes: I&E
All other waterbodies: BPJ</td></tr>
</table>

Key: BPJ - Best Professional Judgement.
I&E - 80-95% reduction in impingement mortality and a 60-90% reduction in entrainment.
I only - 80-95% reduction in impingement mortality only.
Estuaries - includes tidal rivers and streams.

Source: U.S. EPA Analysis, 2004.

In the remainder of this document, the discussion for existing facilities (i.e., the Manufacturers and Generators industry segments) focuses on the three proposed options listed above: the "50 MGD for All Waterbodies" option (Option 5 – also referred to as the "50 MGD All" option); the "200 MGD for All Waterbodies" option (Option 8 – also referred to as the "200 MGD All" option); and the "100 MGD for Certain Waterbodies" Option (Option 9 – also referred to as the "100 MGD CWB" option). In addition to presenting analyses for the three proposed options in the chapter texts of this document, the appendixes to the relevant chapters also present analyses for the other evaluated options (Option 1, Option 2, Option 3, Option 4, and Option 6). EPA did not conduct economic analyses for one of the options defined above (Option 7). More information on the potential costs of Option 7 can be found in the *Technical Development Document for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004).

1-2 Study Design

EPA's analysis of the proposed regulation examined cooling water intake structure impacts and regulatory benefits at the regional scale, and then combined regional results to develop national estimates. EPA grouped facilities into regions for its analysis based on (1) the locations of facilities potentially subject to regulation in Phase III, (2) similarities among the aquatic species affected by these facilities, and (3) characteristics of commercial and recreational fishing activities in the area. Table 1-2 lists the number of potentially regulated facilities in each study region, weighted using statistical weights from EPA's survey of the industry. The six regions and the waterbody types within each region are described below. Maps showing the facilities in each region are provided in the introductory chapter of each regional report (Parts B-G of this document).

Table 1-2: Number of Potentially Regulated Phase III Facilities by Region

Region	# Facilities (weighted)[a]
California[b]	9
North Atlantic	5
Mid-Atlantic	13
South Atlantic	4
Gulf of Mexico	11
Great Lakes	68
Inland	493
National total	603

[a] Excludes 80 facilities expected to close before rule goes into effect.
[b] Includes 1 facility in Hawaii.

1-2.1 Coastal Regions

Coastal regions include estuary/tidal river and ocean facilities in four of the NOAA Fisheries regions. The North Atlantic region encompasses Maine, New Hampshire, Massachusetts, Connecticut, and Rhode Island. The Mid-Atlantic region includes New York, New Jersey, Pennsylvania, Maryland, the District of Columbia, Delaware, and Virginia. The Gulf of Mexico region includes Texas, Louisiana, Mississippi, Alabama, and the west coast of Florida. Finally, the California region includes all estuary/tidal river and ocean facilities in California, plus one facility in Hawaii. Although the Hawaii facility was considered in estimating baseline I&E in the California region, no benefits are anticipated for this facility.

A South Atlantic region was included in the Phase II analysis, but it is not included here because there is only one sample Phase III facility (equals four sample weighted) in the region, and there are no benefits expected for this facility. However, baseline I&E at this facility (equals four facilities weighted) was estimated by extrapolation, on the basis of operational flow, of I&E estimates for the Gulf of Mexico and Mid-Atlantic, and added to the national total. As for the Phase II analysis, the formula used was:

South Atlantic I&E = [(Gulf + Mid-Atlantic I&E)/(Gulf + Mid-Atlantic intake flow)]* South Atlantic intake flow

1-2.2 Great Lakes Region

The Great Lakes region includes all facilities located on the shoreline of a Great Lake or on a waterway with open passage to a Great Lake and within 30 miles of a lake in Minnesota, Wisconsin, Illinois, Michigan, Indiana, Ohio, Pennsylvania, and New York. This definition is based on EPA's estimate of the extent of the spawning habitat of Great Lakes fish species, including spawning habitat in rivers and tributaries of the Great Lakes. The distance each species may travel upstream to spawn varies depending on both the species and the waterway, and is influenced by obstacles such as dams. After consultation with local fisheries experts, EPA determined that inclusion of waters within 30 miles of the Great Lakes is likely to encompass spawning areas of Great Lakes fishes. EPA used GIS to determine which facilities are on a waterbody that has unobstructed passage to the Great Lakes and is within 30 miles of a Great Lake. Data from the Lake Huron Project were used for areas encompassed by that project. For areas not covered by the Lake Huron Project, this was done using the ERF1 streams coverage (available at http://water.usgs.gov/lookup/getspatial?erf1), the national dams coverage (available at http://data.geocomm.com/catalog/US/group7.html), and a basic U.S. states coverage. No facilities drawing from other lakes or reservoirs were included among the Great Lake facilities unless the waterbodies were connected to the Great Lakes.

1-2.3 Inland Region

The Inland region includes all facilities located on freshwater rivers or streams and lakes or reservoirs, in all states, with the exception of facilities located in the Great Lakes region (defined above in section 1-2.2).

1-3 Report Organization

1-3.1 Part A: Study Methods

1-3.1.1 Evaluation of I&E

Chapter A1 of Part A of this Regional Benefits Assessment describes the methods used to evaluate facility I&E data. Chapter A2 discusses uncertainties in the analysis. To obtain regional I&E estimates, EPA extrapolated loss rates from model facilities to all Phase III facilities within the same region. These results were then summed to develop national estimates. It was necessary to use I&E data from Phase II facilities to supplement the limited data available for Phase III facilities. However, the Phase II data were not included in I&E and benefits estimates for the Phase III analysis.

1-3.1.2 Economic Benefits

Chapters A3-A6 and A8-A9 of Part A of this document describe the methods that EPA used for its analysis of the economic benefits of the proposed section 316(b) rule for Phase III facilities. As discussed in Chapter A3, EPA considered the following benefit categories: recreational fishing benefits, commercial fishing benefits, and non-use benefits. The analysis of use benefits included benefits from improved commercial fishery yields and benefits to recreational anglers from improved fishing opportunities. Chapters A4 and A5 provide details on the methods used for these analyses. Chapter A6 presents qualitative assessment of ecological non-use benefits of the proposed regulation. Chapter A8 discusses discounting of recreational and commercial benefits. Non-use benefits included benefits from reduced I&E of forage species, threatened and endangered species, and the non-landed portion of commercial and recreational species. Non-use methods are described in Chapter A9.

1-3.2 Parts B-G: Regional Reports

Parts B-G of this Regional Benefits Assessment are reports of results for each study region. Chapter 1 of each report provides background information on the facilities in the region and a map showing facility locations. Chapter 2 provides I&E estimates. Benefits estimates are presented in Chapters 3 and 4. Chapter 3 presents estimates of commercial fishing benefits, and Chapter 4 presents recreational fishing benefits. In addition, Chapter B5 presents an analysis of benefits to threatened and endangered species from reducing I&E at California facilities. An appendix to each regional report indicates the life history data and data sources used for the species evaluated in the region.

1-3.3 Part H: Total National Benefits

Chapter H1 summarizes the results of the six regional analyses and presents the total monetary value of national baseline losses and policy option benefits for all section 316(b) Phase III manufacturing facilities and generators.

Part A: Evaluation Methods

Chapter A1: Methods Used to Evaluate I&E

Introduction

This chapter describes the methods used by EPA to evaluate facility impingement and entrainment (I&E) data. Section A1-1 discusses the main objectives of EPA's I&E evaluation. Section A1-2 describes EPA's general approach to modeling fishery yield, the primary focus of its analysis, and the rationale for this approach. Section A1-3 describes the source data for EPA's I&E evaluations. Section A1-4 presents details of the biological models used to evaluate I&E. Finally, section A1-5 discusses methods used to extrapolate I&E rates from facilities with I&E data to other facilities in the same region without data.

Chapter Contents

A1-1 Objectives of EPA's Evaluation of I&E Data

EPA's evaluation of I&E data had four main objectives:

- to develop a national estimate of the magnitude of I&E;
- to standardize I&E rates using common biological metrics so that rates could be compared across species, years, facilities, and geographical regions;
- to estimate changes in these metrics as a result of projected reductions in I&E under the proposed section 316(b) rule for Phase III facilities; and
- to estimate the national economic benefits of reduced I&E.

Three loss metrics were derived from facility I&E monitoring data: (1) foregone age-1 equivalents, (2) foregone fishery yield, and (3) foregone biomass production. The methods used to calculate these metrics are described in section A1-4. Age-1 equivalent estimates were used to quantify losses of individuals in terms of a single life stage. Losses of commercial and recreational species were expressed as foregone fishery yield. Estimates of production foregone were used to quantify the contribution of forage species to the yield of harvested species. The following section discusses EPA's rationale for evaluating the I&E of harvested species in terms of foregone yield.

A1-2 Rationale for EPA's Approach to Evaluating I&E of Harvested Species

Harvested species were the main focus of EPA's analysis, primarily because of the availability of economic methods for valuing these species (see Chapters A3-A6 and A8-A9 for a discussion of all of the economic methods used by EPA to estimate benefits of the proposed section 316(b) rule for Phase III facilities). EPA's approach to estimating changes in harvest assumed that I&E losses result in a reduction in the number of harvestable adults in years after the time that individual fish are killed by I&E and that future reductions in I&E will lead to future increases in fish harvest. The approach does not require knowledge of population size or the total yield of the fishery; it only estimates the incremental yield that is foregone because of the number of deaths due to I&E.

As discussed in detail in section A1-4.2, EPA's yield analysis employed a specific application of the Thompson Bell model of fisheries yield (Ricker, 1975) to assess the effects of I&E on net fish harvest. This model is a relatively simple yield-per-recruit (YPR) model that provides estimates of yield (a.k.a. "harvest" or "landed fish") that can be expected from a cohort of fish that is recruited to a fishery. The model requires estimates of size-at-age for particular species and stage-specific schedules of natural mortality (M) and fishing mortality (F). All of the key parameters used in the yield model (F, M, and size-at-age), were assumed to be constant for a given species regardless of changes in I&E rates. Because these parameters are held static for any particular fish stock, YPR is also a constant value. With this set of parameters fixed, the Thompson Bell model holds that an estimate of recruitment is directly proportional to an estimate of yield.

EPA recognizes that the assumption that the key parameters are static is an important one that is not met in reality. However, by focusing on a simple interpretation of each individual I&E death in terms of foregone yield, EPA concentrated on the simplest, most direct assessment of the potential economic value of eliminating that death. EPA believes that this approach was warranted given the (1) scope and objectives of its analysis of harvested species, (2) data available, and (3) difficulties in distinguishing the causes of population changes. Each of these factors is discussed in the following sections.

A1-2.1 Scope and Objectives of EPA's Analysis of Harvested Species

The simplicity of EPA's approach to modeling yield was consistent with the need to examine the dozens of harvested species that are vulnerable to I&E at the hundreds of facilities throughout the country that are in scope of the rule and the overall objective of developing regional- and national-scale estimates. This approach is not necessarily the best alternative for studies of single facilities for which site-specific details on local fish stocks and waterbody conditions might make possible the use of more complex assessment approaches, including some form of population model.

A1-2.2 Data Availability and Uncertainties

Although EPA's approach to modeling yield requires estimates of a large number of stage-specific growth and mortality parameters, the use of more complex fish population models would rely on an even larger set of parameters and would require numerous additional and stronger assumptions about the nature of stock dynamics that would be difficult to defend with available data. Additional uncertainties of population dynamics models include the relationship between stock size and recruitment, and how growth and mortality rates may change as a function of stock size and other factors. Obtaining this information for even one fish stock is time-consuming and resource intensive; obtaining this information for the many species subject to I&E nation-wide was not possible for EPA's national benefits analysis.

It is also important to note that information on stock status is generally only available for harvested species, which represent a very small fraction of I&E losses. Even for harvested species, stock status is often poorly known. In fact, only 23% of U.S. managed fish stocks have been fully assessed (U.S. Ocean Commission, 2002).

In addition to a lack of data, there are numerous issues and difficulties with defining the size and spatial extent of fish stocks. As a result, it is often unclear how I&E losses at particular cooling water intake structures can be related to specific stocks. For example, a recent study of Atlantic menhaden (*Brevoortia tryannus*), one of the major fish species subject to I&E along the Atlantic Coast of the U.S., indicated that juveniles in Delaware Bay result from both local and long distance recruitment (Light and Able, 2003). Thus, accounting only for influences on local recruitment would be insufficient for understanding the relationship between recruitment and menhaden stock size.

Another difficulty is that fisheries managers typically define fish stocks by reference to the geographic scope of the fishery responsible for landings. However, landings data are reported state by state, which is generally not a good way to delineate the true spatial extent of fish populations.

A1-2.3 Difficulties Distinguishing Causes of Population Changes

Another problem in developing more complex models of harvested species is that it is fundamentally difficult to demonstrate that any particular kind of stress causes a reduction in fish population size. All fish populations are under a variety of stresses that are difficult to quantify and that may interact. Fish populations are perpetually in flux for numerous reasons, so determining a baseline population size, then detecting a trend, and then determining if a trend is a significant deviation from an existing baseline or is simply an expected fluctuation around a stable equilibrium is problematic. Fish recruitment is a multidimensional process, and identifying and distinguishing the causes of variance in fish recruitment remains a fundamental problem in fisheries science, stock management, and impact assessment (Hilborn and Walters, 1992; Quinn and Deriso, 1999; Boreman, 2000). This issue was beyond the scope and objectives of EPA's section 316(b) benefits analysis.

A1-3 Source Data

A1-3.1 Facility I&E Monitoring Data

The inputs for EPA's analyses included facility I&E monitoring data and species life history characteristics from the scientific literature such as growth rates, natural mortality rates, and fishing mortality rates. The general approach to I&E monitoring was similar at most facilities, but investigators used a wide variety of methods that were specific to the individual studies, e.g., location of sampling stations, sampling gear, sampling frequency, and enumeration techniques.

Impingement monitoring typically involves sampling impingement screens or catchment areas, counting the impinged fish, and extrapolating the count to an annual basis. Entrainment monitoring typically involves intercepting a small portion of the intake flow at a selected location in the facility, collecting fish by sieving the water sample through nets or other collection devices, counting the collected fish, and extrapolating the counts to an annual basis.

EPA retained all information regarding species, life stage, and loss modality (I or E) just as they were originally reported by the facilities, with the exception of some species aggregation that is described in section A1-3.2. Facility studies were excluded from EPA's analysis if the information reported was not suitable for the models used by EPA, which require annual loss rates expressed on a species- and age-specific basis. Studies were also excluded if they did not sample all of the facility's intakes, or indicate how to extrapolate from the sampled intakes to those not sampled. In some cases, entrainment sampling was conducted only during the months that larvae are present (usually spring and summer), and in such cases EPA assumed that entrainment rates for these months were indicative of the total annual loss.

In most cases the size or life stage of impinged fish are not reported. However, the EPA modeling procedure requires the age (or life stage) of the killed fish. Therefore, EPA assumed the age of impinged fish ranged from the juvenile stage to age 5, and divided the total impingement losses into age groups using proportions corresponding to the expected life table dictated by species-specific mortality schedules.

EPA adjusted annualized loss rates at some facilities as needed to reflect the history of technological changes at the facility. The purpose of the adjustments was to interpret loss records in a way that best reflects the current conditions at each facility. For example, if a facility was known to have installed a protective technology subsequent to the time that I&E loss rates were recorded, EPA reduced the loss rates in an amount corresponding to the presumed effectiveness of the protective technology.

Loss rates recorded at each facility were expressed as an annual average rate, regardless of the number of years of sampling data available. The annual total among the facilities evaluated was then the subject of the detailed modeling procedure described in section A1-4. Once this analysis was completed, estimates of total losses, by region, were generated using the extrapolation procedures described in section A1-5.

A1-3.2 Species Groups Evaluated

To evaluate I&E, EPA organized species into groups and then conducted detailed analyses of I&E rates for each species group. Species groups were based on similarities in life history characteristics and groupings used by the National Marine Fisheries Service (NMFS) for landings data. An appendix to each regional report in Parts B-G of this document provides details on the species groups and life history data that were used.

A1-3.3 Species Life History Parameters

The life history parameters used in EPA's analysis of I&E data included species growth rates, the fraction of each age class vulnerable to harvest, fishing mortality rates, and natural (nonfishing) mortality rates. Each of these parameters was also stage-specific. For the purpose of this assessment, EPA uses the terms "age" and "stage" interchangeably. For fish age 1 and older, a stage corresponds directly to the age of the fish. For fish younger than age one, a stage corresponds to a specific early life developmental stage (e.g., post yolk sac larvae). Early developmental stages may occur at different ages, and may have different durations for different species.

EPA obtained life history parameters from facility reports, the fisheries literature, local fisheries experts, and publicly available fisheries databases (e.g., FishBase). To the extent feasible, EPA identified region-specific life history parameters. All I&E losses within a region were modeled with a single set of parameters. Detailed citations are provided in the life history appendix accompanying each regional report (Parts B-G of the Regional Benefits Assessment).

For most species in most regions a reasonable set of life history parameter values was identified. However, in a few cases where no information on survival rates was available for individual life stages, EPA deduced survival rates for an equilibrium population based on records of lifetime fecundity using the relationship presented in Goodyear (1978) and below in Equation (1):

$$S_{eq} = 2/fa \qquad \text{(Equation 1)}$$

where:

S_{eq} = the probability of survival from egg to the expected age of spawning females
fa = the expected lifetime total egg production

Published fishing mortality rates (F) were assumed to reflect combined mortality due to both commercial and recreational fishing. Basic fishery science relationships (Ricker, 1975) among mortality and survival rates were assumed, such as:

$$Z = M + F \qquad \text{(Equation 2)}$$

where:

Z = the total instantaneous mortality rate
M = natural (nonfishing) instantaneous mortality rate
F = fishing instantaneous mortality rate

and

$$S = e^{(-Z)} \qquad \text{(Equation 3)}$$

where:

S = the survival rate as a fraction

A1-4 Methods for Evaluating I&E

The methods used to express I&E losses in units suitable for economic valuation are outlined in Figure A1-1 and described in detail in the following sections.

A1-4.1 Modeling Age-1 Equivalents

The Equivalent Adult Model (EAM) is a method for expressing I&E losses as an equivalent number of individuals at some other life stage, referred to as the age of equivalency (Horst, 1975; Goodyear, 1978; Dixon, 1999). The age of equivalency can be any life stage of interest. The method provides a convenient means of converting losses of fish eggs and larvae into units of individual fish and provides a standard metric for comparing losses among species, years, and regions. For the Regional Benefits Assessment, EPA expressed I&E losses at all life stages as an equivalent number of age-1 individuals.

The EAM calculation requires life-stage-specific I&E counts and life-stage-specific mortality rates from the life stage of I&E to the life stage of equivalence. The cumulative survival rate from age at impingement or entrainment until age 1 is the product of all stage-specific survival rates to age 1. For impinged fish that are older than age 1, age-1 equivalents are calculated by modifying the basic calculation to inflate the loss rates in inverse proportion to survival rates. In the case of entrainment, the basic calculation is:

$$S_{j,1} = S_j^* \prod_{i=j+1}^{j_{\max}} S_i \qquad \text{(Equation 4)}$$

where:

$S_{j,1}$ = cumulative survival from stage j until age 1
S_i = survival fraction from stage i to stage $i + 1$
S^*_j = $2S_j e^{-\log(1+Sj)}$ = adjusted S_j
$j_{\max}$ = the stage immediately prior to age 1

Equation 4 defines $S_{j,1}$, which is the expected cumulative survival rate (as a fraction) from the stage at which entrainment occurs, j, through age 1. The components of Equation 4 represent survival rates during the different life stages between life stage j, when a fish is entrained, and age 1. Survival through the stage at which entrainment occurs, j, is treated as a special case because the amount of time spent in that stage before entrainment is unknown and therefore the known stage specific survival rate, S_j, does not apply because S_j describes the survival rate through the entire length of time that a fish is in stage j. Therefore, to find the expected survival rate from the day that a fish was entrained until the time that it would have passed into the subsequent stage, an adjustment to S_j is required. The adjusted rate S^*_j describes the effective survival rate for the group of fish entrained at stage j, considering the fact that the individual fish were entrained at various specific ages within stage j.

Age-1 equivalents are then calculated as:

$$AE1_{j,k} = L_{j,k}\, S_{j,1} \qquad \text{(Equation 5)}$$

where:

$AE1_{j,k}$ = the number of age-1 equivalents killed during life stage j in year k
$L_{j,k}$ = the number of individuals killed during life stage j in year k
$S_{j,1}$ = the cumulative survival rate for individuals passing from life stage j to age 1

The total number of age-1 equivalents derived from losses at all stages in year k is then given by:

$$AE1_k = \sum_{j=j_{\min}}^{j_{\max}} AE1_{j,k} \qquad \text{(Equation 6)}$$

where:

$AE1_k$ = the total number of age-1 equivalents derived from losses at all stages in year k

A1-4.2 Modeling Foregone Fishery Yield

Foregone fishery yield is a measure of the amount of fish or shellfish (in pounds) that is not harvested because the fish are lost to I&E. EPA estimated foregone yield using the Thompson-Bell equilibrium yield model (Ricker, 1975). The model provides a simple method for evaluating a cohort of fish that enters a fishery in terms of their fate as harvested or not-harvested individuals. EPA's application of the Thompson-Bell model assumes that I&E losses result in a reduction in the number of harvestable adults in years after the time that individual fish are killed by I&E and that future reductions in I&E will lead to future increases in fish harvest.

The Thompson-Bell model is based on the same general principles that are used to estimate the expected yield in any harvested fish population (Hilborn and Walters, 1992; Quinn and Deriso, 1999). The general procedure involves multiplying age-specific harvest rates by age-specific weights to calculate an age-specific expected yield (in pounds). The lifetime expected yield for a cohort of fish is then the sum of all age-specific expected yields, thus:

$$Y_k = \sum_j \sum_a L_{jk} S_{ja} W_a (F_a / Z_a) \quad \text{(Equation 7)}$$

where:

Y_k = foregone yield (pounds) due to I&E losses in year k
L_{jk} = losses of individual fish of stage j in the year k
S_{ja} = cumulative survival fraction from stage j to age a
W_a = average weight (pounds) of fish at age a
F_a = instantaneous annual fishing mortality rate for fish of age a
Z_a = instantaneous annual total mortality rate for fish of age a

The model assumes that:

- the yield from a cohort of fish is proportional to the number recruited;
- annual growth, natural mortality, and fishing mortality rates are known and constant; and
- natural mortality includes mortality due to I&E.

The assumption that fishing mortality, F, remains constant despite possible reductions in I&E is central to the modeling approach used to estimate changes in fishery yield. This assumption implies that fishing activity and fishing regulations will adapt to increases in fish stock in a manner that leads to harvest increases in direct proportion to the magnitude of increases in harvestable stock.

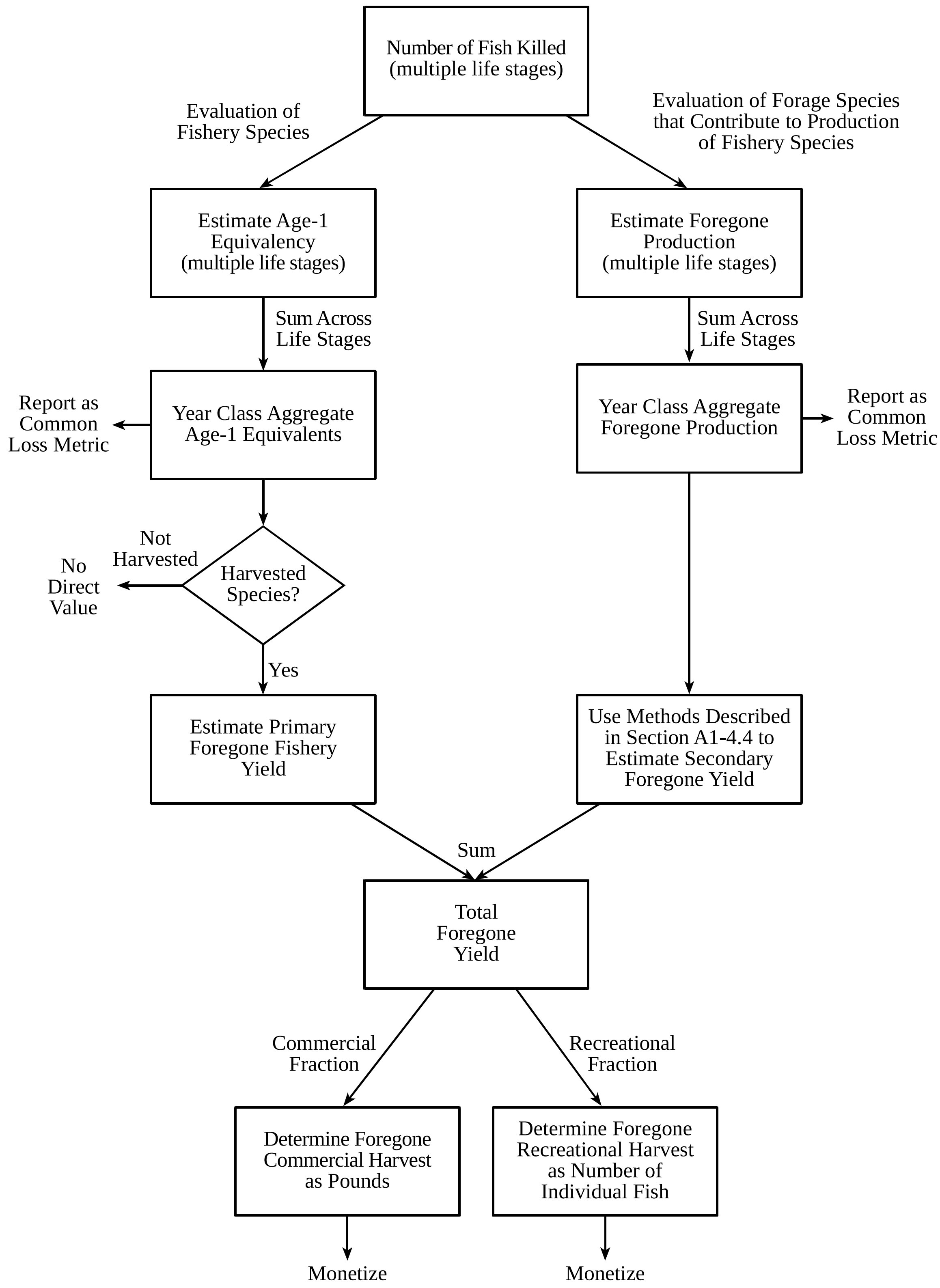
The assumption that M and F are constant is based on EPA's assumptions that:

- I&E losses are a relatively minor source of mortality in comparison to the total effects of all other sources of natural mortality (e.g., predation); and
- the scale of changes in I&E loss rates being considered will not lead to dramatically large increases in the size of harvestable stocks.

EPA acknowledges that in some cases the importance of I&E as a source of mortality in a fishery might be large enough that it would be unlikely that natural and fishing mortality would remain constant, but such cases are not expected to be the norm.

As indicated in Figure A1-1, EPA partitioned its estimates of total foregone yield for each species into two classes, foregone recreational yield and foregone commercial yield, based on the relative proportions of recreational and commercial state-wide aggregate catch rates of that species in that region. Pounds of foregone yield to the recreational fishery were re-expressed as numbers of individual fish based on the expected weight of an individual harvestable fish. Chapter A3 describes the methods used to derive dollar values for foregone commercial and recreational yields for the Regional Benefits Assessment.

Figure A1-1: General Approach Used to Evaluate I&E Losses as Foregone Fishery Yield



A1-4.3 Modeling Production Foregone

In addition to expressing I&E losses as lost age-1 equivalents (and subsequent lost yield, for harvested species), I&E losses were also expressed as foregone production. Foregone production is the expected total amount of future growth (expressed as pounds) of individuals that were impinged or entrained, had they not been impinged or entrained (Rago, 1984). Production foregone estimates are used in EPA's analysis to calculate the contribution of forage species lost to I&E to foregone fishery yield, as discussed in section A1-4.4.

Production foregone is calculated by simultaneously considering the stage-specific growth increments and survival probabilities of individuals lost to I&E, where production includes the biomass accumulated by individuals alive at the end of a time interval as well as the biomass of those individuals that died before the end of the time interval. Thus, the production foregone for a specified stage, *i*, is calculated as:

$$P_i = \frac{G_i N_i W_i (e^{(G_i - Z_i)} - 1)}{G_i - Z_i} \qquad \text{(Equation 8)}$$

where:

P_i = expected production (pounds) for an individual during stage *i*
G_i = the instantaneous growth rate for individuals of stage *i*
N_i = the number of individuals of stage *i* lost to I&E (expressed as equivalent losses at subsequent stages)
W_i = average weight (in pounds) for individuals of stage *i*
Z_i = the instantaneous total mortality rate for individuals of stage *i*

P_j, the production foregone for all fish lost at stage *j*, is calculated as:

$$P_j = \sum_{i=j}^{t_{max}} P_{ji} \qquad \text{(Equation 9)}$$

where:

P_j = the production foregone for all fish lost at stage *j*
t_{max} = oldest stage considered

P_T, the total production foregone for fish lost at all stages *j*, is calculated as:

$$P_T = \sum_{j=t_{min}}^{t_{max}} P_j \qquad \text{(Equation 10)}$$

where:

P_T = the total production foregone for fish lost at all stages *j*
t_{min} = youngest stage considered

A1-4.4 Evaluation of Forage Species Losses

I&E losses of forage species (i.e., species that are not targets of recreational or commercial fisheries) have both immediate and future impacts because not only is existing biomass removed from the ecosystem, but also the biomass that would have been produced in the future is no longer available as food for predators (Rago, 1984; Summers, 1989). The Production Foregone Model described in the previous section accounts for these consequences of I&E losses by considering the biomass that would have been transferred to other trophic levels but for the removal of organisms by I&E (Rago, 1984; Dixon, 1999). Consideration of the future impacts of current losses is particularly important for fish, since there can be a substantial time between loss and replacement, depending on factors such as spawning frequency and growth rates (Rago, 1984).

To evaluate I&E losses of forage species, EPA translated forage species production foregone into foregone yield of harvested species that are impinged and entrained using a simple trophic transfer model. These estimates of the foregone yield of impinged and entrained harvested species were distinct from the primary foregone yield of these species and are termed “secondary yield.” This procedure is presented in Equations 11 and 12, and illustrated schematically in Figure A1-2.

The basic assumption behind EPA’s approach to evaluating losses of forage species is that a decrease in the production of forage species can be related to a decrease in the production of impinged and entrained harvested (predator) species based on an estimate of trophic transfer efficiency. Thus, in general,

$$P_h = k\, P_f \qquad \text{(Equation 11)}$$

where:

P_h = foregone biomass production of a harvested species *h* (in pounds)
k = the trophic transfer efficiency
P_f = foregone biomass production of a forage species *f* (in pounds)

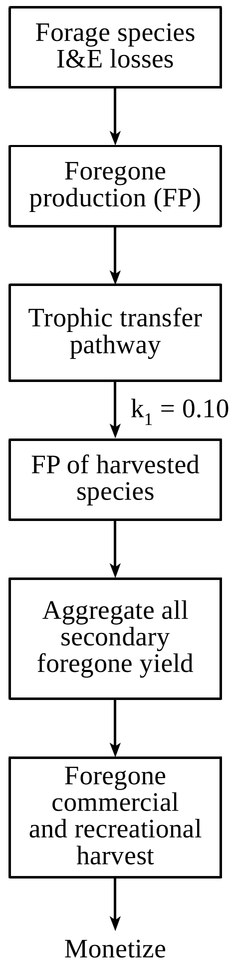
Equation 11 is applicable to trophic transfer on a species-to-species basis where one species is strictly prey and the other species is strictly a predator. For the section 316(b) Regional Benefits Assessment, commercially or recreationally valuable fish were considered predators. The aggregate total secondary yield is estimated on a regional basis under the assumption that the trophic value of total foregone production among forage species is allocated equally among all harvested species that occur in the I&E losses, thus:

$$Y_{\text{sec}} = \sum_{\substack{h \in all \\ harvested \\ species}} \left(\frac{k}{H} \sum_{\substack{f \in all \\ forage \\ species}} P_f \right) \left(Y_h / P_h \right) \qquad \text{(Equation 12)}$$

where:

Y_{sec} = total secondary yield (as a generic predator species)
H = number of harvested species among regional loss estimates
Y_h = primary estimate of foregone yield for harvested species *h*
P_h = estimate of foregone production for harvested species *h*

Figure A1-2: Trophic Transfer Model



It is difficult to determine, on a community basis, an appropriate value of *k* that relates aggregate forage production and aggregate predator production, since the actual trophic pathways are complicated. For the purposes of the regional case studies, EPA used the value of $k = 0.10$ based on a review of the available literature by Pauly and Christensen (1995).

A1-5 Extrapolation of I&E Rates

EPA examined I&E losses and the economic benefits of reducing these losses at the regional scale. The estimated benefits were then aggregated across all regions to yield a national benefits estimate. These regions and the waterbody types within each region are described in the Introduction to this Regional Benefits Assessment. Maps showing the facilities in each region that are in scope of the proposed section 316(b) rule for Phase III facilities are provided in the introductory chapter of each regional report (Parts B-G of this document).

To obtain regional I&E estimates, EPA extrapolated losses observed at the facilities evaluated (facilities with suitable records of I&E rates) to other in-scope facilities within the same region. Extrapolation of I&E rates from these “model” facilities was necessary because not all in scope facilities within a given region have conducted I&E studies. Model facilities included both Phase II and Phase III facilities, based on the assumption that I&E

rates at Phase II and Phase III facilities are similar after normalization by intake flow. Phase II facilities were included to make use of the largest possible data set and to accommodate the lack of Phase III I&E data in some regions (see Table A1-1).

Table A1-1: Number of Model Facilities, by Region and Phase of Rulemaking

	Phase	
Region	**II**	**III**
California	18	0
North Atlantic	4	0
Mid-Atlantic	6	1
Gulf of Mexico	4	0
Great Lakes	7	4
Inland	29	11

I&E data were extrapolated on the basis of operational flow, in millions of gallons per day (MGD), where MGD is the average operational flow over the period 1996-1998 as reported by facilities in response to EPA's section 316(b) Detailed Questionnaire and Short Technical Questionnaire. Operational flow at each facility was rescaled using factors reflecting the relative effectiveness of currently in-place technologies for reducing I&E. Thus,

$$F_{f,e} = G_f (1 - T_{f,e}) \qquad \text{(Equation 13)}$$

where:

$F_{f,e}$ = effective relative flow rate for entrainment at facility *f*
G_f = mean operational flow at facility *f* (10^6 gallons/day)
$T_{f,e}$ = fractional effectiveness of entrainment-reducing technology at facility *f* ($0<T_{f,e}<1$)

$$F_{f,i} = G_f (1 - T_{f,i}) \qquad \text{(Equation 14)}$$

where:

$F_{f,i}$ = effective relative flow rate for impingement at facility *f*
G_f = mean operational flow at facility *f* (10^6 gallons/day)
$T_{f,i}$ = fractional effectiveness of impingement-reducing technology at facility *f* ($0<T_{f,i}<1$)

Next, regional estimates were developed as outlined in equations 15-18. Statistical weighting factors (from EPA's survey of the industry) were multiplied by flow rates at each facility prior to estimating the total regional flow rate.

(Equation 15)

$$S_{r,e} = \sum_{\substack{f \in \text{All facilities} \\ \text{in region r}}} F_{f,e} \Big/ \sum_{\substack{f \in \text{All model facilities} \\ \text{in region r}}} F_{f,e}$$

where:

$F_{f,e}$ = effective relative flow rate for entrainment at facility *f*
$S_{r,e}$ = scaling factor to relate total entrainment losses among model facilities to regional total entrainment losses

(Equation 16)

$$S_{r,i} = \sum_{\substack{f \in \text{All facilities} \\ \text{in region r}}} F_{f,i} \Big/ \sum_{\substack{f \in \text{All model facilities} \\ \text{in region r}}} F_{f,i}$$

where:

$F_{f,i}$ = effective relative flow rate for impingement at facility *f*
$S_{r,i}$ = scaling factor to relate total impingement losses among model facilities to regional total impingement losses

(Equation 17)

$$L_{r,e} = S_{r,e} \sum_{\substack{f \in \text{All model facilities} \\ \text{in region r}}} L_{f,e}$$

where:

$S_{r,e}$ = scaling factor to relate total entrainment losses among model facilities to regional total entrainment losses
$L_{r,e}$ = estimated annual total entrainment losses at region *r*
$L_{f,e}$ = estimated annual total entrainment losses at facility *f*

(Equation 18)

$$L_{r,i} = S_{r,i} \sum_{\substack{f \in \text{All model facilities} \\ \text{in region r}}} L_{f,i}$$

where:

$S_{r,i}$ = scaling factor to relate total impingement losses among model facilities to regional total impingement losses
$L_{r,i}$ = estimated annual total impingement losses at region *r*
$L_{f,i}$ = estimated annual total impingement losses at facility *f*

EPA recognizes that there may be substantial among-facility variation in the actual I&E losses per MGD resulting from a variety of facility-specific features, such as location and type of intake structure, as well as from ecological features that affect the abundance or species composition of fish in the vicinity of each facility. The accuracy of EPA's extrapolation procedure relies heavily on the assumption that I&E rates recorded at model facilities are representative of I&E rates at other facilities in the region. Although this assumption may be violated in some cases, limiting the extrapolation procedure to particular regions reduces the likelihood that the model facilities are unrepresentative.

EPA believes that this method of extrapolation makes best use of a limited amount of empirical data, and is the only currently feasible approach for developing an estimate of national I&E and the benefits of reducing I&E. While acknowledging that an extrapolation necessarily introduces additional uncertainty into I&E estimates, EPA has not identified information that suggests that application of the procedure causes a systematic bias in the regional loss estimates.

The assumption that I&E is proportional to flow is consistent with other predictive I&E studies. For example, a key assumption of the Spawning and Nursery Area of Consequence (SNAC) model (Polgar et al., 1979) is that entrainment is proportional to cooling water withdrawal rates. The SNAC model has been used as a screening tool for assessing potential I&E impacts at Chesapeake Bay plants. As a first approximation, percent entrainment has been predicted on the basis of the ratio of cooling water flow to source water flow (Goodyear, 1978). A study of power plants on the Great Lakes (Kelso and Milburn, 1979) demonstrated an increasing relationship (on a log-log scale) between plant "size" (electric production in MWe) and I&E. There is scatter in these relationships, not just because there is variation in the cooling water intake for different plants having similar electric production, but also because of the imprecision (sampling variability) inherent in the usual methods of estimating I&E. These relationships are nonetheless strong. EPA's 1976 "Development Document for the Best Technology Available for the Location, Design, Construction and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact" concluded that "reduction of cooling water intake volume (capacity) should, in most cases, reduce the number of organisms that are subject to entrainment in direct proportion to the fractional flow reduction."

Chapter A2: Uncertainty

Introduction

This chapter discusses sources of uncertainty in EPA's impingement and entrainment (I&E) analyses, and presents the preliminary results of an uncertainty analysis of the yield model used by EPA to estimate the benefits of reducing I&E of commercial and recreational fishery species. Section A2-1 discusses major uncertainties in EPA's I&E assessments, section A2-2 briefly describes Monte Carlo analysis as a tool for quantifying uncertainty, section A2-3 provides preliminary results of an uncertainty analysis by EPA of winter flounder yield estimates, and section A2-4 discusses results of the uncertainty analysis.

Chapter Contents

A2-1 Types of Uncertainty

Despite following sound scientific practice throughout, it was impossible to avoid numerous sources of uncertainty that may cause EPA's I&E estimates in the regional analysis to be imprecise or to carry potential statistical bias. Uncertainty of this nature is not unique to EPA's I&E analysis.

Uncertainty may be classified into two general types (Finkel, 1990). One type, referred to as structural uncertainty, reflects the limits of the conceptual formulation of a model and relationships among model parameters. The other general type is parameter uncertainty, which flows from uncertainty about any of the specific numeric values of model parameters. The following discussion considers these two types of uncertainty in relation to EPA's I&E analysis.

A2-1.1 Structural Uncertainty

The models used by EPA to evaluate I&E simplify a very complex process. The degree of simplification is substantial but necessary because of the limited availability of empirical data. Table A2-1 provides examples of some potentially important considerations that are not captured by the models used. EPA believes that these structural uncertainties will generally lead to inaccuracies, rather than imprecision, in the final results.

Table A2-1: Uncertainties Associated with Model Structure

Type	General Treatment in Model	Specific Treatment in Model
Generally simple structure	Species lost to I&E treated independently	Fish species grouped into two categories: harvested or not harvested (forage for harvested species).
Biological submodels	No dynamic elements	Life history parameters constant (i.e., growth and survival did not vary through time); growth and survival rates did not change in response to possible compensatory effects.
Economic submodels	No dynamic elements	Ratio of direct to indirect benefits was static through time; market values of harvested species were inelastic (i.e., were fixed and thus not responsive to market changes that may occur due to increased supply when yield is higher).
	Fish stock	Landings of commercial and recreational fish associated with I&E losses assumed to be within the State where facility is located.
	Angler experience	I&E losses at a facility assumed to be relevant to angler experience (or perception) and Random Utility Model (RUM) models of sport fishery economics.

A2-1.2 Parameter Uncertainty

Uncertainty about the numeric values of model parameters arises for two general reasons. The first source of parameter uncertainty is imperfect precision and accuracy of I&E data reported by facilities and growth and mortality rates obtained from the scientific literature. This results from unavoidable sampling and measurement errors. The second major source of parameter uncertainty is the applicability of parameter estimates obtained from I&E or life history studies conducted at other locations or under different conditions.

Table A2-2 presents some examples of parameter uncertainty. In all of these cases, increasing uncertainty about specific parameters implies increasing uncertainty about EPA’s point estimates of I&E losses. The point estimates are biased only insofar as the input parameters are biased in aggregate (i.e., inaccuracies in multiple parameter values that are above the “actual” values but below the “actual” values in other cases may tend to counteract). In this context, EPA believes that parameter uncertainty will generally lead to imprecision, rather than inaccuracies, in the final results.

Table A2-2: Parameters Included in EPA's I&E Analysis that are Subject to Uncertainty

Type	Factors	Examples of Uncertainties in Model
I&E monitoring /loss rate estimates	Sampling regimes	Sampling regimes subject to numerous plant-specific details; no established guidelines or performance standards for how to design and conduct sampling regimes.
	Extrapolation assumptions	Extrapolation of monitoring data to annual I&E rates requires numerous assumptions regarding diurnal/seasonal/annual cycles in fish presence and vulnerability and various technical factors (e.g., net collection efficiency; hydrological factors affecting I&E rates); no established guidelines or consistency in sampling regimes.
	Species selection	Criteria for selection of species to evaluate not well-defined or uniform across facilities.
	Sensitivity of fish to I&E	Through-plant entrainment mortality assumed by EPA to be 100%; some back-calculations required in cases where facilities had reported entrainment rates that assumed <100% mortality. Impingement survival included if presented in facility documents.
Biological/life history	Natural mortality rates	Natural mortality rates (M) difficult to estimate; model results highly sensitive to M.
	Growth rates	Simple exponential growth rates or simple size-at-age parameters used.
	Geographic considerations	Migration patterns; I&E occurring during spawning runs or larval out-migration; location of harvestable adults; intermingling with other stocks.
	Forage valuation	Harvested species assumed to be food limited; trophic transfer efficiency to harvested species estimated by EPA based on general models; no consideration of trophic transfer to species not impinged and entrained.
Stock characteristics	Fishery yield	For harvest species, used only one species-specific value for fishing mortality rate (F) for all stages subject to harvest; used stage-specific constants for fraction vulnerable to fishery.
	Harvest behavior	No assumed dynamics among harvesters to alter fishing rates or preferences in response to changes in stock size; recreational access assumed constant (no changes in angler preferences or effort).
	Stock interactions	I&E losses assumed to be part of reported fishery yield rates on a statewide basis; no consideration of possible substock harvest rates or interactions.
	Compensatory growth	None.
	Compensatory mortality	None.
Ecological system	Fish community	Long-term trends in fish community composition or abundance not considered (general food webs assumed to be static); used constant value for trophic transfer efficiency; specific trophic interactions not considered. Trophic transfer to organisms not impinged and entrained is not considered.
	Spawning dynamics	Sampled years assumed to be typical with respect to choice of spawning areas and timing of migrations that could affect vulnerability to I&E (e.g., presence of larvae in vicinity of intake structure).
	Hydrology	Sampled years assumed to be typical with respect to flow regimes and tidal cycles that could affect vulnerability to I&E (e.g., presence of larvae in vicinity of CWIS).
	Meteorology	Sampled years assumed to be typical with respect to vulnerability to I&E (e.g., presence of larvae in vicinity of intake structure).

A2-1.3 Uncertainties Related to Engineering

EPA's evaluation of I&E was also affected by uncertainty about the engineering and operating characteristics of the study facilities. It is unlikely that plant operating characteristics (e.g., seasonal, diurnal, or intermittent changes in intake water flow rates) were constant throughout any particular year, which therefore introduces the possibility of bias in the loss rates reported by the facilities. EPA assumed that the facilities' loss estimates were provided in good faith and did not include any intentional biases, omissions, or other kinds of misrepresentations.

A2-2 Monte Carlo Analysis as a Tool for Quantifying Uncertainty

Stochastic simulation is among a class of statistical procedures commonly known as Monte Carlo modeling methods. Monte Carlo methods allow investigators to quantify uncertainty in model results based on knowledge or assumptions about the amount of uncertainty in each of the various input parameters. The Monte Carlo approach also allows investigators to conduct sensitivity analyses to elucidate the relative contribution of the uncertainty in each input parameter to overall uncertainty. Monte Carlo methods are particularly useful for assessing models where analytic (i.e., purely mathematical) methods are cumbersome or otherwise unsuitable. A thorough introduction to the statistical reasoning that underlies Monte Carlo methods, and their application in risk assessment frameworks, is provided in an EPA document "Guiding Principles for Monte Carlo Analysis" (U.S. EPA, 1997).

The characteristic feature of Monte Carlo methods is the generation of artificial variance through the use of pseudorandom numbers. The solution to the model of interest is recalculated many times, each time adding perturbations to the values of the model parameters. The types of perturbations are selected to reflect the actual uncertainty in knowledge of those parameters. Recalculations are conducted thousands of times, and the variation in the resulting solution is assessed and interpreted as an indicator of the aggregate uncertainty in the basic result.

A2-3 EPA's Uncertainty Analysis of Yield Estimates

A2-3.1 Overview of Analysis

As described in detail in Chapter A1 of this report, EPA estimated foregone yield using the Thompson-Bell equilibrium yield model (Ricker, 1975). The Thompson-Bell model is based on the same general principles that are used to estimate the expected yield in any harvested fish population (Hilborn and Walters, 1992; Quinn and Deriso, 1999). The general procedure involves multiplying age-specific weights by age-specific harvest rates to calculate an age-specific expected yield (in pounds). The lifetime expected yield for a cohort of fish is then the sum of all age-specific expected yields.

$$Y_k = \sum_j \sum_a L_{jk} S_{ja} W_a (F_a / Z_a)\left(1 - e^{-Z_a}\right) \qquad \text{(Equation 1)}$$

where:

Y_k = foregone yield (pounds) due to I&E losses in year *k*
L_{jk} = losses of individual fish of stage *j* in the year *k*
S_{ja} = cumulative survival fraction from stage *j* to age *a*
W_a = average weight (pounds) of fish at age *a*
F_a = instantaneous annual fishing mortality rate for fish of age *a*
Z_a = instantaneous annual total mortality rate for fish of age *a*

Quantifying the variance in yield estimates resulting from uncertainty in the numeric values of *L*, *S*, *W*, *F*, and *Z* assists in the interpretation of results, gives a sense of the precision in yield estimates, provides insight into the sensitivity of predictions to particular parameter values, and indicates the contribution of particular parameters to overall uncertainty.

EPA evaluated uncertainty in yield estimates for winter flounder using I&E data for a facility located on a North Atlantic estuary. The I&E loss records and winter flounder life history parameters that were used are provided in the Phase II docket as DCN #4-2037.

EPA developed a custom program written in the S language to conduct the Monte Carlo analysis. Wherever possible, the simulation tool re-used the same code that was used to calculate yield for the original assessment. Graphical displays were used to confirm the behavior of random number generation and to examine results.

Selection of input distributions for parameters of interest are a key element of any Monte Carlo analysis. In the winter flounder test case, the input distributions were uniform distributions with a range defined as the initial, best estimate of the parameter +/- 15%. A uniform distribution was selected because of its simplicity and the 15% range was selected because this magnitude of variance is considered plausible.

EPA investigated sensitivity of the model to variations in parameters by grouping the parameters into five classes:

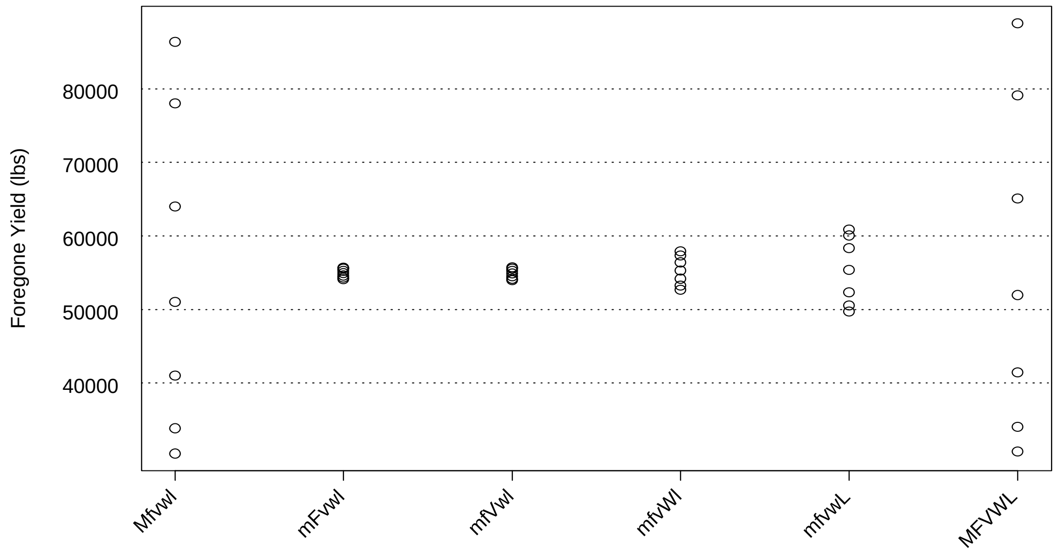
- natural mortality (*M*) at all life stages;
- fishing mortality (*F*) at all life stages;
- fraction vulnerable to fishing (*V*) at all life stages (i.e., age of recruitment to the fishery);
- weight at age (*W*); and
- the reported I&E loss rates (*L*).

The analysis consisted of repeating runs (n = 10,000 in each run) of the model wherein each of the groups of parameters was either held constant at their best estimates or were varied stochastically according to the defined input distributions. The relative importance of these groups of parameters was assessed by comparing the relative amount of variation between each set of runs. Model sensitivity to individual parameters has not been examined.

A2-3.2 Preliminary Results

For entrainment losses, the analysis indicated that the yield model is most sensitive to uncertainty in natural mortality rates, followed by uncertainty in the I&E loss rates themselves (Figure A2-1). Age-specific weights were the third most important group, followed by fishing mortality and age at recruitment, which were relatively insignificant sources of uncertainty.

Figure A2-1: Results of Preliminary Parameter Sensitivity Analysis of Estimates of Foregone Yield (pounds) of Winter Flounder due to Entrainment by a Power Plant Located in a North Atlantic Estuary



Data points are plotted at the 5th percentile, 10th percentile, 25th percentile, median, 75th percentile, 90th percentile, and 95th percentile of 10,000 independent estimates of foregone yield within each parameter set. Groups are distinguished by uppercase letters designating which types of parameters were treated stochastically in the simulation and lowercase letters for types of parameters fixed at their best estimates. M = natural mortality rates; F = fishing mortality rates; V = age of recruitment to the fishery; W = weight at age; L = entrainment loss rates.

A2-4 Conclusions

This chapter includes a general discussion of uncertainty and describes a general approach that was tested by EPA as a way to quantify uncertainty associated with the yield model described in Chapter A1. Preliminary results of the uncertainty analysis suggest that uncertainty about natural mortality rates is a significant contributor to aggregate uncertainty in yield estimates. Unfortunately, as noted in a review article by Vetter (1988), “True rates of natural mortality, and their variability, are poorly known for even the great stocks of commercial fish in temperate regions that have been subject to continuous exploitation for decades” (Vetter, 1988, p. 39). As a result, the uncertainty in mortality parameters cannot be overcome. As Vetter (1988) noted, this is a difficulty shared by all models of fish stock dynamics. Nonetheless, through consultation with local fish biologists as well as the scientific literature, EPA expended considerable effort to identify reasonable mortality rates and other life history information for use in its yield analyses. These parameter values and data sources are presented in Appendix 1 of each regional report (Parts B-G of this document).

Chapter A3: Economic Benefit Categories and Valuation

Introduction

Changes in cooling water intake structure (CWIS) design or operations resulting from the proposed section 316(b) rule for Phase III facilities are expected to reduce impingement and entrainment (I&E) losses of fish, shellfish, and other aquatic organisms and, as a result, the rulemaking is expected to increase the numbers of individuals present, increase local and regional fishery populations, and ultimately contribute to the enhanced environmental functioning of affected waterbodies (rivers, lakes, estuaries, and oceans) and associated ecosystems. The economic welfare of human populations is expected to increase as a consequence of the improvements in fisheries and associated aquatic ecosystem functioning.

Chapter Contents

The aquatic resources affected by cooling water intake structures provide a wide range of environmental services. Ecosystem services are the physical, chemical, and biological functions performed by natural resources and the human benefits derived from those functions, including both ecological and human use services (Daily, 1997; Daily et al., 1997). Scientific and public interest in protecting ecosystem services is increasing with the recognition that these services are vulnerable to a wide range of human activities and are difficult, if not impossible, to replace with human technologies (Meffe, 1992).

In addition to their importance in providing food and other goods of direct use to humans, the organisms lost to I&E are critical to the continued functioning of the ecosystems of which they are a part. Fish are essential for energy transfer in aquatic food webs, regulation of food web structure, nutrient cycling, maintenance of sediment processes, redistribution of bottom substrates, the regulation of carbon fluxes from water to the atmosphere, and the maintenance of aquatic biodiversity (Peterson and Lubchenco, 1997; Postel and Carpenter, 1997; Holmund and Hammer, 1999; Wilson and Carpenter, 1999). Examples of the impact of I&E on ecological and public services include:

- decreased numbers of ecological keystone, rare, or sensitive species;
- decreased numbers of popular species that are not fished, perhaps because the fishery is closed;
- decreased numbers of special status (e.g., threatened or endangered) species;
- increased numbers of exotic or disruptive species that compete well in the absence of species lost to I&E;
- disruption of ecological niches and ecological strategies used by aquatic species;
- disruption of organic carbon and nutrient transfer through the food web;
- disruption of energy transfer through the food web;
- decreased local biodiversity;
- disruption of predator-prey relationships;
- disruption of age class structures of species;

- disruption of natural succession processes;
- disruption of public uses other than fishing, such as diving, boating, and nature viewing; and
- disruption of public satisfaction with a healthy ecosystem.

Many of these services can only be maintained by the continued presence of all life stages of fish and other aquatic species in their natural habitats.

The traditional approach of EPA and other natural resource agencies to quantifying the environmental benefits of proposed regulations has focused on active use values, particularly direct use values such as recreational or commercial fishing. Nonconsumptive uses (such as the importance of fish for aquatic food webs), and passive use or non-use values (including the value of protecting a resource for its own sake), are seldom considered because they are difficult to monetize with available economic methods. However, even though economists debate methods for indirect and non-use valuation, there is general agreement that these values exist and can be important (Freeman, 2003).

This chapter first identifies the types of economic benefits that are likely to be generated from improved ecosystem functioning resulting from the proposed rule for Phase III facilities. Then, the basic economic concepts applicable to the economic benefits, including benefit categories and benefit taxonomies associated with market and nonmarket goods and services that are likely to flow from reduced I&E, are discussed. Sections in this chapter refer to the chapters in this report that detail the methods used to estimate the values of reductions in I&E. These methods are in turn applied in the regional studies described in Parts B through G of this document.

A3-1 Economic Benefit Categories Applicable to the Proposed Section 316(b) Rule for Phase III Facilities

The term "economic benefits" for our purposes refers to the dollar value associated with all the expected positive impacts of the proposed rule for Phase III facilities. The basic approach for estimating the benefits of a policy event is to evaluate changes in social welfare realized by consumers and producers. These surplus measures are standardized and widely accepted concepts within applied welfare economics, and reflect the degree of well-being derived by economic agents (e.g., people and/or firms) given different levels of goods and services, including those associated with environmental quality.[1] For the case of market goods, analysts typically use money-denominated measures of consumer and producer surplus, which provide an approximation of exact welfare effects (Freeman, 2003). For nonmarket goods, such as aquatic habitat, values must be assessed using nonmarket valuation methods. In such cases, valuation estimates are typically restricted to effects on individual households (or consumers), and either represent consumer surplus or analogous exact Hicksian welfare measures (e.g., compensating surplus). The choice of welfare (i.e., value) measures is often determined by the valuation context.

Estimating economic benefits of reducing I&E at existing CWISs can be challenging. Many steps are needed to analyze the link between reductions in I&E and improvements in human welfare. The changes produced by the new regulations on fisheries and other aspects of relevant aquatic ecosystems must be determined, and then linked in a meaningful way to the associated environmental goods and services that ultimately produce increased benefits. Key challenges in environmental benefits assessment include uncertainties, data availability, and the fact that many of the goods and services beneficially affected by CWIS are not traded in the marketplace (i.e., monetary values can not be established based on observed market transactions for some of the important beneficial outcomes). In this case, several types of benefits need to be estimated using nonmarket valuation

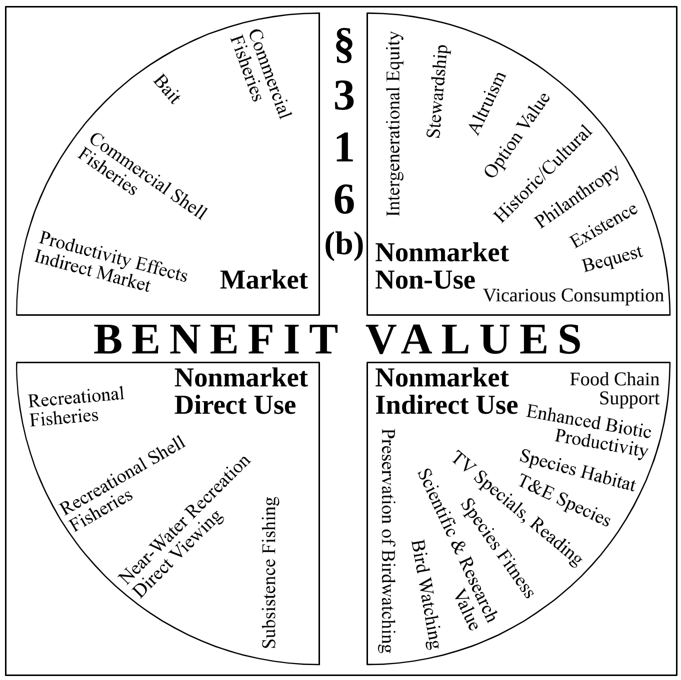
[1] Technically, consumer surplus reflects the difference between the "value" an individual places on a good or service (as reflected by the individual's "willingness-to-pay" (WTP) for that unit of the good or service) and the "cost" incurred by that individual to acquire it (as reflected by the "price" of a commodity or service, if it is provided in the marketplace). See Chapter A4 for a more detailed discussion of consumer and producer surplus.

techniques. Where this cannot be done in a reliable manner, the benefits need to be described and considered qualitatively.

For the proposed rule for Phase III facilities, the benefits are likely to consist of several categories; some are linked to direct use of market goods and services, and others pertain to nonmarket goods and services. Figure A3-1 outlines the most prominent categories of benefits expected from the rule. The four quadrants are divided by two principles:

- whether the benefit can be tracked in a market (i.e., market goods and services); and
- how the benefit of a nonmarket good is received by human beneficiaries (either from direct use of the resource, from indirect use, or from non-use).

Figure A3-1: Benefits Categories for the Section 316(b) Rule for Phase III Facilities



Source: U.S. EPA analysis for this report.

The best example of market benefits for the proposed rule are commercial fisheries, where a change in fishery conditions will manifest itself in the price, quantity, and/or quality of fish harvests. These fishery changes result in changes in the marketplace, and can be evaluated based on market exchanges. A discussion of methods used in the commercial fishing benefits analysis can be found in Chapter A4 of this document.

Direct use benefits also include the value of improved environmental goods and services used and valued by people (whether or not these services and goods are traded in markets). A typical nonmarket direct use would be recreational angling. Recreational fishing studies of sites throughout the United States have shown that anglers place high value on their fishing trips and that catch rates are one of the most important attributes contributing to the quality and, as a result, value of their trips. Higher catch rates resulting from reduced I&E of fish species targeted by recreational anglers may translate into two components of recreational angling benefits: (1) an increase in the value of existing recreational fishing trips resulting in a more enjoyable angling experience, and (2) an increase in recreational angling participation. A discussion of methodology used in valuation of recreational fishing benefits can be found in Chapter A5.

Indirect use benefits refer to changes that contribute indirectly to an increase in welfare for users (or non-users) of the resource. An example of an indirect benefit would be when the increase in the number of forage fish enables the population of valued predator species to improve (e.g., when the size and numbers of prized recreational or commercial fish increase because their food source has been improved). In such a context, reducing I&E of forage species will indirectly result in welfare gains for recreational or commercial anglers. See Chapter A1 for a discussion on the indirect influence of forage fish on abundance of commercial and recreational species.

Non-use benefits, often referred to as passive use benefits, arise when individuals value improved environmental quality apart from any past, present, or anticipated future use of the resource in question. Such passive use values have been categorized in several ways in the economic literature, typically embracing the concepts of existence, altruism, and bequest motives. Existence value is the value that individuals may hold for simply knowing that a particular good exists regardless of its present or expected use.[2] This motive applies not only to protecting endangered and threatened species (i.e., avoiding an irreversible impact), but also applies (though perhaps the values held may be different) for impacts that potentially are reversible or that affect relatively abundant species and/or habitats.[3] Bequest value exists when someone gains utility through the knowledge that an amenity will be available for others (family or future generations) now and in the future (Fisher and Raucher, 1984). Altruistic values arise from interpersonal concerns (valuing the happiness that others get from enjoying the resource). Non-use values also may include the concept that some ecological services are valuable apart from any human uses or motives. Examples of these ecological services may include improved reproductive success for aquatic and terrestrial wildlife, increased diversity of aquatic and terrestrial species, and improved conditions for recovery of I&E species.

In older published studies, option value, which may exist regardless of actual future use, has been classified as either non-use value, use value, or as a third type of value, apart from both the use and non-use components of total value. Fisher and Raucher (1984) define *option price* for such an individual as “the sum of the expected value of consumer surplus from using the resource plus an *option value* or risk premium that accounts for uncertainty in demand or in supply.” Mitchell and Carson (1989) argue that on theoretical grounds this risk premium should be small for non-unique resources. It is increasingly recognized, however, that option value “cannot be a separate component of value” (Freeman, 2003; p. 249). As noted by Freeman (2003; p. 250), option value is “not mentioned in EPA’s most recent set of guidelines for economic assessment.” Accordingly, the following analysis does not assess option value as a distinct component of value.

Although different benefit categories can be developed, it makes little difference where specific types of benefits are classified as long as the classification system captures all of the types of beneficial outcomes that are expected to arise from a policy action, while at the same time avoiding any possible double counting. Some valuation approaches may capture more than one benefit category or reflect multiple types of benefits that exist in more than one category or quadrant in the diagram. For example, reducing I&E may enhance populations of recreational, commercial, and forage species alike. Thus, decision-makers need to be careful to account for the mix of direct and indirect uses included in the benefits estimates, including both market and nonmarket goods and services as well as non-use values.

[2] The term “existence value” is sometimes used interchangeably with or in place of “non-use value.” In this case, where the whole of non-use benefits is represented, existence value has been described as including vicarious consumption and stewardship values. Vicarious consumption reflects the value individuals may place on the availability of a good or service for others to consume in the current time period, and stewardship includes inherent value as well as bequest value. In this case inherent value may be considered the existence value individuals hold for knowing that a good exists (described above), and bequest value is the value individuals place on preserving or ensuring the availability of a good or service for family and others in the future.

[3] Some economists consider option values to be a part of non-use values because the option value is not derived from actual current use. Alternatively, some other writers place option value in a use category, because the option value is associated with preserving opportunity for a future use of the resource. Both interpretations are supportable, but for this presentation EPA places option value in the non-use category in Figure A3-1.

A3-2 Direct Use Benefits

Direct use benefits are the simplest to envision. The welfare of commercial, recreational, and subsistence fishermen is improved when fish stocks increase and their catch rates rise. This increase in stocks may be induced by reduced I&E of species sought by fishermen, or through reduced I&E of forage and bait fish, which leads to increases in the number of commercial and recreational species that prey on the forage species. For subsistence fishermen, the increase in fish stocks may reduce the amount of time spent fishing for their meals or increase the number of meals they are able to catch. For recreational anglers, more fish and higher catch rates may increase the enjoyment of a fishing trip and may also increase the number of fishing trips taken. For commercial fishermen, larger fish stocks may lead to increased revenues through increases in total landings and/or increases in the catch per unit of effort (i.e., lower costs per fish caught). Increases in catch may also lead to growth in related commercial enterprises, such as commercial fish cleaning/filleting, commercial fish markets, recreational charter fishing, and fishing equipment sales.[4]

Evidence that the use value of fishery resources is considerable can be seen in the market and other observable data. For example, in 1996, over 35 million recreational anglers spent nearly $38 billion on equipment and fishing trip related expenditures (U.S. DOI, 1997), and the 1996 GDP from fishing, forestry, and agricultural services (not including farms) was about $39 billion (BEA, 1998). Americans spent an estimated 626 million days engaged in recreational fishing in 1996, an increase of 22% over the 1991 levels (U.S. DOI, 1997). If the average consumer surplus per angling day were only $20 — a conservative figure relative to the values derived by economic researchers over the years (Walsh et al., 1990)[5] — then the national level of consumer surplus based on these 1996 levels of recreational angling would be approximately $12.6 billion per year (and probably is appreciably higher).

However, these baseline values do not provide a sense of how benefits change with improvements in environmental quality, such as due to reduced I&E and increased fish stocks. If the improvement resulted in a aggregate increase of 1.0% in recreational angling consumer surplus, it would translate into potential recreational angling benefits of approximately $100 million per year or more, based on the limited metrics in the previous paragraph.

Methodologies for estimating use values for recreational and commercial species are well developed, and some of the species affected by I&E losses have been extensively studied. As a result, estimation of associated use values is often considered to be straightforward. However, the portion of I&E losses consisting of fish that are recreationally and commercially landed represents only a very small fraction of the total age-1 equivalent I&E losses and, as a result, changes in direct use values resulting from the proposed rule for Phase III facilities provide an incomplete estimate of the regulation's benefits.

The following bullets discuss techniques of estimating direct use value for I&E losses of harvested fish.

❖ **Commercial fisheries**

The social benefits derived from increased landings by commercial fishermen can be valued by examining the markets through which the landed fish are sold. The first step of the analysis involves a fishery-based assessment of I&E-related changes in commercial landings (pounds of commercial species as sold dockside by commercial

---

[4] Increased revenues are often realized by commercial ventures whose businesses are stimulated by environmental improvements. These revenue increases do not necessarily reflect gains in national level "economic welfare" and, therefore, are not usually included in a national benefit-cost analysis. However, these positive economic impacts may be sizable and of significance to local or regional economies — and also of national importance — in times when the economy is not operating at full capacity (i.e., when the economic impacts reflect real gains and not transfers of activity across regions or sectors).

[5] Walsh et al. (1990) review 20 years of research and derive an average value of over $30 per day for warm water angling, and higher values for cold water and saltwater angling.

harvesters). The changes in landings are then valued according to market data from relevant fish markets (dollars per pound) to derive an estimate of the change in gross revenues to commercial fishermen. The final steps entail converting the I&E-related changes in gross revenues into estimates of social benefits. These social benefits consist of the sum of the producers' and consumers' surpluses that are derived as the changes in commercial landings work their way through the multi-market commercial fishery sector. Each step of this analysis is described in detail in Chapter A4.

❖ **Recreational fisheries**

The benefits of recreational use cannot be tracked in the market, since much of the recreational activity associated with fisheries occurs as nonmarket events. However, a variety of nonmarket valuation methods exist for estimating use value, including both "revealed" and "stated" preference methods (Freeman, 2003). Where appropriate data are available or may be collected, revealed preference methods may represent a preferred set of methods for estimating use values. These methods use observed behavior to infer users' value for environmental goods and services. Examples of revealed preference methods include travel cost, hedonic pricing, and random utility models. Compared to non-use values, use values are often considered relatively easy to estimate, due to their relationship to observable behavior, the variety of revealed preference methods available, and public familiarity with the recreational services provided by surface waterbodies.

To evaluate recreational benefits of the proposed section 316(b) regulation for Phase III facilities, EPA developed a benefit transfer approach based on a meta-analysis of recreational fishing valuation studies designed to measure the various factors that determine willingness-to-pay (WTP) for catching an additional fish per trip. The estimated meta-model allows calculation of the marginal value per fish for different species based on resource and policy context characteristics. Benefit transfer is a secondary research method applied when data and other constraints limit the feasibility of doing site-specific primary research. Although primary research methods are generally considered to be superior to benefit transfer methods, benefit transfer is often a second-best (or only) alternative to original studies. Additional details on the benefit transfer method EPA used in the recreational fishing benefits analysis can be found in Chapter A5, "Recreational Fishing Benefits Methodology."

To validate the meta-analysis results, EPA also used regional random utility models (RUM) of recreational fishing behavior developed for the Phase II analysis to estimate welfare gain to recreational anglers from improved recreational opportunities resulting from reduced I&E of fish species. The models' main assumption is that anglers will get greater satisfaction, and thus greater economic value, from sites where the catch rate is higher due to reduced I&E, all else being equal. This method has been applied frequently to value recreational fisheries and is thought to be quite reliable because it is based on people's demand for nonmarket goods and services through observable behavior. The RUM approach has been applied to the four coastal regions and the Great Lakes region. Chapter A11 of the Phase II Regional Analysis document provides more detailed discussion of the methodology used in EPA's RUM analysis (see DCN 6-0003).

❖ **Avoiding double-counting of direct use benefits**

Many of the fish species affected by I&E at CWIS sites are harvested both recreationally and commercially. To avoid double-counting the economic impacts of I&E of these species, the Agency determined the proportion of total species landings attributable to recreational and commercial fishing, and applied this proportion to the number of affected fishery catch.

❖ **Subsistence anglers**

Subsistence use of fishery resources can be an important issue in areas where socioeconomic conditions (e.g., the number of low income households) or the mix of ethnic backgrounds make such angling economically or culturally important to a component of the community. In cases of Native American use of affected fisheries, the value of an improvement can sometimes be inferred from settlements in legal cases (e.g., compensation agreements between affected Tribes and various government or other institutions in cases of resource acquisitions or resource use restrictions). For more general populations, the value of improved subsistence fisheries may be estimated from the costs saved in acquiring alternative food sources (assuming the meals are replaced rather than foregone). This method may underestimate the value of a subsistence-fishery meal to the extent that the storebought foods may be less preferred by some individuals than consuming a fresh-caught fish. Subsistence fishery benefits are not included in EPA's regional analyses, although impacts on subsistence anglers may constitute an important environmental justice consideration, leading to an underestimation of the total benefits of the regulation.

A3-3 Indirect Use Benefits

Indirect use benefits refer to welfare improvements that arise for those individuals whose activities are enhanced as an indirect consequence of fishery or habitat improvements generated by the proposed rule for Phase III facilities. For example, the rule's positive impacts on local fisheries may generate an improvement in the population levels and/or diversity of fish-eating bird species. In turn, avid bird watchers might obtain greater enjoyment from their outings, as they are more likely to see a wider mix or greater numbers of birds. The increased welfare of the bird watchers is thus a legitimate but indirect consequence of the proposed rule's initial impact on fish.

Another example of potential indirect benefits concerns forage species. A rule-induced improvement in the population of a forage fish species may not be of any direct consequence to recreational or commercial anglers. However, the increased presence of forage fish will have an indirect affect on commercial and recreational fishing values if it increases food supplies for commercial and recreational predatory species. Thus, direct improvements in forage species populations can result in a greater number (and/or greater individual size) of those fish that are targeted by recreational or commercial anglers. In such an instance, the incremental increase in recreational and commercial fishery benefits would be an indirect consequence of the proposed rule's effect on forage fish populations.

A3-4 Non-Use Benefits

In contrast to direct use values, non-use values are often considered more difficult to estimate. Stated preference methods, or benefit transfer based on stated preference studies, are the generally accepted techniques for estimating these values. Stated preference methods rely on carefully designed surveys, which either (1) ask people to state their WTP for particular ecological improvements, such as increased protection of aquatic species or habitats with particular attributes, or (2) ask people to choose between competing hypothetical "packages" of ecological improvements and household cost. In either case, analysis of survey responses allows estimation of values.

Non-use values may be more difficult to assess than use values for several reasons. First, non-use values are not associated with easily observable behavioral trails. Second, non-use values may be held by both users and non-users of a resource. Because non-users may be less familiar with particular services provided by a resources their values may be different from the non-use values for users of the same resource. Third, the development of a defensible stated preference survey that meets the NOAA blue ribbon panel requirements is often a time and resource intensive process.[6] Fourth, even carefully designed surveys may be subject to certain biases associated with the hypothetical nature of survey responses (Mitchell and Carson, 1989).

EPA routinely estimates changes in use values of the affected resources as part of regulatory development. However, given EPA's regulatory schedule, developing and implementing stated preference surveys to elicit total value (i.e., non-use and use) of environmental quality changes resulting from environmental regulations is often not feasible. An extensive body of environmental economics literature demonstrates the importance of valuing all

[6] The NOAA blue ribbon panel provided an extensive set of guidelines for survey construction, administration, and analysis to ensure that "... CV produces estimates reliable enough to be the starting point of a judicial process of damage assessment, including passive-use values [i.e. non-use values]" (see FR 58:10 pp.4601-4614, 1993).

service losses, rather than just readily measured direct use losses. These studies typically reveal that the public holds significant value for service flows from natural resources well beyond those associated with direct uses (Fisher and Raucher, 1984; Brown, 1993; Boyd et al., 2001; Fischman, 2001; Heal et al., 2001; Herman et al., 2001; Ruhl and Gregg, 2001; Salzman et al., 2001; Wainger et al., 2001). Studies have documented public values for the non-use services provided by a variety of natural resources potentially affected by environmental impacts, including fish and wildlife (Stevens et al., 1991; Loomis et al., 2000); wetlands (Woodward and Wui, 2001); wilderness (Walsh et al., 1984); critical habitat for threatened and endangered species (Whitehead and Blomquist, 1991a; Hagen et al., 1992; Loomis and Ekstrand, 1997); overuse of groundwater (Feinerman and Knapp, 1983); hurricane impacts on wetlands (Farber, 1987); global climate change on forests (Layton and Brown, 1998); bacterial impacts on coastal ponds (Kaoru, 1993); oil impacts on surface water (Cohen, 1986); and toxic substance impacts on wetlands (Hanemann et al., 1991), shoreline quality (Grigalunas et al., 1988), and beaches, shorebirds, and marine mammals (Rowe et al., 1992). Brown (1993) reports that in many studies, total values exceed direct use values by greater than a factor of two.

The Agency has begun the preliminary development of a stated preference survey that would measure non-use benefits from reduced I&E attributable to the section 316(b) regulation. EPA hopes to complete this stated preference study in time to rely on its findings for the final regulation for Phase III facilities. For the proposed regulation, no primary research was feasible within the budgeting, scheduling, and other constraints faced by the Agency. Thus, the Agency explored various alternatives to quantifying and monetizing non-use benefits based on secondary research. However, given the uncertainties in estimating non-use benefits with secondary estimation techniques at the national level, the Agency presented only a qualitative assessment of the non-use benefits of the environmental protections at issue in the benefit-cost analysis for the proposed section 316(b) regulation for Phase III facilities. Various alternatives to quantifying and monetizing non-use benefits based on secondary research considered by EPA are briefly summarized below.[7] Chapter A6 provides a qualitative assessment of non-use benefits stemming from the proposed regulation. Approaches to valuing I&E impacts on special status species are examined in Chapter A9.

A3-4.1 Role of Non-Use Benefits in the Benefits Analysis for the Proposed Section 316(b) Rule for Phase III Facilities

Accounting for non-use values in the Phase III benefits analysis is especially important because the portion of I&E losses consisting of organisms that have a direct human use value (i.e., those that contribute to forgone harvest) represents only a very small percentage of the organisms impinged and entrained by CWIS. Of the organisms that are anticipated to be protected by the proposed section 316(b) regulation for Phase III facilities, approximately 2.4 percent will eventually be harvested by commercial and recreational fishers and therefore can be valued with direct use valuation techniques. Unharvested fish, which have no direct use value, represent 97.6 percent of the total loss. These unlanded fish include forage fish and the unlanded portion of the stock of harvested species. Their value to the public has two sources: (1) their indirect use as both food and breeding population for fish that are harvested; and (2) their non-use value, stemming from a sense of altruism, stewardship, bequest, or vicarious consumption, as indicated by the willingness of individuals to pay for the protection or improvement in fish numbers. The indirect use value of forage fish is estimated by translating foregone production among forage species into foregone production among harvested fish.[8] However, this indirect use value represents only a portion of the total value of unlanded fish. In fact, society may value both landed and unlanded fish for reasons unrelated to their use value. Such non-use values include the value that people may hold simply for knowing these fish exist. While non-use values are difficult to quantify, EPA believes it is important to

---

[7] DCN 7-5133 provides details on the benefit transfer approaches considered for estimating non-use benefits of the proposed regulation.

[8] See Chapter A1 of this report for detail on this analysis.

consider such values, particularly since 97.6 percent of impinged and entrained organisms have no direct use value.

Table A3-1 provides detailed information on the number and percentage of organisms and age-1 adult equivalent losses valued by EPA in the commercial and recreational fishing benefits analyses.

Table A3-1 —Number and Percentage of Baseline I&E Losses by Species Category

	Age-1 Adult Equivalents (Millions)				
Region	**All Species**	**Forage Species**	**Commercial and Recreational Species**	**Harvested Commercial and Recreational Species**	**I&E of Harvested Species as Percentage of Total I&E**
California	1.31	0.67	0.64	0.06	4.54%
North Atlantic	2.34	1.77	0.57	0.05	2.32%
Mid-Atlantic	23.20	14.80	8.47	1.46	6.29%
Gulf of Mexico	12.70	3.71	9.01	1.20	9.43%
Great Lakes	34.40	32.80	1.54	0.54	1.58%
Inland	44.20	35.60	8.60	0.51	1.15%
National total[a]	120.00	90.20	29.60	3.94	3.29%

[a] The national total includes four sample-weighted facilities in the South Atlantic region. This region was not part of the benefits analysis because these facilities withdraw less than 50 MGD and none of the facilities in this region would be required to install technology to comply with the proposed options.

Source: U.S. EPA analysis for this report.

The organisms that remain unvalued in the analysis provide many important ecological services that do not translate into direct human use. While some ecological services of aquatic species have been studied, other ecosystems services, relationships, and interrelationships are unknown or poorly understood. To the extent that the latter are not captured in the benefits analyses, total benefits are underestimated.

Although individuals do not directly use most of the of the organisms lost at cooling water intake structures, individuals may nonetheless value these organisms. All individuals, including both commercial and recreational fishermen as well as those who do not use the resource, may have non-zero non-use values for unlanded and forage fish. When small per capita non-use values held by a substantial fraction of the population, they may be very large in the aggregate and may in some cases exceed use values.

For resource non-users, non-use values (if >0) must by definition exceed use values, which are zero if resource use is zero. Economic literature suggests that the non-use values for users of aquatic resources are significantly higher than the non-use values for non-users. This may result from additional information about water resources associated with past or expected future use, which is likely to enhance non-use value (Whitehead and Blomquist, 1991a). Other studies (e.g., Silberman et al., 1992), however, suggest that users may include their personal use values in non-use values, which could potentially result in double-counting of use values. In its exploratory analysis of non-use benefits, EPA used values from non-users (who have zero use values) to estimate non-use values for users *and* non-users in order to avoid this problem.

A3-4.2 Overview of Explored Methods for Estimating Non-Use Benefits of the Proposed Rule for Phase III Facilities

In addition to the ongoing development of an original stated preference survey (to be completed for the final regulation), EPA explored two different types of methodological approaches to evaluate the non-use benefits of eliminating baseline I&E losses at Phase III facilities and reducing I&E through a rule for Phase III facilities: (1) a benefit transfer method based on the ratio of non-use-to-use WTP values estimated in stated preference valuation studies; (2) a benefit transfer approach where regression-based meta-analysis of a set of stated preference valuation studies is used to examine the effect of various study, resource, and demographic characteristics on non-use WTP values.

EPA notes that results of the analyses discussed below were not used as a part of the national benefits analysis due to the unavoidable uncertainties in estimating non-use benefits at the national level.

❖ **Benefit Transfer: Ratio-Based Non-Use Analysis**

EPA examined the relationship between non-use and use values based on 20 original stated preference studies that estimated both direct use and non-use values for changes in the quality of aquatic resources. EPA derived non-use-to-use value ratios from each study by examining the estimated components of total value (e.g. recreational use value, existence value; see section A3-1). The estimated ratios of non-use-to-use value can be used together with separate estimates of recreational use value to estimate the per-household non-use value of changes in I&E losses. Applying this non-use value to all the households with non-use motives for the affected waterbody (including both user and non-user households) would yield an estimate of the total non-use value. EPA notes the limitation of using the ratio-based approach because the estimation of non-use values is based solely on the linear relationship between the use and non-use components of total value. In addition to correlation with use values, non-use values are likely to be affected by other factors not directly related to use value, including the geographic scope of improvement, resource characteristics, and the baseline conditions.

❖ **Benefit Transfer: Regression-Based Meta-Analyses**

EPA also explored regression-based meta analysis techniques to estimate the passive, or non-use, benefits of a proposed rule for Phase III facilities. EPA considered two meta regression models, which are designed to statistically summarize the relationship between the computed benefit measures and a set of characteristics compiled from original primary study sources. The Agency considered (1) a regression model to examine the factors that influence household non-use value (Johnston et al., 2003), and (2) a model to examine the factors that influence total household WTP (U.S. EPA, 2004). The mathematical estimation of the functional relationships between non-use/total value and study- and resource-specific characteristics allows the researcher to better forecast estimates of WTP for the policy-specific scenario and sites versus other types of benefit transfer. Additional advantages of the regression-based meta-analyses that EPA explored include:

- meta-analysis utilizes varied source studies which provide increased information on the underlying components of reported benefits measures;
- methodological differences that contribute to differences in estimated benefits across source studies can be determined and controlled with meta-analysis;
- in developing benefits estimates for the policy site and scenario, the independent variable values used in the meta function can be adjusted to account for differences between the forecasted application and the values derived within the original studies; and
- meta regression analysis can provide forecasted values of benefits outside the specific geographical region, site and policy specific characteristics, and scope constraints of the source study data.[9]

[9] The forecasted values derived from meta regression analysis, like any other forecast, decrease in confidence or probability of correctness when used further from the range of the source data.

Much of the primary research into non-use values that is potentially applicable to estimating benefits produced by the implementation of the proposed rule deals with eliciting an individual's WTP for improvements in site water quality. EPA used meta-analysis of information from a number of these studies to determine the relationship between generally reported WTP values for improved water quality and those produced in studies where people were asked to value improvements in water quality that specifically affect only fish populations. This information can be used to estimate an individual's non-use WTP for an improvement in water quality that produces an increase in fish populations, a measure that the Agency believes is closely correlated with a pure WTP for increases in fish.

The results of both regression-based meta-analyses, presented in DCN 7-5133, can be used to estimate annual WTP for fish habitat improvement per non-user household (e.g., Mitchell and Carson, 1986; Carson and Mitchell, 1993). Applying this non-use value to all the households with non-use motives for the affected waterbody (including both user and non-user households) would yield an estimate of the total non-use value.[10]

A3-5 Summary of Benefit Categories

Table A3-2 displays the types of benefit categories expected to be affected by the proposed section 316(b) rule for Phase III facilities. The table also reveals the various data needs, data sources, and estimation approaches associated with each category. Economic benefits can be broadly defined according to direct use and indirect use, and are further categorized according to whether or not they are traded in the market. As indicated in Table A3-2, "direct use" and "indirect use" benefits include both "marketed" and "nonmarketed" goods, whereas "non-use" benefits include only "nonmarketed" goods.

[10] EPA notes that this method of estimating non-use values may underestimate non-use values for users of aquatic resources (Whitehead and Blomquist, 1991a). Mitchell and Carson (1981) estimate "total value," including use and non-use components. However, total value estimates for non-users can be interpreted as their non-use value (i.e., there is no difference between their total and non-use value). Since non-users of a resource generally have lower non-use values than users, assuming that all members of the relevant population (users and non-users) have non-use values equal to the total values of non-users is a conservative assumption.

Table A3-2: Summary of Benefit Categories
Data Needs, Potential Data Sources, Approaches, and Analyses Completed

Benefit Category	Basic Data Needs	Potential Data Sources/Approaches/Analyses Completed
	Direct Use, Marketed Goods	
Increased commercial landings	▸ Estimated change in landings of specific species ▸ Estimated change in total economic impact	▸ Based on facility-specific I&E data and ecological modeling ▸ Market-based approach using data on landings and the value of landings data from the National Marine Fisheries Service (NMFS)
Fishing tournaments with entry fees and prizes	Estimated change in total economic impact	Not estimated. Changes in tournament participation are expected to be negligible
	Indirect Use, Market Goods	
Increase in market values: ▸ equipment sales, rental, and repair ▸ bait and tackle sales ▸ increased consumer market choices ▸ increased choices in restaurant meals ▸ increased property values near water ▸ ecotourism (charter trips, festivals, other organized activities with fees such as riverwalks)	▸ Estimated change in landings of specific species ▸ Relationship between increased fish/shellfish landings and secondary markets ▸ Local activities and participation fees ▸ Estimated numbers of participating individuals	Not estimated due to data constraints
	Direct Use, Nonmarket Goods	
Improved value of a recreational fishing trip: ▸ increased catch of targeted/preferred species ▸ increased incidental catch	▸ Estimated number of affected anglers ▸ Value of an improvement in catch rate	▸ Benefit transfer ▸ Regional RUM analysis (to validate benefit transfer)
Increase in recreational fishing participation	▸ Estimated number of affected anglers or estimate of potential anglers ▸ Value of an angling day	Not estimated. Changes in recreational participation are expected to be negligible at the regional level.

	Indirect Use, Nonmarket Goods	
Increase in value of boating, scuba-diving, and near-water recreational experience: ▸ enjoying observing fish while boating, scuba-diving, hiking, or picnicking ▸ watching aquatic birds fish or catch aquatic invertebrates	▸ Estimated number of affected near-water recreationists, divers, and boaters ▸ Value of boating, scuba-diving, and near-water recreation experience	Not estimated due to data constraints
Increase in boating, scuba-diving, and near-water recreation participation	▸ Estimated number of affected boating, scuba-diving, and near-water recreationists ▸ Value of a recreation day	Not estimated. Changes in recreational participation are expected to be negligible at the regional level
	Non-use, Nonmarket Goods	
Increase in non-use values: ▸ existence (stewardship), ▸ altruism (interpersonal concerns), ▸ bequest (interpersonal and intergenerational equity) motives ▸ appreciation of the importance of ecological services apart from human uses or motives (e.g., eco-services interrelationships, reproductive success, diversity, and improved conditions for recovery).	▸ I&E loss estimates ▸ Primary research using stated preference approach (not feasible within EPA constraints) ▸ Applicable studies upon which to conduct benefit transfer	▸ Site-specific studies or national stated preference surveys ▸ Benefit transfer, including ratio-based and regression-based meta-analysis of applicable studies ▸ Benefit transfer of values for preserving threatened and endangered species

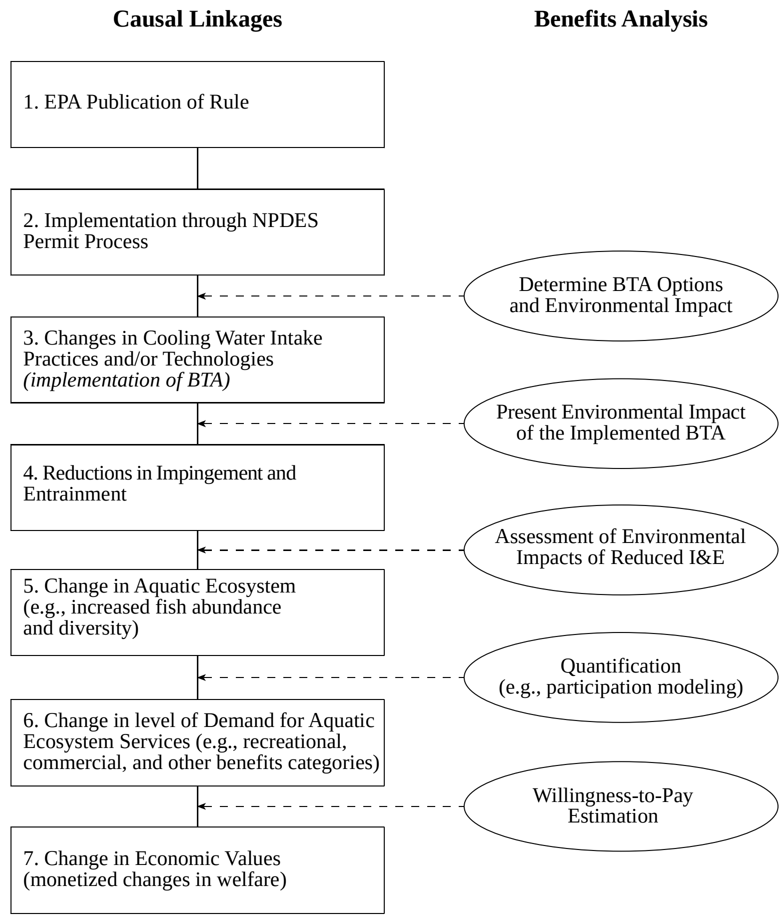
Source: U.S. EPA analysis for this report.

A3-6 Causality: Linking the Proposed Rule for Phase III Facilities to Beneficial Outcomes

Understanding the anticipated economic benefits arising from changes in I&E requires understanding a series of physical and socioeconomic relationships linking the installation of Best Technology Available (BTA) to changes in human behavior and values. As shown in Figure A3-2, these relationships span a broad spectrum, including institutional relationships to define BTA (from policy making to field implementation), the technical performance of BTA, the population dynamics of the aquatic ecosystems affected, and the human responses and values associated with these changes.

The first two steps in Figure A3-2 reflect the institutional aspects of implementing the proposed rule for Phase III facilities. In step 3, the anticipated applications of BTA (or a range of BTA options) must be determined for the regulated entities. This technology forms the basis for estimating the cost of compliance, and provides the basis for the initial physical impact of the rule (step 4). Hence, the analysis must predict how implementation of BTAs (as predicted in step 3) translates into changes in I&E at the regulated CWIS (step 4). These changes in I&E then serve as input for the ecosystem modeling (step 5).

Figure A3-2: Causal Linkages in the Benefits Analysis



Source: U.S. EPA analysis for this report.

In moving from step 4 to step 5, the selected ecosystem model (or models) are used to assess the change in the aquatic ecosystem from the pre-regulatory baseline (e.g., losses of aquatic organisms before BTA) to the post-regulatory conditions (e.g., losses after BTA implementation). The potential output from these steps includes estimates of reductions in I&E rates, and changes in the abundance and diversity of aquatic organisms of commercial, recreational, ecological, or cultural value, including T&E species.

In step 6, the analysis involves estimating how the changes in the aquatic ecosystem (estimated in step 5) translate into changes in the level of demand for goods and services. For example, the analysis needs to establish links between improved fishery abundance, potential increases in catch rates, and enhanced participation. Then, in step 7, as an example, the value of the increased enjoyment realized by recreational anglers is estimated. These last two steps are the focal points of the economic benefits portion of the analysis.

A3-7 Conclusions

The general methods described here are applied to the regional studies, which are provided in Parts B through G of this document. Variations may occur to these general methodologies within distinct regional analyses to better reflect site-specific circumstances or data availability.

Chapter A4: Methods for Estimating Commercial Fishing Benefits

Chapter Contents

Introduction

Commercial fisheries can be adversely impacted by impingement and entrainment (I&E) and many other stressors. Because commercially landed fish are exchanged in markets with observable prices and quantities, it may seem as if estimating the economic value of losses due to I&E (or the economic value of the benefits of reducing I&E) would be relatively straightforward. However, many complicating conceptual and empirical issues pose significant challenges to estimating the change in economic surplus from changes in the number of commercially targeted fish.

This chapter provides an overview of these issues, and demonstrates how EPA estimated the change in commercial fisheries-related economic surplus associated with the section 316(b) regulation. This chapter includes a review of the concept of economic surplus, and describes the theory and empirical evidence on how readily observable dockside prices and quantities may relate to the economic welfare measures of producer and consumer surplus that are suitable for a cost-benefit assessment. This chapter also provides an overview of the commercial fishery sector of the economy, including an assessment of several relevant fishery stocks, trends and patterns of how the commercial fishing sector operates, and issues within commercial fisheries management and how they affect the analysis of economic welfare measures.

A4-1 Overview of the Commercial Fishery Sector

In estimating the effects of increased fish as a result of reduced quantities of I&E, it is important to understand who is affected. First and foremost, there are the commercial watermen, the individuals engaged in harvesting fish. These watermen typically haul their catch to established dockside wholesale markets, where they sell their catch to processors or wholesalers. Processors package or can the fish so that they can be sold as food products for people, as pet and animal feed, or as oils and meals for various other uses. Wholesalers often resell fish to retailers (e.g., grocery stores), restaurants, or final consumers (households).

The market and welfare impacts of a change in commercial fishery harvests can be traced through a series of economic agents — individuals and businesses — that are linked through a series of “tiered markets.” Through these economic relationships between the various levels of buyers and sellers, the final value of the fish product (e.g., a family dinner) creates economic signals (e.g., prices) that carry back through the various intermediate parties to the watermen who actually engage in the harvest. Additionally, beneficial changes in the commercial fishery may encourage watermen to purchase more fishing gear, fuel, and vessel repairs, which will benefit the suppliers of these goods and services (although such purchases from input suppliers would not typically be estimated as part of benefits, because they are transfers).

A4-1.1 Commercial Watermen

Commercial watermen include the individuals supplying the labor and/or capital (e.g., fishing vessels) engaged in the harvesting of fish. These watermen typically haul their catch to established dockside wholesale markets, where they sell their catch to processors or wholesalers. The transactions between the watermen and these intermediate buyers provide observable market quantities and prices of dockside landings, and it is these data that serve as a starting point for estimating changes in economic surplus.

Commercial fishing is often a demanding and risky occupation. However, commercial anglers often find great satisfaction in their jobs and lifestyles. Additional detail on the economic and noneconomic aspects of commercial fishing is provided in several of the sections that follow, including a discussion of the nonmonetary benefits of commercial fishing (section A4-10).

A4-1.2 Processors, Wholesalers, and Other Middlemen

Dockside transactions typically involve buyers for whom the fish are an input to their production or economic activity. For example, processors convert raw fish into various types of final or intermediate products, which they then sell to other entities (e.g., retailers of canned or frozen fish products, or commercial or industrial entities that rely on fish oil as a production input). Wholesalers may serve as middlemen between the watermen who harvest the fish and those who will use the fish as production inputs or to retail vendors (e.g., supermarkets). Depending on the market and the type of fish, there may be numerous economic actors and layers between the commercial watermen who caught the fish and the final consumer who eats or otherwise uses the fish product.

A4-1.3 Final Consumers

After passing through perhaps several intermediate buyers and sellers, the fish (or fish products) ultimately end up with a final consumer (typically a household). This final consumption may take the form of a fish dinner prepared at home or purchased in a restaurant. Final consumption may also be in the form of food products served to household pets, or as part of a nonfood product that relies on fish parts or oils as an input to production.

A4-2 The Role of Fishing Regulations and Regulatory Participants

Transactions in the fishery sector are often affected by various levels of fishery management regulations. Nearshore fishing (ocean and estuary fishing less than 3 miles from shore) and Great Lakes fishing are primarily regulated by State, Interstate, and Tribal entities. The content and relative strength of State laws affecting ocean fishing vary across states.

The regulated nature of many fisheries affects the manner in which the impacts and economic benefits of the section 316(b) regulation should be evaluated. For example, if the impacted fisheries were perfectly competitive with open access (i.e., no property rights or fishery regulations), then all economic rents, producer surplus, and economic profits associated with the resource would be driven to zero at the margin. However, where fisheries are regulated or in other ways depart from the neoclassical assumptions of perfectly competitive markets, there are rents and economic surplus that will be affected by changes in I&E. These economic considerations are addressed later in this chapter.

The primary Federal laws affecting commercial fishing in U.S. ocean territory are the Magnuson Fishery Conservation and Management Act of 1976 and the Sustainable Fisheries Act (SFA) of 1996 (the SFA amended the 1976 act and renamed it the Magnuson-Stevens Fishery Conservation and Management Act). The purpose of the 1976 act was to establish a U.S. exclusive economic zone that ranges from 3 to 200 miles offshore, and to create eight regional fishery councils to manage the living marine resources within each area. These councils comprised “commercial and recreational fishermen, marine scientists and State and Federal fisheries managers, who combine their knowledge to prepare Fishery Management Plans (FMPs) for stocks of finfish, shellfish and crustaceans. In developing these FMPs the Councils use the most recent scientific assessments of the ecosystems involved with special consideration of the requirements of marine mammals, sea turtles and other protected resources” (NMFS, 2002c). The SFA amended the law to include numerous provisions requiring science, management, and conservation action by the National Marine Fisheries Service (NMFS) (NMFS, 2002e).

The eight fisheries management councils created by the 1976 act have regulatory authority within their respective regions [five of these councils are relevant to the section 316(b) Phase III rulemaking]. They receive technical and scientific support from the National Oceanic and Atmospheric Administration (NOAA) Fisheries Science Centers. Table A4-1 presents how the regions used for the section 316(b) regulation analysis fit into the fisheries management council regions and other fishery regions defined by NOAA Fisheries.

Table A4-1: Regional Designation of Fisheries

EPA 316(b) Analysis Region	States	NOAA Fisheries Marine Recreation Region	NOAA Fisheries Commercial Region	Fishery Management Council (FMC)	Large Regions Reported in *Our Living Oceans* (NMFS, 1999a)
North Atlantic	Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island	North Atlantic	New England	New England	Northeast
Mid-Atlantic	New York, New Jersey, Delaware, Maryland, District of Columbia, Virginia	Mid-Atlantic	Chesapeake Mid-Atlantic	Mid-Atlantic	Northeast
South Atlantic	North Carolina, South Carolina, Georgia, Florida (Atlantic Coast)	South Atlantic	South Atlantic	South Atlantic (NC in Mid-Atlantic)	Southeast
Gulf of Mexico	Florida (Gulf Coast), Alabama, Mississippi, Louisiana, Texas	Gulf of Mexico	Gulf	Gulf of Mexico	Southeast
Northern California	California, north of San Luis Obispo/Santa Barbara county border	Northern California	Pacific Coast	Pacific	Pacific Coast
Southern California	California, south of San Luis Obispo/Santa Barbara county border	Southern California	California	Pacific	Pacific Coast
Great Lakes	Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, New York	na	Great Lakes	na	na

A4-3 Overview of U.S. Commercial Fisheries

In estimating the benefits of reducing I&E losses, it is important to understand how increased fish populations may affect stocks in different fisheries. Where stocks are thriving, a small increase in the number of individual fish may not be noticed, but where stocks are already depleted the marginal impact of a small increase may be much more important.

Many fisheries in the United States tend to be heavily fished. In the mid-1900s, many U.S. fisheries were over-fished, some to the point of near collapse (NMFS, 1999a, 2001a; U.S. Bureau of Labor Statistics, 2002). The current situation is somewhat improved due to recent management efforts mandated by the Magnuson-Stevens Act and others regulations. However, many of the current management practices have not been in place long enough to have a noticeable impact on fisheries.

Table A4-2 shows the utilization rate of fisheries in the United States by region based on information from the NMFS report *Our Living Oceans* (NMFS, 1999a). The regions in Table A4-2 are defined more broadly than those used in the section 316(b) Phase III regional analysis. The Northeast region comprises both the North and Mid-Atlantic regions for the 316(b) analysis; the Southeast region in the table includes the South Atlantic and Gulf of Mexico Phase III regions; and the Pacific Coast region includes the Northern and Southern California regions as well as the states of Oregon and Washington.

Table A4-2: Utilization of U.S. Ocean and Nearshore Fisheries by Region in 1999

Our Living Oceans Region[a]	# Fisheries with Known Status	# Fisheries with Unknown Status	# Under-Utilized	# Fully Utilized	# Over-Utilized
Alaska	43	8	10	33	0
Northeast	55	15	4	15	36
Pacific Coast	55	11	12	37	6
Southeast	34	35	2	15	17
Western Pacific	20	7	8	9	3
Total	207	76	36	109	62
% of Total Known			17%	53%	30%

[a] The Northeast region includes the North and Mid-Atlantic regions; the Pacific Coast region includes the Northern and Southern California regions, as well as the states of Oregon and Washington; and the Southeast region includes the South Atlantic and Gulf of Mexico regions. The Alaska and Western Pacific regions are not included in the 316(b) Phase III analysis, but are included here for comparison.

Source: NMFS, 1999a.

Based on NOAA Fisheries definitions, a fishery is considered to be producing at a less than optimal level if its recent average yield (RAY)[1] is less than the estimated long-term potential yield (LTPY).[2] This can occur as a result of either under-utilization of the fishery or the collapse of the fish stock. These data indicate that a majority, 53%, of the ocean and nearshore fisheries with known status, were fully utilized in 1999. Approximately 30% of these fisheries are identified as over-utilized. For more than a third of all fisheries, the status is unknown.

Table A4-3 shows the overall production of U.S. fisheries by region, including current potential yield (CPY). In total, the annual RAY has been over 12 million metric tons, with Alaska and the Western Pacific providing nearly two-thirds of the catch. Because of under-utilization in some fisheries and over-fishing in others, the total RAY in the United States is only 60% of the estimated LTPY.

[1] RAY is measured as "reported fishery landings averaged for the most recent 3-year period of workable data, usually 1995-1997" (NMFS, 1999a, p. 4).

[2] LTPY is "the maximum long-term average catch that can be achieved from the resource. This term is analogous to the concept of maximum sustainable yield (MSY) in fisheries science" (NMFS, 1999a, p. 5). LTPY may not be the yield that maximizes economic rents.

Table A4-3: Productivity of U.S. Regional Fisheries in 1999 (million metric tons)

Our Living Oceans Regions[a]	Total Long-Term Potential Yield (LTPY)	Total Current Potential Yield (CPY)		Total Recent Average Yield (RAY)		
		CPY	% of LTPY	RAY	% of LTPY	% of CPY
Alaska	4.47	3.52	78.7%	2.51	56.1%	71.3%
Northeast	1.59	1.35	85.2%	0.89	55.7%	65.4%
Pacific Coast	1.04	0.85	81.9%	0.62	59.7%	72.9%
Southeast	1.50	1.15	76.7%	1.16	76.8%	100.2%
Western Pacific	3.44	3.44	100.1%	2.05	59.6%	59.6%
Total	12.04	10.32	85.7%	7.22	60.0%	70.0%

[a] The Northeast region includes the North and Mid-Atlantic regions; the Pacific Coast region includes the Northern and Southern California regions, as well as the states of Oregon and Washington; the Southeast region includes the South Atlantic and Gulf of Mexico regions. The Alaska and Western Pacific regions are not included in the 316(b) Phase III analysis, but are included here for comparison.

Source: NMFS, 1999a.

A4-4 Prices, Quantities, Gross Revenue, and Economic Surplus

Dockside landings and revenues are relatively easy to observe, and readily available from NOAA Fisheries. These data can be used to develop a rough estimate of the value of increased commercial catch. However, it is not always easy to interpret these data properly in estimating benefits. First, there are some empirical issues as to whether the data accurately reflect the full market value of the commercial catch. Second, simply applying an average price to a change in catch does not account for a potential price response to change in catch. Third, even if the price effect is accounted for, change in gross revenue is not necessarily the right conceptual or empirical basis for estimating benefits from reduced I&E. This section addresses these key issues.

A4-4.1 Accuracy of Price and Quantity Data

Although the commercial landings data available from NOAA Fisheries are the most comprehensive data available at the national and regional levels, the data may not fully capture the economic value of the commercial catch in the United States. As with any large-scale data collection effort, there are potential limitations such as database overlap and human error. Additional reasons the data may not fully capture the economic value of the commercial catch are varied and include, but are not limited to, the following:

- Fishermen often receive noncash payments for their catch. Crutchfield et al. (1982) noted that “the full amount of the payment to fishermen should include the value of boat storage, financing, food, fuel, and other non-price benefits that are often provided to fishermen by processors. These are clearly part of the overall ‘price,’ but are very difficult to measure, since they are not generally applicable to all fishermen equally and are not observed as part of dockside prices.”

- Some fishermen may sell their catch illegally. There are three main reasons why illegal transactions occur:
  - To circumvent quantity restrictions (quotas) on landings allowed under fishery management rules.
  - To avoid or reduce taxes by having a reported income less than true earnings.
  - To reduce profit sharing, boat owners have been know to negotiate a lower price with the buyer and then recover part of their loss “in secret” so they do not have to share the entire profit with the crew.

- Some species are recorded inaccurately. Seafood dealers fill out the reports for commercial landings and may mislabel a species or not specifically identify the species — for example, entering ‘rockfish’ instead of “blue rockfish.” In this example the landings data for blue rockfish would under-estimate total landings, while data for “other rockfish” would be over-estimated (David Sutherland, NMFS, Fisheries Statistics and Economics Division, personal communication, November 4, 2002).

- Federal law prohibits reporting confidential data that would distinguish individual producers or otherwise cause a competitive disadvantage. These “confidential landings” are entered as “unclassified” data (e.g., “finfishes, unc.”) and do not distinguish individual species. Although most summarized landings are not confidential, species summary data may under-report actual landings if some of those landings were confidential and therefore not reported by individual species (NMFS, 2002b).

- Landings data are combined from nine databases that overlap spatially and temporally, and although they are carefully monitored for double-counting, some overlap may go unnoticed (NMFS, 2002b).

A4-4.2 The Impact of Potential Price Effects

A key issue in this analysis is whether the change in fishery conditions associated with regulatory options will be sufficiently large to generate price changes in the relevant fishery markets:

- If the estimated changes in commercial landings are sufficiently small in size relative to the applicable markets that no price change of consequence is anticipated (as appears to be the case in all regions included in this analysis), then the approach to estimating benefits becomes relatively simple. As will be developed later in this chapter, this is because the change in revenues becomes straightforward to estimate (i.e., the estimated change in quantity landed times the original price). Further, with no change in price, there is a fairly transparent relationship between the change in revenues and the change in economic surplus measures that are suitable for a benefits assessment (i.e., there is no change in consumer surplus, and the change in producer surplus may be equivalent to a percentage of or even equal to the change in revenues).

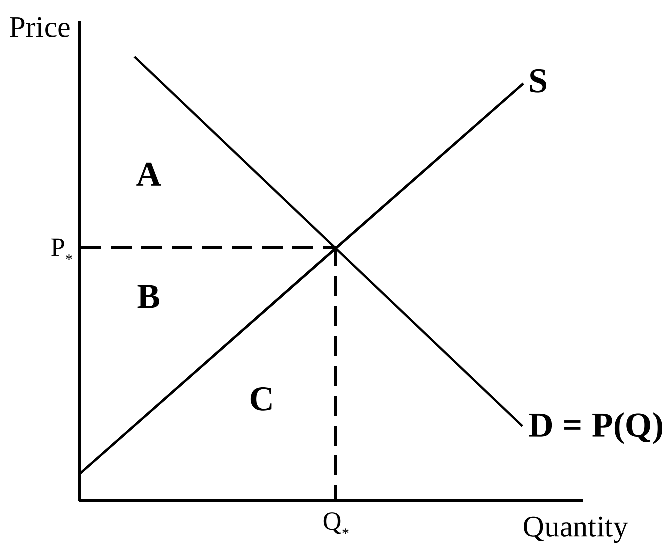
- If changes in landings are such that a price change is anticipated, then the conceptual and empirical analysis becomes more complicated. As detailed in greater depth later in this chapter, a price change makes it more difficult to estimate changes in gross revenues (in fact the change in revenues may be either positive or negative, depending on the relative elasticity of demand). Further, a change in price is anticipated to generate changes in both producer and consumer surplus, and there are numerous complex factors to be considered in assessing these changes in welfare (e.g., some of the gain in consumer surplus will reflect a transfer away from producer surplus, the overall change in producer surplus may be positive or negative, and the relationship between these measures of surplus and the estimated market revenues is much less transparent than in the case where price is reasonably constant).

As discussed later in this chapter, in all regions evaluated, the change in estimated harvest as a result of reduced I&E is small relative to the applicable market, and EPA therefore has assumed that there would be no significant change in price. The issues with estimating changes in revenues and surplus are then relatively straightforward. It may be the case in future rulemakings, however, that price changes will apply in some markets. Therefore, this chapter provides additional discussion of conceptual and empirical issues that may arise if a price change scenario is found to be relevant in future analyses.

A4-4.3 Key Concepts Applicable to the Analysis of Revenues and Surplus

Before progressing into the details of defining and measuring revenues and surplus, or discussing further why prices may change and how one might estimate the changes, it is important to first establish some basic economic concepts relative to markets and measures of welfare. Figure A4-1 depicts a simple market for a typical economic good, with demand (labeled as line D) downward sloping to reflect what economists refer to as decreasing marginal utility, and supply (line S) upward sloping to reflect increasing marginal costs. There are numerous reasons why the market for commercial fish often differs in important ways from the typical market depicted in the figure. Commercial fisheries are considered renewable natural resources whereby supply is limited by ecological constraints. As a consequence, fisheries markets deviate from the traditional neoclassical view of fully competitive markets due to the impacts of open access, the socially desirable need to maximize resource rents, the corresponding need for regulations that limit catch or prevent the entry of fishermen (suppliers), and the possibility that costs may not increase in the relevant range of changes to fishery conditions. Nonetheless, to help introduce some core concepts, we begin with the standard neoclassical depiction of a market as shown in the figure.

Figure A4-1: Market for Typical Economic Good

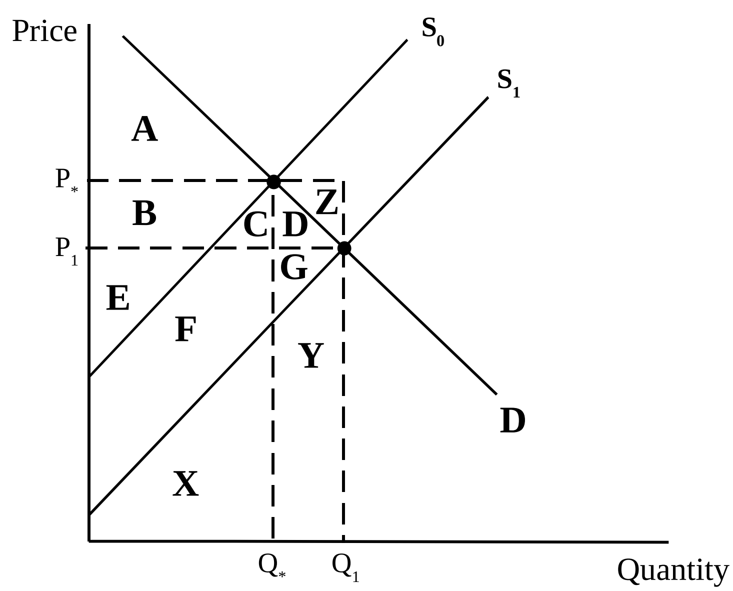


An equilibrium is established where supply and demand intersect, such that Q_* reflects the quantity of the good exchanged and P_* reflects the market clearing price (i.e., the price at which the quantity supplied is equal to the quantity demanded). The gross revenue in this market (the sum total paid by consumers, which is equivalent to payments received by sellers) is equal to P_* multiplied by Q_*, which in the figure is depicted by the rectangle made up of areas B plus C.

While the level of total (gross) revenues is of interest, it is not the same as the amount of benefit (economic welfare) that is generated by this market, which is measured by what is referred to as economic surplus (see sections A4-5.1 and A4-5.2 for further discussion of concepts related to economic surplus). Economic surplus consists of the consumer surplus generated (which is depicted by area A) plus the producer surplus generated (depicted as area B). Consumer surplus reflects the amount by which willingness-to-pay (WTP) (as reflected by the demand curve) exceeds the market-clearing price for each quantity exchanged up to Q_* (i.e., it reflects the degree by which consumers obtained the traded commodity at a price below what the good was worth to them). Likewise, producer surplus reflects the extent to which suppliers realized revenues above and beyond the marginal cost of producing some of the units (up to Q_*). Beyond Q_*, there is neither additional consumer nor producer surplus to be gained — at the margin, all the surplus has been extracted and there is no additional surplus to be gained by adding more output to the market.

Now suppose there is a change that increases the amount of a key input to production, such that the more bountiful input is now available at a lower cost to suppliers than before (e.g., when increasing the amount of locally harvestable fish makes it easier to catch a given number of fish). This could result in an outward shift in supply (a decrease in the marginal cost of producing any given quantity of the good). This is depicted in Figure A4-2, where supply shifts from S_0 to S_1. With the increased supply, a new market clearing price emerges at P_1 (which is lower than the original P_*), and the quantity exchanged increases from Q_* to Q_1.

Figure A4-2: Increased Supply in Typical Economic Market



These changes in the quantity exchanged and the market clearing price make it somewhat complex to envision how (and by what degree) gross revenues and economic surplus measures may change as a consequence of the shift in supply. Using Figure A4-2 as a guide:

- Under the original supply conditions (S_0) consumer surplus had been area A, but it has now increased to A + B + C + D. Therefore, consumer surplus has increased by an amount depicted by areas B + C + D.

- Producer surplus had been area B + E before the supply shift, but becomes E + F + G after the shift in supply. Hence, the change in producer surplus is depicted as areas F + G - B.
  - Note that area B is subtracted from producer surplus but added to consumer surplus — i.e., it represents a transfer of surplus from producers to consumers when supply shifts outward and prices decline.
  - Also note that consumer surplus has increased by more than the transfer of area B from producers; the additional consumer surplus (above and beyond the transfer) is depicted by the amount C + D.
  - Finally, note that the change in producer surplus might be positive or negative, depending on whether the addition of F + G outweighs the loss of B (assuming the supply curves are parallel).

- The total change in economic surplus (consumer plus producer surplus) therefore equals C + D + F + G.

- Revenues had been P_* times Q_* (areas B + C + E + F + X), but now becomes P_1 times Q_1 (areas E + F + X + G + Y). The change in revenues thus becomes (G + Y) - (B + C).

- Note that the change in revenue can be positive or negative, depending on whether G + Y is greater than or less than B + C.
- Also note that if one does not know by how much the price will decrease, and relies on the original price (P_*) to estimate the change in revenues, then the change in revenues would be over-estimated as P_* times (Q_1 - Q_*), which is equivalent to the areas G + Y + D + Z.
- If the change in revenues is estimated relying on the original price level (P_*) when in fact the new price becomes P_1, then the amount by which the change in revenues will be over-estimated would be B + C + D + Z.

Even though the illustration above relies on a relatively simple depiction of a market that adheres to the basic economic assumptions and conditions of perfect competition, it reveals how complex the analysis can become if there is an anticipated change in price when supply is increased. The analysis can become even more complex when fishery-related deviations from the assumptions of open access perfect competition are considered.

A4-4.4 Estimating Changes in Price (as applicable)

One key observation from the illustration above is the importance of predicting the change in price, because relying on the baseline price can lead to potential errors. Correct estimation of the change in the price of fish as a result of regulation requires two pieces of information: the expected change in the commercial catch, and the relationship between demand for fish and the price of fish. Ideally, a demand curve would be estimated for the market for each fish species in each regional market. The level of effort required to model demand in every market is not feasible for the 316(b) analysis. However, if reasonable, empirically based assumptions can be made for the price elasticity of demand for fish in each region, the change in price can be accurately estimated.

The price elasticity of demand for a good measures the percentage change in demand in response to a percentage change in price. If the price elasticity of demand for fish is assumed to be -2 over the relevant portion of the demand function, then a 1% *increase* in price creates a 2% *decrease* in the quantity demanded. Essentially, this determines the shape of the demand curve because it indicates how demand responds to a change in price. The inverse of the price elasticity of demand can be used to estimate the change in price as a result of a change in the quantity demanded. If the price elasticity of demand is assumed to be -2, the inverse is 1/-2 = -0.5. This would imply that a 1% *increase* in demand would correspond to a 0.5% *decrease* in price.

For example, in Figure A4-2, if Q_* is equal to 10,000 pounds of fish per year and reductions in I&E are expected to add 500 pounds of fish to the annual catch, Q_1 will equal 10,500 per year. This is a 5% increase in the quantity of fish supplied to the market. In response to the increase in supply, price will need to decrease from P_* to P_1. To clear the market, the quantity demanded would need to increase until Q_1 is also the quantity of fish demanded. If the price elasticity of demand for fish in this market is known to be approximately -2, then the inverse of the price elasticity of demand is -0.5 and, as described above, the expected change in price necessary to clear the market would be 5% x -0.5 = -2.5%. If P_* equals $1.00 per pound, then P_1 will equal $0.975 per pound, and the change in gross revenues will be (10,500 × $0.975) - (10,000 × $1.00) = $237.50. This represents a 2.375% increase in gross revenues for commercial fishermen in this market.

A variety of sources in the economics literature provide estimates of the price elasticity of demand for fish. In this analysis, EPA has assumed that the changes in supply of fish as a result of reduced I&E will not be large enough to create a significant change in price (see discussion below describing regional results). Therefore, assumptions about price elasticity are not necessary in this case. In future analyses if there are markets in which the estimated change in harvest is predicted to be large enough to generate a price change of consequence, EPA will revisit this issue in light of information available in the literature.

A4-5 Economic Surplus

Even if the change in gross revenue is measured accurately and potential price effects (if any) are accounted for, changes in gross revenues are not generally considered to be a true measure of economic benefits. According to broadly accepted principles of microeconomics, benefits should be expressed in terms of economic surplus to consumers and producers.

A4-5.1 Consumer Surplus

To understand consumer surplus, consider the following illustration. Suppose a seafood lover goes to a fish market and pays $$P^1$ for a tasty salmon dinner. She pays $$P^1$ because that is the current market price. However, she would have been willing to pay a lot more than $$P^1$, if necessary. The maximum she would have paid for the salmon is $B. The difference between $B and $$P^1$ represents an additional benefit to the consumer. When this benefit is summed across all consumers in the market, it is called consumer surplus.

Figure A4-3 shows one possible representation of a market for fish. The demand curve, D(F), shows the aggregate demand that would prevail in the market at each price level (P).[3,4] The curve Q^1 is the quantity of fish supplied to the market by fishermen. Equilibrium is attained a the point where D(F) equals Q^1. Under these conditions, the price is P^1. In this case the total amount paid by consumers for fish is equal to $P^1 \times Q^1$, which is equal to the area of the boxes U + V + W in the graph. The extra benefit to consumers, i.e., the consumer surplus, is equal to the area of the triangle T.[5]

If the quantity of fish available to the market increases from Q^1 to Q^2, then the price decreases to P^2. This changes the total amount paid by consumers to $P^2 \times Q^2$, which is equal to the area of the boxes V + W + Y + Z, and increases the consumer surplus to be equal to the area of the triangle T + U + X.

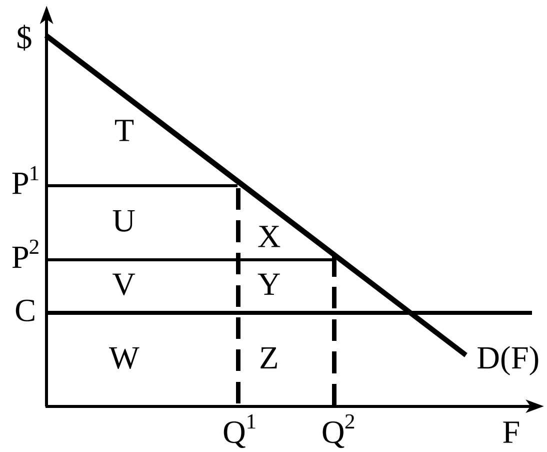
---

[3] Note that in the graph the quantity supplied, curves Q^1 and Q^2, is assumed to be constant under a given set of conditions. This assumption allows for a simplified case to be presented in the figure. An assumption of constant supply is more appropriate for a short-term analysis or for an analysis of a fishery regulated via quotas. Section A4-6 offers a discussion of the case where the supply curve is upward sloping.

[4] In this simplified illustration D(F) is really an inverse demand curve since it determines price as a function of quantity, F. The distinction is not of vital importance here.

[5] Note that Figure A4-3 is a highly simplified characterization of benefits derived from a commercial fishery, where the goal is to maximize producer surplus and consumer surplus. Figure A4-3 is drawn from Bishop and Holt (2003), who indicate that D(F) represents a general equilibrium demand function, accounting for markets downstream of harvesters, and that the welfare triangle (area T in Figure A4-3) represents consumer surplus plus post-harvest rents. Q^1 is the supply of fish under a fixed, optimal quota before the proposed section 316(b) rule for Phase III facilities and Q^2 is the supply after the proposed section 316(b) rule for Phase III facilities takes effect. A more complete interpretation of the graph in the context of renewable resources also reveals that costs for the harvester (e.g., fishing fleet) are equal to the area W (for a quota equal to Q^1) and that area U + V is equal to the rents potentially captured by the harvester at Q^1.

Figure A4-3: Conceptual Model of Benefits from an Increase in Fish Catch



Source: Bishop and Holt (2003).

A4-5.2 Producer Surplus

In the example above, there is also a producer surplus that accrues to the fish seller. When the fish market sold the salmon to our consumer, it sold it for $$P^1$ because that was the market price. However, it is likely that it cost less than $$P^1$ to supply the salmon. If $C is the cost to supply the fish, then the market earns a profit of $$P^1$ minus $C per fish. This profit is akin to the economic concept of producer surplus.[6]

In Figure A4-3, the line C represents a simplified representation of the cost to the producer of supplying a pound of fish.[7] When the supply of fish is equal to Q^1, the producers sell Q^1 pounds of fish at a price of P^1. The difference between P^1 and C is the producer surplus that accrues to producers for each pound of fish.[8] Total producer surplus realized by producers is equal to $(P^1 - C) \times Q^1$. In the example, this producer surplus is equal to the area of U + V. The area W is the amount that producers pay to their suppliers if the harvest equals Q^1. In the example presented here, W might be the amount that the fish market paid to a fishing boat for the salmon plus the costs of operating the market.

---

[6] Producer surplus equals economic profit minus the opportunity cost of the owner's resources invested in the fishery enterprise (see section A4-8 for additional details).

[7] In this case average cost is assumed to equal marginal cost at C and the marginal cost is assumed constant. Note that this is a simplification used here only to assist with the discussion. For example, the section 316(b) rulemaking might lead to a small decrease in cost per unit of fish caught. Also, if marginal cost were assumed to be upward sloping, the figure would more closely resemble the familiar graph of supply and demand with an upward-sloping supply curve, as depicted in Figure A4-2.

[8] Note that economists usually assume that C includes the opportunity cost of investing and working in commercial fishing. Thus, producer surplus is profit earned above and beyond normal profit. In a perfectly competitive market, when economic profit is being earned, it induces more producers to join the market until producer surplus is zero. However, many commercial fisheries are no longer allowing open access to all fishermen, thus it is realistic to assume that a level of producer surplus greater than zero is attainable in many U.S. commercial fisheries. In the case of managed fisheries, $(P^1 - C)$ can be referred to as rent.

When supply increases to Q^2, the producers sell Q^2 pounds of fish at a price of P^2. The total cost to produce Q^2 increases from W to W + Z. The total producer surplus changes from U + V to V + Y.[9]

In this simple example, where C is assumed to be constant, the producer surplus earned by suppliers is equal for all units of F produced. If C increases as F increases, however, some of the producer surplus per unit will be eaten away by increased costs. In the figure, this would be seen as a decrease in the areas of V and Y and an increase in the areas of W and Z as a greater share of the revenues from the sale of the catch go to cover costs.

Figure A4-3 is a graphical representation of a single market. In the real world, a fishing boat captain will sell the boat's catch to a processor, who sells processed fish to fish wholesalers, who in turn sells fish to retailers, who may sell fish directly to a consumer or to a restaurant, which will sell fish to a consumer. There will be consumer and producer surplus in each of these markets.[10] As a result, it is conceptually inaccurate to estimate the change in the quantity of fish harvested, multiply by the price per pound, and call this change in gross revenue the total benefits of the regulation.

The sections of this chapter that follow detail methods used in the analysis of commercial fishing benefits attributable to the proposed section 316(b) rule for Phase III facilities. This involves three basic steps: estimating the increase in pounds of commercial catch under the rule, estimating the gross value of the increased catch, and estimating the increase in producer surplus as a proportion of increased gross value. If the rule were expected to have a greater impact on markets, an additional step would be estimating the increase in consumer surplus across all affected markets as a proportion of increased gross value. The appropriate methods to use depend on whether or not a price change is anticipated; hence the methods are presented according to these two possible scenarios.

A4-6 A Context of No Anticipated Change in Price

While some species may experience larger increases in annual harvest and therefore impact price levels, modest overall changes in landings are not expected to greatly influence markets for the fish. Thus, it seems reasonable to presume that there will be no appreciable impacts on wholesale or retail fish prices. Under such a scenario of no price impacts, economic theory indicates that all changes in economic welfare will be confined to changes in producer surplus (i.e., changes in consumer and related post-harvest surplus will be zero). The benefits estimation issue then can be confined to examining producer surplus, and the core empirical and conceptual issue becomes how the change in producer surplus relates to estimates of added gross revenues, when prices remain constant.

A4-6.1 Producer Surplus as a Percentage of Gross Revenues: Assuming No Change in Prices

Given the potential for increases in producer surplus for the harvest sector (including rents to harvesters) under conditions where fish price does not change, EPA has relied on estimates, derived from the literature, of the percentage or fraction of gross revenue change that can be used as a proxy for the change in producer surplus. There are two relevant cases to consider: the case when fisheries are not regulated and the case when they are regulated with quotas or restrictive permits.

---

[9] Note that the producer surplus may be smaller at quantity Q^2 than at Q^1, depending on whether U is bigger than Y. The relative sizes of U and Y depend on the slope of D(F). When the D(F) curve is less steep, i.e., when demand is more price elastic, Y will be larger compared to U. When the D(F) curve is steeper, i.e., when demand is more price inelastic, Y will be smaller compared to U. Changes in producer surplus may be negative with increased harvest if demand is sufficiently inelastic.

[10] As described in section A4-7 and Bishop and Holt (2003), the total consumer surplus accumulated through tiered markets can be estimated from a general equilibrium demand function (but not from a more typical single market partial equilibrium demand curve).

a. Unregulated fisheries

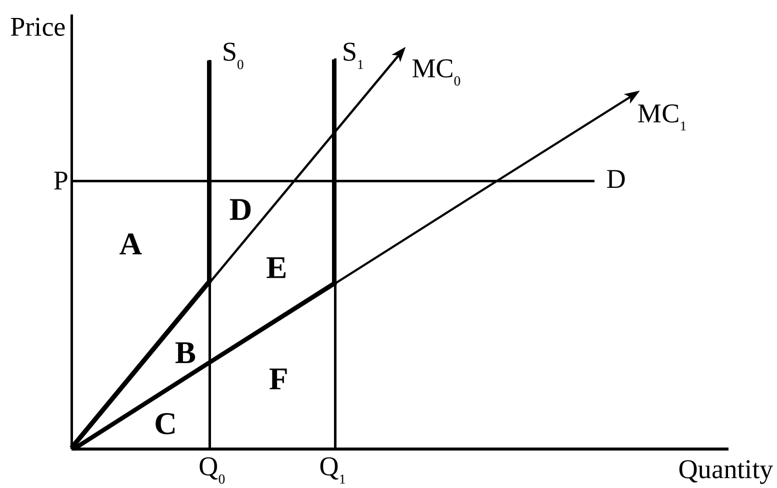
In an unregulated fishery, a reduction in I&E will lead to an increase in quantities of fish. This will decrease the marginal cost of catching more fish, creating the possibility for fishermen to earn economic rents and increasing producer surplus. According to basic microeconomic principles, in a competitive market these economic rents will attract additional fishing effort in one of two ways: either existing fishermen will exert greater effort or new fishermen will enter the market (or both). In either case, fishing effort theoretically will increase until a new equilibrium is reached where economic rents are equal to zero. In this case, there may be economic benefits to commercial fishermen in the short term, but in the long run producer surplus will be zero. Thus, in an unregulated fishery economic theory suggests that the long-run change in producer surplus will be 0% of the change in gross revenues.

b. Regulated fisheries

The story is different in a fishery that is regulated such that harvests are sustainable and reflect efforts to maximize resource rents. A reduction in I&E also leads to an increase in the stock of fish, which in turn leads to increases in harvest (assuming harvest limits are raised, if prior harvests were at the limits). In this case, however, there are lasting benefits to commercial fishermen.

As an example, assume that quotas are the regulatory instrument and that quotas increase (from Q_0 to Q_1) in response to reduced I&E, and that the supply curve (as represented by a marginal cost curve) shifts as a result of increased stock (from S_0 to S_1). Then, we can relate change in producer surplus to change in gross revenue using Figure A4-4. Producer surplus, before the increase in stock and change in quota, is equal to area A. Producer surplus after increase in stock and change in quota is equal to area (A + B + D + E). Change in producer surplus is therefore equal to area (B + D + E).

Figure A4-4: Surplus in a Regulated Fishery



Three scenarios can be used to show how a change in revenue may over- or under-estimate the change in producer surplus:

1. If B < F, then the change in revenue over-estimates the change in producer surplus.
2. If B = F, then the change in revenue approximates the change in producer surplus.
3. B > F, then the change in revenue under-estimates the change in producer surplus.

Note that if the first scenario prevails, then some fraction of gross revenue may be more suitable as a reliable proxy for change in producer surplus when price is assumed constant. If the marginal cost of supplying the extra fish for Q_1 is minimal or close to zero, then the second or third scenario prevails, and 100% or more of the change in revenue may serve as a reliable proxy for change in producer surplus.

A4-6.2 Conclusions on Surplus When No Change in Price is Anticipated

Various scenarios may arise when fishery conditions improve such that supply shifts outward, but not enough to generate any price change of consequence. In such cases, there is no anticipated change in post-harvest surplus to consumers or other post-harvest entities, because reduction in price is required to generate such surplus improvements. Hence, the change in economic welfare is limited to changes in producer surplus under these conditions.

As shown in the previous section, estimates of changes in dockside revenues become, under some scenarios, equivalent to the change in producer surplus. Hence, the change in gross revenues can be used as a proxy to estimate of the change in producer surplus for the regional analyses.[11] EPA also recognizes that under some of the possible scenarios that may arise when there is a quota-governed market, using the full change in revenues (as estimated through a projected change in landings with no price change) might overstate the change in producer surplus. However, if dockside prices and/or dockside landings (quantities) are understated — as may often be the case — then the change in surplus will be understated in most scenarios by the estimated change in gross revenues.

EPA's analysis of the commercial fishery benefits of the proposed section 316(b) rule for Phase III facilities relies on the premise that the change in producer surplus is only a fraction of the projected change in revenues. EPA has assumed a range of 0% to 40% of the estimated gross revenue changes as a means of estimating the change in producer surplus. The lower estimate of 0% represents the case of an unregulated fishery, as well as the lower bound identified in the literature. The range is based on the discussion above and on a review of empirical literature (restricted to only those studies that compared producer surplus to gross revenue) that is described in greater detail in section A4-8.[12]

A4-7 Surplus Estimation Under Scenarios in Which Price May Change

In the preceding section, the discussion was limited to cases in which no notable change in price was anticipated. These scenarios appear reasonable for very small improvements in fishery conditions, which is relevant for EPA's 316(b) regional analyses. If the estimated impacts were larger, as may be the case in other analyses, it may be inappropriate to assume that there will be no price effects in any commercial fishery markets. To ensure a complete treatment of the relevant economic theory, this section discusses the conceptual and empirical basis to estimate economic surplus (i.e., benefits) in instances where price changes are more likely to arise.

A4-7.1 Neoclassical Economic Perspective on the Market and Economic Welfare

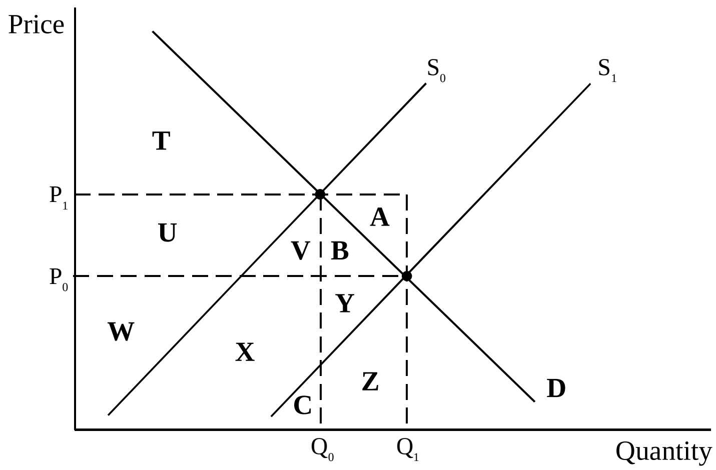
Figure A4-5 portrays a standard, neoclassical economic depiction of a market, with demand downward sloping and supply upward sloping to reflect increasing marginal costs. There are several reasons why this neoclassical depiction may not be directly revealing or applicable to the commercial fisheries market, as discussed later in this chapter. But for the moment, Figure A4-5 provides a useful starting point for considering how the measures of economic benefit — the sum of producer and consumer surplus — might change due to a policy that shifts the supply curve outward from S_0 to S_1.

---

[11] This would be consistent with EPA's guidelines (U.S. EPA, 2000a). The guidelines describe options for estimating ecological benefits for fisheries, and note that "if changes in service flows are small, current market prices can be used as a proxy for expected benefit . . . a change in the commercial fish catch might be valued using the market price for the affected species."

[12] The 0% to 40% assumption represents a change from the analysis for the proposed rule, which assumed a range of 40% to 70%.

Figure A4-5: Neoclassical Model



At baseline, producer surplus is depicted by areas U + W, consumer surplus by area T, and gross revenues by areas U + V + W + X + C. With an outward shift in the supply curve to S_1, we observe:

- Producer surplus becomes W + X + Y, hence the change in producer surplus is (W + X + Y) - (U + W), which is equal to X + Y - U.

- Consumer surplus becomes T + U + V + B, hence the change in consumer surplus (which previously had been area T alone) becomes U + V + B.

- Total change in surplus (the sum of changes in consumer and producer surplus) is therefore equal to areas X + Y + V + B.

- Gross revenues become W + X + Y + Z + C, hence the change in revenues becomes (W + X + Y + Z + C) minus (U + V + W + X + C), which equals (Y + Z) - (U + V).

There are several observations to make based on the above. First, note that the area U is instrumental in the change of all three measures. Area U is a positive component of the change in consumer (post-harvest) surplus, but it is subtracted from baseline producer surplus to obtain a measure of the change in that measure of welfare. Hence, in the neoclassical market model, part of the gain in consumer surplus is, in effect, a transfer from producer surplus. Area U reflects this conceptual transfer of surplus, and any empirical effort to estimate changes in surplus needs to ensure that if area U is included in the estimate of post-harvest surplus, the producer surplus estimate should be made net of area U to ensure no double counting.[13]

[13] Later in this chapter an approach developed by Bishop and Holt (2003) to estimating post-harvest surplus as depicted by areas U + V + B is described. Also, note that if the fishery in question is being conducted under open access, this means that rents to the resource are zero or very close it. Suppose furthermore that in this particular case other rents (e.g., rents to scarce fishing skills and knowledge) are also zero. Now suppose that section 316(b) regulations are imposed on power plants, causing an increase in the harvest of fish. The catch increases, but any effects in rents to the resource are dissipated by entry. The effect of the regulation is to increase consumer surplus by an amount comparable to areas U + V + B in Figure A4-5, but there is no offsetting decline in producer surplus because there was no producer surplus in the first place.

Another noteworthy observation from the above neoclassical characterization is that, under some circumstances, the change in revenues may be zero or even negative (depending on how area Y + Z compares to area U + V). Likewise the change in producer surplus can be positive or negative (depending on how X + Y compares to area U); with the transfer of area U from producer to consumer surplus, there are still positive net gains in producer surplus if X + Y > U.

A4-7.2 Issues in Estimating Changes in Welfare

The discussion above regarding welfare measures — and how they change with shifts in supply within the neoclassical framework — is fairly complex, even in its simplest form. To estimate such changes in welfare as may arise from the section 316(b) regulation, the problem becomes even more complicated. Some of the empirical and conceptual complications are discussed below.

In an expedited regulatory analysis that must cover a broad range of fish species across locations and fishery markets that span the nation, EPA must rely on readily applicable generalized approaches (rather than more detailed, market-specific assessments) to estimate changes in welfare. Hence, as noted earlier in this chapter, EPA must rely on readily estimated changes in gross revenues and from there infer potential changes in post-harvest (consumer) and producer surplus. Also, there are several issues associated with how to implement an expedited approach.

First, there is the issue of how to estimate the change in gross revenues. Each change in revenue is the product of the projected change in fish harvest multiplied by the observed baseline market price. Thus, EPA can readily obtain an estimate comparable to the area Y + Z + A + B in Figure A4-5. This is the approach contemplated by the Agency for this rulemaking to handle the case in which prices change. To more suitably capture the impact of a price change, in future analyses EPA may attempt to apply an applicable estimate of price elasticity to obtain an estimate that better reflects the true measure of the change in gross revenues (i.e., areas Y + Z - U - V in Figure A4-5).

Second, there is the issue of how to infer changes in post-harvest (consumer) surplus based on changes in revenues. The approach described by Bishop and Holt (2003), described in greater detail in section A4-9, is specifically designed to examine this benefits transfer issue. Their empirical research — currently limited to some regions and fisheries (e.g., the Great Lakes) — suggests that the changes in post-harvest surplus may be approximated by the estimated change in gross revenues (where the latter is based on holding price constant at baseline levels). This method may also be revisited by EPA in future analyses.

Third, there are a series of issues associated with how to estimate the change in producer surplus. Estimating the change in producer surplus under a scenario in which market forces produce a price change is a challenging exercise for a number of reasons, including:

- Many commercial fishery markets do not adhere to the usual assumptions of the neoclassical model because of regulations that establish harvest quotas and/or restrict entry through a permit system. These regulations typically are instituted to protect stocks that have been or are at risk of being over-fished. There also may be nonregulatory barriers to entry that affect this market, such as the high fixed costs and specialized knowledge and skill set required to effectively compete in some fisheries.

- Barriers to entry, regardless of the source, can have a profound impact on the economic welfare analysis. For example, the neoclassical model of open access would have rents driven to zero, but it is more likely in regulated markets (or a nonregulated market with economic barriers to entry) that there are positive rents accruing from the fishery resource (not to mention rents that accrue as well to specialized fishing skills and knowledge).[14]

- Empirical evidence regarding the magnitude of producer surplus is limited (especially for inferring a relationship with gross revenues). These data, presented later in this chapter, suggest producer surplus may be from 0% to 40% of gross revenues. However, interpreting these data properly is challenging, for a number of reasons:

  - Available empirical data pertain to average producer surplus, and EPA's regulatory analysis must instead address changes in producer surplus at the margin.

  - The portion of producer surplus that is transferred to consumers when there is a price reduction (represented by area U in Figure A4-5) should not be double-counted if it is captured in the estimate of post-harvest surplus and also in the estimated change in producer surplus. Since area U is included in the Bishop-Holt analysis of changes in post-harvest surplus, one needs to ensure that area U is not included in (e.g., has been netted out of) the applicable estimate of the change in producer surplus.

  - The limited empirical data from the literature that estimates producer surplus and gross revenues for fisheries can be expanded to include studies with data on 'normal profits.' However, these estimates of normal profits need to be adjusted downward in a logical manner to provide the more suitable producer surplus estimate. Later in this chapter some empirical evidence is provided to indicate the potential magnitude of such an adjustment.

These issues are discussed at greater length later in the chapter, but it is important to address them here because of the manner in which the departure from the neoclassical model affects how to interpret estimates of average producer surplus relative to changes expected at the margin. For example, marginal costs (MC) for commercial watermen may be minimal for a small increase in landings arising from a small increase in harvestable fish — for small increases in numbers of fish suitable for harvest in an area, small increases in harvest are likely to be realized with minimal added operating expense (i.e., MC at or near zero). This might arise where the watermen fill their quotas more easily, or exert essentially the same level of effort but come back with a few more fish. Where fishing effort and hence fishing costs would not change much, benefits (producer surplus) would equal the change in total revenue or be very close to it. For larger changes, marginal and average costs could shift down.

This has implications when interpreting the empirical literature available on producer surplus as a percentage of gross revenues. The standard neoclassical model always asserts increasing MC in the relevant range, so that producer surplus approaches zero with additional increments in landings. But for the type of situation that applies to section 316(b) — i.e., with a small change in the harvestable number of fish — and given the nature of the commercial fishery (e.g., high barriers to entry due to quotas or high fixed costs), the context is likely to reflect a situation in which costs decrease (e.g., a shift downward in MC, and perhaps MC that are at or near zero). If so, then the argument that the average estimate for producer surplus overstates the marginal value does not hold (in fact, the opposite may be true — average surplus could be less than producer surplus at the margin).

[14] Given the highly regulated nature of many fisheries today, a wide range of producer effects is conceivable. Even where revenues decline with a reduction in price, producer surplus could increase despite the loss in revenues. This could occur if the effect on price is relatively small and the effect on costs and revenues is relatively large. The only way to know for sure is to examine producer effects in specific cases or do a benefits transfer exercise using experience in real world fisheries as a guide. Simple approaches (e.g., assuming that there is no consumer surplus because of offsetting producer effects) are not satisfactory if there are changes in prices.

A4-8 Estimating Producer Surplus

An important portion of commercial fishing benefits is the producer surplus generated by the estimated marginal increase in landings. The level of effort and data required to model supply and demand in every regional fishing market to compute producer surplus are unavailable to EPA. Various researchers, however, have developed empirical estimates that can be used to infer producer surplus for watermen based on gross revenues (landings times wholesale price). EPA reviewed the economic literature on commercial fishing to examine the available results. This body of research provides two types of data that can be used to estimate producer surplus as a percentage of gross revenues. These percentages can easily be applied to changes in gross revenues expected under the proposed section 316(b) rule for Phase III facilities to estimate changes in producer surplus.

The most common result reported in the literature is normal profit. A large number of studies across a variety of fisheries estimate the revenues earned and costs borne by commercial fishing operations. These results can be used to estimate normal profit. As defined here, normal profit is the standard accounting definition of profit, i.e., total revenues earned minus the costs of production (e.g., fishing equipment, fuel, boat maintenance, hired labor, bait). For example, assume a commercial fishing vessel brings in a total catch worth $100,000 in a given year. Also assume that it incurred variable material costs of $50,000 and hired labor costs of $30,000. The normal profit received by the owner would then be $20,000 ($100,000 - $50,000 - $30,000 = $20,000).

The more useful concept and result reported in the literature is producer surplus because, as described above, producer surplus is a more appropriate indicator of social welfare than is profit. Producer surplus equals normal profit minus the vessel owner’s opportunity cost of participating in commercial fishing. In other words, producer surplus nets out the return to capital that the owner of a commercial fishing operation could expect to earn in another industry. Thus, producer surplus is the level of profits *above and beyond* what the owner would earn on his capital in another industry (or by investing in the stock market), and is less than or equal to normal profits. If the owner of the commercial fishing vessel in the previous example could expect to make a $1,000 return by investing his capital in another industry, then the producer surplus for this vessel owner would be $19,000 ($100,000 - $50,000 - $30,000 - $1,000 = $19,000).

While producer surplus is a preferable welfare measure, EPA’s literature review identified only four studies reporting results that can be used as direct estimates of producer surplus. Available measures of producer surplus and normal profits are reported as a percentage of gross revenue in Tables A4-4 and A4-5, respectively. Table A4-4 reports estimates of the more desirable producer surplus, and Table A4-5 reports the more common estimates of normal profits. EPA calculated these percentage values from data included in each cited study.[15] Looking at the values reported in the studies, it is clear that no single estimate of producer surplus as a percentage of gross revenue is appropriate for all regions, boat types, and species. For those studies that most closely approximate producer surplus (Table A4-4), the rough estimates of producer surplus range from 0% to 37%, with an average of approximately 23%. Therefore, EPA has assumed a range of 0% to 40% in the regional analyses. Note that the lower estimate of 0% is also consistent for the case of an unregulated fishery.

The estimates of normal profit span a wider range, with results in Table A4-5 ranging from a low of -5% to a high of 91.2%. One of the key issues for using the data on “normal profit” is whether some adjustment is reasonable to convert the ratios of normal profit to revenues into suitable estimates of the ratio of producer surplus to revenues. EPA has found limited empirical information on which to evaluate the potential adjustment factor. For example, King and Flagg (1984) provide data for California fisheries, itemizing various components of fixed and variable costs, and also providing annual revenues. Assuming that owners might be able to earn a 7% real rate return on all of their fixed costs that might otherwise be invested productively elsewhere, and netting these estimated returns from normal profit, the implied ratios of producer surplus to revenues are only between

[15] Most of the estimates in Table A4-5 are a variation of the following equation: 1 - (variable cost / gross revenue), where the variable cost includes the opportunity cost of participating in commercial fishing for the producer surplus measures.

0.4% and 2.6% lower than the ratios of normal profit to revenues, for the seven fishery types evaluated to date by EPA from the King and Flagg data. EPA also identified another study that contained relevant data (Larkin et al., 2000), and interpreting the data provided in similar fashion, the change in ratios is only 2.3% (consistent with the effect seen in King and Flagg). Because EPA identified only limited empirical evidence related to estimating an adjustment factor, the results in Table A4-5 are presented for comparative purposes only. Analysts for future rulemakings may wish to consider this issue and explore it further.

Table A4-4: Summary of Research on Commercial Fisher Producer Surplus Measures: Producer Surplus (studies that report profit estimates that include a return to the owner as part of costs)

Author(s)	Year	Geographic Area/Fishery	Analysis Year(s)	Type Boat(s)	Fish Species Sought	Producer Surplus % of Gross Revenue[a]	Notes on Study
Cleland and Bishop	1984	Michigan's Upper Great Lakes	1981	Varied	Most common: whitefish, lake trout, chubs	28%	Reported data used by EPA to calculate costs (including return to owner) as % of gross revenue — for 5 large Native American fishing operations
						35%	Reported data used by EPA to calculate costs (including return to owner) as % of gross revenue — for 11 moderately large Native American fishing operations
						27%	Reported data used by EPA to calculate costs (including return to owner) as % of gross revenue — for 36 small Native American fishing operations
Huppert and Squires	1987	U.S. Pacific coast	1984	Trawlers	Groundfish	37%	Reported results used by EPA to estimate: 1 - (profit + variable costs)/(total revenue) Estimates include return to owner as part of costs
Gilbert	1988	North-East North Island, New Zealand	1980s	Varied	Snapper	35%	Estimated economic surplus at dynamic maximum economic yield Estimates include return to owner as part of costs
		Hauraki Gulf, New Zealand	1980s	Varied	Red gurnard	20%	
		Firth of Thames, New Zealand	1980s	Varied	Yellow belly flounder	15%	
Norton et al.	1983	U.S. South Atlantic coast	1980	Varied	Striped bass	0%	Estimated producer surplus per pound of fish and revenue per pound of fish
		U.S. New England coast	1980	Varied	Striped bass	11%	

[a] Estimate includes returns to owners as part of costs, and thus excludes them from calculation of profit. This estimate can be considered a close proxy for producer surplus.

Table A4-5: Summary of Research on Commercial Fisher Producer Surplus Measures: Normal Profits (studies that do not report profit estimates that include a return to the owner as part of costs)

Author(s)	Year	Geographic Area/Fishery	Year(s) of Analysis	Type Boat(s)	Fish Species Sought	Normal Profit as % of Gross Revenue[a]	Notes on Study
Brown and Pollakowski	1976	Columbia River	1960s	Varied	Salmon and steelhead	90%	Citation from other literature of percentage of gross revenue that goes to total surplus in a salmon fishery
Crutchfield et al.	1982	Tazimina River (Bristol Bay, Alaska)	1970s	Varied	Salmon	85% to 90%	Authors estimate net economic value of a change in availability of salmon in a fishery with limited access and excess capacity
King and Flagg	1984	California coast	1982	Trawlers in North CA	Groundfish	67%	Reported data by fish/boat type used by EPA to calculate
				Trawlers in South CA	Groundfish	89%	1 - (variable cost / gross revenue) Costs do not include return to owner
				Trawlers	Shrimp	4%	
				Seiners	Tuna	45%	
				Seiners	Wetfish	22%	
				Gillnetters	Herring	-5%	
				Gillnetters	Other	69%	
				Small trollers	Salmon	49%	
				Large trollers	Salmon	52%	
				Crabbers	Salmon	74%	
				Albacore	Salmon	57%	
				Longliners	Varied	89%	
				Varied: using hook and line	Varied	66%	
				Varied: using pots	Black cod	91%	
				Varied	Crab-lobster, north	74%	

Table A4-5: Summary of Research on Commercial Fisher Producer Surplus Measures: Normal Profits (studies that do not report profit estimates that include a return to the owner as part of costs)

Author(s)	Year	Geographic Area/Fishery	Year(s) of Analysis	Type Boat(s)	Fish Species Sought	Normal Profit as % of Gross Revenue[a]	Notes on Study
King and Flagg (cont.)	1984	California coast	1982	Varied	Crab-lobster, south	50%	
				Bailboats	Varied	38%	
				Jigboats	Varied	22%	
				Diveboats	Varied	59%	
				Varied: using harpoon	Billfish	49%	
Rettig and McCarl	1985	U.S. varied	Varied	Varied	Varied	50%	Authors review several studies and suggest that 'variable costs may be approximately 50% of revenues for all commercial operators' Estimates do not include return to owner as part of costs
Usher	1987	Lake of the Woods, Ontario	1980-1982	Varied	Varied	28%	Reported results used by EPA to estimate: (net revenue) / (gross revenue) Estimate does not include return to owner as part of costs
Talhelm	1988	Great Lakes	1985	Varied	Varied	51%	Reported food fishery stats used by EPA to calculate: (gross value minus harvest costs) / (total value) Estimate does not include return to owner as part of costs
Larkin et al.	2000	U.S. Atlantic coast	1996	Longline	Varied, includes swordfish, tuna, sharks, and other	55%	Reported data used by EPA to calculate: (total net revenue) / (total gross revenue) Estimate does not include return to owner as part of costs

[a] Estimate does not include returns to owners as part of costs, and thus overstates producer surplus by that amount.

A4-9 Estimating Post-Harvest Economic Surplus in Tiered Markets

Estimating producer surplus provides an estimate of the benefits to commercial fishermen, but significant benefits can also be expected to accrue to final consumers of fish and to commercial consumers (including processors, wholesalers, retailers, and middlemen) if the projected increase in catch is accompanied by a reduction in price. These benefits can be expected to flow through the tiered commercial fishery market (as described in section A4-1 and in Bishop and Holt, 2003).

Bishop and Holt (2003) developed an inverse demand model of six Great Lakes fisheries that they use to estimate changes in welfare as a result of changes in the level of commercial harvest. This flexible model can be used to model welfare changes under a variety of conditions in the fishery. It takes as an input the expected change in harvest and baseline gross revenues, and provides as outputs the expected change in gross revenues and change in total compensating variation (CV).

CV is the change in income that would be necessary to make consumers' total utility the same as it was before the reduction in I&E losses resulting from the proposed section 316(b) rule for Phase III facilities. This is analogous to a measure of willingness to accept compensation in order to forgo the improvement. Conceptually, CV is a measure of welfare similar to consumer surplus. The key difference is that consumer surplus is calculated using the familiar demand function (or curve), which defines the quantity demanded as a function of price and income (in the simple example, Figures A4-1 and A4-2, income is assumed to be constant). CV, on the other hand, is calculated using a compensated demand function, which defines the quantity demanded as a function of price and utility. While consumer surplus and CV are generally very similar welfare measures, CV is considered to be the true measure of benefits (i.e., a more consistent indicator of utility), and consumer surplus is an approximation. The distinction between the two is a subtle point in welfare economics; the exact details are not crucial to the analysis.[16]

The key point to note is that estimates of CV from the Holt-Bishop model capture the benefits to final consumers and commercial consumers throughout the various markets in which fish are bought and resold for a given level of harvest. The model output provides a convenient way to estimate the benefits of an increase in harvest as a percentage of gross revenues, and thus a tractable way to estimate the benefits of increased catch that do not accrue to the primary producers.[17] See Holt and Bishop (2002) for further detail on the model.

Based on comments received on the commercial benefits analysis for the proposed Phase II rule, EPA worked with Dr. Bishop to assess the suitability of using the results from Holt and Bishop (2002) in a benefits transfer. EPA determined that the magnitude of the changes in commercial catch modeled in the Holt and Bishop paper is, in most cases, larger than the magnitude of the expected changes as a result of the Phase II regulations, and thus the benefits may be quite different. To address this issue, Bishop and Holt (2003) explore the impacts on surplus measures for more moderate changes in fishery conditions, and Bishop and Holt (2003) reports on the findings of the re-estimation of their Great Lakes model in terms that related economic surplus to levels of gross revenues.

In their recent work, Bishop and Holt (2003) observe that, as a general rule of thumb, in the fisheries they model the change in CV as a percentage of the change in gross revenues is more or less linearly related to the change in catch. In other words, a 10% increase in catch as a result of the proposed section 316(b) rule for Phase III facilities would be expected to produce an increase in CV equal to approximately a 10% of the change in gross revenues. As an example, if the proposed section 316(b) rule for Phase III facilities increases the catch of a

[16] For a more detailed discussion of the difference in consumer surplus and CV, the reader is referred to Varian (1992, Chapters 7 and 9) or any graduate-level microeconomics text.

[17] Bishop and Holt do not estimate changes in producer surplus, and indicate such changes need to be estimated separately and then combined with post-harvest consumer surplus results.

species by 10% and the gross value of the additional catch is $100,000, then the increase in CV would be $10,000.

Since no significant price changes are expected in any of the regions included in EPA's analysis, the effective change in CV attributable to the proposed section 316(b) rule for Phase III facilities is expected to be minimal. In estimating benefits, EPA has assumed the change will be $0.

A4-10 Nonmonetary Benefits of Commercial Fishing

As with many activities, commercial fishing provides benefits that are not measured in the value of the catch. Fishing is hard work. It involves strenuous outdoor work, long hours, and lengthy trips to sea, often in hazardous weather conditions. Fishing is also dangerous work. "Fishing has consistently ranked as the most deadly occupation since 1992," when the Bureau of Labor Statistics (BLS) started publishing fatality rates by occupation (Drudi, 1998, p. 1). In addition, the *BLS Occupational Handbook: Fishers and Fishing Vessel Operators* (U.S. Bureau of Labor Statistics, 2002) predicts that "employment of fishers and fishing vessel operators is expected to decline through the year 2010. These occupations depend on the natural ability of fish stocks to replenish themselves through growth and reproduction, as well as on governmental regulation of fisheries. Many operations are currently at or beyond maximum sustainable yield, partially because of habitat destruction, and the number of workers who can earn an adequate income from fishing is expected to decline."

In spite of this evidence, individuals still express a desire to fish, perhaps even because of the hardships and challenges of the job. Studies on why fishermen choose to fish have determined that income is, not surprisingly, the primary reason for participating in commercial fishing. Fishermen fish to support themselves and their families, and generally earn more in fishing than they would in other occupations. There are other important factors, though, including the importance of fishing to the way of life in small, coastal towns (not unlike the importance of farming to many rural towns throughout the United States); the belief that fishing helps the U.S. economy; and identity, i.e., people opt to work in commercial fishing because it provides enjoyment and because it is an integral part of how they identify themselves psychologically and socially (Smith, 1981; Townsend, 1985; Berman et al., 1997).

Research in the economic literature indicates that some fishermen opt to remain in the fishing industry despite the ability to make higher incomes in other industries. Some economists have suggested that there exists a worker satisfaction bonus that can, at least in theory, be measured and should be included in cost-benefit analyses when making policy decisions (Anderson, 1980). One study identified in a cursory literature review of this topic also found evidence in the Alaskan fisheries that as many as 29.5% of all vessels across 14 fisheries from 1975 to 1980 earned net incomes that were lower than the income they could receive from selling their fishing permit. The author concluded that "this pattern of apparent losses seems to confirm much of the casual observation that is the source of speculation that non-pecuniary returns are a significant factor in commercial fishing. It is thought that these financial losses are accepted only because they are offset by non-money gains" (Karpoff, 1985).

Because the Alaskan fisheries exist under much different conditions than those in the rest of the United States, it would be a mistake to assume that nearly 30% of U.S. fishing vessels earn incomes less than the value of their fishing permits. However, based on the cursory review of the commercial fishing literature, there is evidence that commercial fishermen gain nonmonetary benefits from their work. Despite the existence of these nonmonetary benefits in the commercial fishing sector, there is little research that has provided defensible methods for estimating the additional nonmonetary benefits that may accrue to commercial fishermen as a result of the proposed section 316(b) rule for Phase III facilities. Thus, the omission of these nonmonetary benefits is noted here, but no estimates will be included in the benefits analysis.

A4-11 Methods Used to Estimate Commercial Fishery Benefits from Reduced I&E

EPA estimated the commercial benefits expected under the proposed section 316(b) rule for Phase III facilities in the following steps. EPA estimated total losses under current I&E conditions in steps 1 through 3. Then, in step 4, EPA applied the estimated percentage reduction in I&E to estimate the benefits expected under each regulatory option. Each step was performed for each region in the final analysis.

The steps used to estimate regional losses and benefits are as follows:

1. **Estimate losses to commercial harvest (in pounds of fish) attributable to I&E under current conditions.** EPA modeled these losses using the methods presented in Chapter A1 of Part A of this document. The basic approach is to apply a linear stock to harvest assumption, such that if 10% of the current commercially targeted stock were harvested, then 10% of the commercially targeted fish lost to I&E would also have been harvested absent I&E. The percentage of fish harvested is based on data on historical fishing mortality rates.

2. **Estimate lost gross revenue from the reduced commercial catch.** The approach EPA used to estimate the value of the commercial catch lost due to I&E relied on landings and dockside price ($/lb) as reported by NOAA Fisheries for the period 1991-2001. These data are used to estimate the revenue lost as a result of reduced commercial harvest under current conditions (i.e., the increase in gross revenue that would be expected if all I&E impacts were eliminated).

3. **Estimate lost economic surplus.** The conceptually suitable measure of benefits is the sum of any changes in producer and consumer surplus. The methods used to estimate the change in surplus depend on whether the physical impact on the commercial fishery market appears sufficiently small such that it is reasonable to assume there will be no appreciable price changes in the markets for the impacted fisheries.

   For the regions included in EPA's analysis, it is reasonable to assume no change in price will occur, which implies that the welfare change is limited to changes in producer surplus. This change in producer surplus is assumed to be equivalent to a portion of the change in gross revenues, as developed under step 2. EPA estimates that 0% to 40% of the gross revenue losses, estimated in step 2, is representative of the change in producer surplus. This is based on a review of the empirical literature (restricted to only those studies that compared producer surplus to gross revenue) and is consistent with recommendations made in comments on the EPA analysis from Phase II.

   EPA believes this is a conservative approach to estimating producer surplus when there is no anticipated price changes. EPA's *Guidelines for Preparing Economic Analyses* (U.S. EPA, 2000a; EPA 240-R-00-003) describe options for estimating ecological benefits for fisheries, and note that "if changes in service flows are small, current market prices can be used as a proxy for expected benefit . . . a change in the commercial fish catch might be valued using the market price for the affected species." This statement indicates that 100% of gross revenue change, based on current prices, may be a suitable measure of value.

4. **Estimate increase in surplus attributable to the rule.** Once the commercial surplus losses associated with I&E under baseline conditions were estimated according to the approaches outlined in steps 2 and 3, EPA estimated the percentage reduction in I&E at each facility under each regulatory option. This analysis is conducted for each region. An increase in gross revenue is computed using the method described in step 2 and the producer surplus is estimated using the fractional approach in step 3.

A4-12 Limitations and Uncertainties

Table A4-6 summarizes the caveats, omissions, biases, and uncertainties known to affect the estimates that were developed for the benefits analysis.

Table A4-6: Caveats, Omissions, Biases, and Uncertainties in the Commercial Benefits Estimates

Issue	Impact on Benefits Estimate	Comments
Change in commercial landings due to I&E	Uncertain	Projected changes in harvest may be under-estimated because neither cumulative impacts of I&E over time nor interactions with other stressors are considered.
Estimates of commercial harvest losses due to I&E under current conditions are not region/species-specific	Uncertain	EPA estimated the impact of I&E in the case study analyses based on data provided by the facilities. The most current data available were used. However, in some cases these data are 20 years old or older. Thus, they may not reflect current conditions.
Effect of change in stocks on number of landings not considered	Uncertain	EPA assumed a linear stock to harvest relationship, that a 10% change in stock would have a 10% change in landings; this may be low or high, depending on the condition of the stocks. Region-specific fisheries regulations also will affect the validity of the linear assumption.
Effect of uncertainty in estimates of commercial landings and prices is unknown	Uncertain	EPA assumes that NMFS landings data are accurate and complete. In some cases prices and/or quantities may be reported incorrectly.
Estimates of producer surplus as a percentage of gross landings is not region/species-specific	Uncertain	EPA estimated that the increase in producer surplus as a result of the rule will be between 0% and 40% of the estimated change in gross revenues. The research used to develop this range is not region-specific; thus the true value may fall outside this range (higher or lower) for some regions and species.

Chapter A5: Recreational Fishing Benefits Methodology

Introduction

EPA used a benefit transfer approach to estimate the welfare gain to recreational anglers from improved recreational fishing opportunities due to reductions in impingement and entrainment (I&E) under the proposed section 316(b) rule for Phase III facilities.

Benefit transfer involves adapting research conducted for another purpose to address the policy questions at hand (Bergstrom and De Civita, 1999). Although primary research methods are generally considered to be superior to benefit transfer methods, benefit transfer is often the second (or only) alternative to original studies due to resource or data constraints. EPA notes that Smith et al. (2002, p. 134) state that "...nearly all benefit cost analyses rely on benefit transfers...". For the Phase III analysis, EPA used a benefit transfer approach to evaluate recreational fishing benefits of the proposed regulation for all study regions. To validate the meta-analysis results, EPA also used regional random utility models (RUM) of recreational fishing behavior developed for the Phase II analysis to estimate welfare gain to recreational anglers from improved recreational opportunities resulting from reduced I&E of fish species at Phase III facilities. EPA used the RUM approach to validate results for the four coastal regions and the Great Lakes region. Chapter A11 of the Phase II Regional Analysis document provides a more detailed discussion of the methodology used in EPA's RUM analysis (see DCN 6-0003).

Chapter Contents

Benefit transfer methods fall in three fundamental classes: (1) transfer of an unadjusted fixed value estimate generated from a single study site, (2) the use of expert judgment to aggregate or otherwise alter benefits to be transferred from a site or set of sites, and (3) estimation of a value estimator model derived from study site data, often from multiple sites (Bergstrom and De Civita, 1999). Recent studies have shown little support for the accuracy or validity of the first method, leading to increased attention to, and use of, *adjusted values* estimated by one of the remaining two approaches (Bergstrom and De Civita, 1999).

Meta-analysis techniques have been increasingly explored by economists as a potential basis of policy analysis conducted by various government agencies charged with the stewardship of natural resources.[1] Although there are few generally accepted guidelines for meta-analyses applied to environmental policy, EPA believes that this is

[1] Meta-analysis is "the statistical analysis of a large collection of results for individual studies for the purposes of integrating the findings" (Glass, 1976).

a promising methodology for policy evaluation. This chapter describes how EPA applied method 3, which is often cited as a more appropriate means of benefit transfer, to estimate the welfare gain associated with improved recreational catch.

The first step in implementing an "adjusted value" benefit transfer approach is a systematic analysis of the available economic studies that estimate the welfare gain associated with improved recreational catch. The Agency identified 48 valuation studies that use stated preference or revealed preference techniques to elicit benefit values for changes in recreational catch. All of these studies provide estimates of the marginal value to fishermen of catching an additional fish, or provide sufficient information for EPA to calculate such a value. These studies vary in several respects, including valuation methodology, survey administration method, species targeted by anglers, baseline catch rate, location, and economic and demographic characteristics of the sample.

To examine the relative influence of study, economic, and resource characteristics on willingness-to-pay (WTP) for catching an additional fish, the Agency conducted a regression-based meta-analyses of 391 estimates of WTP (or marginal value) per fish, provided by the 48 original studies. The estimated econometric model can be used to calculate per fish values for species that are potentially affected by I&E.

The following discussion summarizes the results of EPA's analysis of recreational fishing studies and outlines the methodology for applying meta-regression results to the estimation of benefits from reduced I&E attributable to the section 316(b) regulation.

A5-1 Literature Review Procedure and Organization

EPA performed an in-depth search of the economic literature to identify valuation studies that estimate – or provide sufficient information to calculate – the value that anglers place on catching an additional fish. EPA used a variety of sources and search methods to identify relevant studies:

- review of EPA's research and bibliographies dealing with the recreational benefits of fishing;
- systematic review of recent issues of resource economics journals [e.g., *Land Economics*, *Journal of Agricultural and Resource Economics*, *Journal of Environmental Economics and Management*, *Water Resources Research*];
- searches of online reference and abstract databases [e.g., Environmental Valuation Resource Inventory (EVRI), the Fish and Wildlife Service's Database of Sportfishing Values];
- queries to academic search engines [e.g., EconLit, ISI Web of Science, Index of Digital Dissertations];
- visits to homepages of authors known to have published valuation studies of recreational fishing;
- searches of web sites of agricultural and resource economics departments at several colleges and universities; and
- searches of web sites of organizations and agencies known to publish environmental and resource economics valuation research [e.g., Resources for the Future (RFF), National Center for Environmental Economics (NCEE), National Oceanic and Atmospheric Administration (NOAA), Library of Congress' Congressional Research Service].

From this review, EPA identified approximately 450 journal articles, academic working papers, reports, books, and dissertations that were potentially relevant for this analysis. Forty-eight of these studies were included in the data set for the recreational meta-analysis because they met the criteria listed below:

- **Specific amenity valued:** Selected studies were limited to those that estimated the marginal value that recreational anglers place on catching an additional fish (WTP) or provided sufficient information for EPA to calculate such a value;
- **Location:** Selected studies were limited to those that surveyed U.S. or Canadian populations; and
- **Research methods:** Selected studies were limited to those that applied primary research methods supported by journal literature.

The Agency utilized information from each of the studies to compile an extensive data set for use in the meta-analysis. The complete data set is provided in the public record for the proposed rule (see DCN 7-4923 and DCN 7-4924), and includes the following information:

- full study citation;
- study methodology (e.g., research method, survey administration method, question format);
- sample characteristics (e.g., sample size, response rate, income, age, gender);
- study location (e.g., waterbody name, waterbody type, geographic location);
- description of fishing quality (e.g., target species, fishing mode, baseline catch rate, post-change catch rate);
- marginal value per fish, updated to June 2003 dollars; and
- methods for obtaining marginal values per fish (i.e., whether marginal value per fish was directly available from the study, marginal value calculation method).

A5-2 Description of Studies

As noted above, EPA selected 48 recreational angling valuation studies that allow estimation of the value of catching an additional fish. These studies were published between 1982 and 2004, and are based on data from surveys conducted between 1977 and 2001. The studies all apply standard, generally accepted valuation methods, such as contingent valuation, travel cost models, and random utility models, to assess marginal value per fish. Studies were excluded if they did not conform to general concepts of economic theory, or if they applied methods not generally accepted in the economic literature.

All selected studies focus on changes in recreational catch rates in the U.S. or Canada. Beyond this general similarity, the studies vary in several respects. Differences include the species targeted by anglers, the magnitude of the change in catch rates, the location of the study, the survey administration method, demographics of the survey sample, and statistical methods employed. The 48 studies include 24 journal articles, 15 reports, five Ph.D. dissertations, three academic or staff papers, and one book. Twenty studies share a primary author with at least one other study. These 20 studies have a combined total of eight individuals as primary authors.

Because multiple estimates of the marginal per-fish value are available from most of the studies, the 48 studies selected for the meta-analysis provide 390 observations for the final data set. Some of the characteristics that allow multiple observations to be derived from a single study include variations in the baseline catch rate, the species being valued, the locations where fish were caught, the fishing method (i.e., boat or shore), and the valuation methodology.

Survey response rates from the studies range from 38% to 99%, and study sample sizes range from 72 to 36,802 responses. Two hundred and nine estimates from 21 studies are based on random utility models, 59 estimates from 11 studies are based on travel cost models, and 122 estimates from 20 studies are based on stated preference methods.[2] EPA calculated the marginal value per fish based on information provided in the study for 92 estimates from 15 studies, and for the remaining estimates the marginal values were provided by the authors.

Table A5-1 lists key study and resource characteristics and indicates the number of observations derived from each study.

[2] The number of studies employing each valuation methodology does not sum to the total number of studies because some studies used different valuation methods, from which multiple observations were derived.

Table A5-1: Select Characteristics of Recreational Angling Valuation Studies Used in the Meta-Analysis[a]

Author and Year	Number of Observations	State(s)	Study Methodology/ Elicitation Format	Marginal Value per Fish[b]
Agnello (1989)	30	FL to NY	travel cost	bluefish ($0.70 to $9.23) flounder ($3.33 to $28.67) weakfish ($0.05 to $9.69) all three species ($1.16 to $15.80)
Alexander (1995)	8	OR	nested RUM	steelhead trout ($3.59 to $23.17)
Berrens et al. (1993)	1	OR	CV (payment card)	Chinook salmon ($3.99)
Besedin et al. (2004)	12	MI	non-nested RUM	bass ($13.14 to $17.12) perch ($1.79 to $2.95) walleye/pike ($10.17 to $21.34) salmon/trout ($20.56 to $23.36) general/no target ($1.58 to $3.34)
Bockstael et al. (1989)	1	MD	travel cost	*striped bass* ($2.23)
Boyle et al. (1998)	4	FWS Mountain Trout, Western Trout, Northeast Trout, and Northern Bass Regions	CV (dichotomous choice)	trout ($0.91 to $3.96) bass ($4.22)
Breffle et al. (1999)	8	WI		*yellow perch* ($0.79 to $1.57) *trout/salmon* ($20.99 to $42.10) *walleye* ($4.13 to $8.34) *smallmouth bass* ($13.70 to $27.48)
Cameron and Huppert (1989)	2	CA	CV (payment card)	*salmon* ($5.82 to $16.76)
Cameron and James (1987a)	1	British Columbia, Canada	CV (dichotomous choice)	salmon ($2.51)
Cameron and James (1987b)	1	British Columbia, Canada	CV (dichotomous choice)	salmon ($19.78)
Carson et al. (1990)	3	AK	CV (payment card, conjoint analysis)	Chinook salmon ($15.80 to $45.92)
Dalton et al. (1998)	2	WY	CV (dichotomous choice)	*trout* ($28.13 to $51.41)
Gautam and Steinbeck (1998)	3	ME, NH, MA, RI, CT	travel cost, non-nested RUM	striped bass ($4.18 to $7.02)
Hicks et al. (1999)	44	ME, NH, MA, RI, CT, NY, NJ, DE, MD, VA	nested RUM	big game ($5.67 to $8.19) bottomfish ($2.02 to $3.25) small game ($3.01 to $4.64)

Table A5-1: Select Characteristics of Recreational Angling Valuation Studies Used in the Meta-Analysis[a]

Author and Year	Number of Observations	State(s)	Study Methodology/ Elicitation Format	Marginal Value per Fish[b]
				flatfish ($3.84 to $7.13)
Hicks (2002)	3	NH to VA	CV (conjoint analysis), non-nested RUM	summer flounder ($2.59 to $4.65)
Huppert (1989)	3	CA	CV (payment card), travel cost	*Chinook salmon and striped bass* ($7.74 to $58.44)
Hushak et al. (1988)	3	OH	travel cost	*walleye* ($2.34 to $3.13)
Johnson et al. (1995)	19	CO	CV (iterative bidding, dichotomous choice)	trout ($0.54 to $2.94)
Johnson (1989)	5	CO	CV (iterative bidding)	brown and rainbow trout ($0.87 to $1.61) rainbow trout ($2.58)
Johnson and Adams (1989)	1	OR	CV (multiple methods)	steelhead trout ($11.15)
Jones and Stokes Associates, Inc (1987)	4	AK	non-nested RUM	*halibut* ($153.91) *Chinook salmon* ($327.29) *coho salmon* ($178.65) *dolly varden* ($23.25)
Kirkley et al. (1999)	10	VA	CV (open-ended)	bottomfish and croaker ($3.05 to $12.88) summer flounder ($4.69 to $19.91) gamefish ($16.40 to $65.59) no target ($1.93 to $8.20)
Lee (1996)	5	WA	CV (conjoint analysis)	trout ($1.13 to $3.83)
Loomis (1988)	13	OR, WA	travel cost	steelhead trout ($40.69 to $182.23) salmon ($13.23 to $114.21)
Lupi and Hoehn (1998)	3	MI	nested RUM	lake trout ($10.12 to $13.90)
Lupi et al. (1997)	10	MI	nested RUM	*bass* ($8.54) *carp* ($1.40) *coho salmon* ($18.33) *northern pike* ($2.34) *rainbow trout* ($10.12 to $15.77) *Chinook salmon* ($4.04 to $13.25) *lake trout* ($6.61) *walleye* ($3.66)
McConnell and Strand (1994)	36	FL to NY	CV (dichotomous choice)	*big game* ($0.65 to $54.56)

Table A5-1: Select Characteristics of Recreational Angling Valuation Studies Used in the Meta-Analysis[a]

Author and Year	Number of Observations	State(s)	Study Methodology/ Elicitation Format	Marginal Value per Fish[b]
				small game ($11.59 to $30.91) *flatfish* ($0.37 to $10.50) *bottomfish* ($0.25 to $4.51)
Milliman et al. (1992)	1	MI	CV (dichotomous choice)	yellow perch ($0.33)
Morey et al. (1993)	2	ME	nested RUM	*Atlantic salmon* ($386.63 to $612.79)
Morey et al. (2002)	2	MT	nested RUM	*trout* ($11.62 to $198.03)
Morey et al. (1991)	3	OR	non-nested RUM	*salmon* ($5.66) *ocean perch* ($13.74) *smelt and grunion* ($32.39)
Murdock (2001)	7	WI	nested RUM	*panfish* ($9.77) *walleye* ($22.63) *smallmouth bass* ($19.47) *temperate bass* ($4.23) *northern pike* ($15.68) *trout* ($32.68) *salmon* ($51.61)
Norton et al. (1983)	4	ME to NC	travel cost	striped bass ($3.39 to $31.98)
Olsen et al. (1991)	6	WA, OR	CV (open-ended)	salmon ($21.95 to $37.44) steelhead trout ($37.00 to $81.29)
Pendleton and Mendelsohn (1998)	3	ME, NH, VT, NY	non-nested RUM	rainbow trout ($23.37) other trout ($4.32 to $26.44)
Rowe et al. (1985)	24	CA, OR, WA	non-nested RUM	coastal pelagics ($3.82 to $4.45) flatfish ($3.31 to $14.33) rockfish and bottomfish ($2.63 to $6.79) salmon ($7.21 to $31.24) smelt and grunion ($0.30 to $7.40)
Samples and Bishop (1985)	1	MI	travel cost	salmon and trout ($19.01)
Schuhmann (1996)	7	NC	non-nested RUM	*big game* ($33.78 to $133.11) *bottomfish* ($14.53) *drum* ($1.65 to $11.57) *surface fish* ($12.67 to $25.96)
Schuhmann (1997)	8	MD, NC	non-nested RUM	*billfish* ($33.72)

Table A5-1: Select Characteristics of Recreational Angling Valuation Studies Used in the Meta-Analysis[a]

Author and Year	Number of Observations	State(s)	Study Methodology/ Elicitation Format	Marginal Value per Fish[b]
				bottomfish ($14.51) *drum* ($11.55) *surface fish* ($12.66)
Shafer et al. (1993)	1	PA	travel cost	*trout* ($1.35)
U.S. EPA (2004a)	31	CA	non-nested RUM	big game ($2.15 to $6.47) bottomfish ($1.38 to $2.76) flatfish ($3.19 to $11.06) jacks ($29.15) salmon ($8.46 to $15.56) sea bass ($0.36 to $0.73) small game ($2.26 to $3.09) striped bass ($4.31 to $8.41) sturgeon ($61.43) no target/other ($0.46 to $6.68)
U.S. EPA (2004b)	15	NY to VA	nested RUM	big game ($20.97) bluefish ($6.32 to $6.42) bottomfish ($4.70 to $4.76) flatfish ($8.55 to $8.75) other small game ($4.68 to $6.64) striped bass ($15.52 to $15.56) weakfish ($14.31 to $14.99) no target ($5.70 to $5.83)
U.S. EPA (2004c)	10	FL, NC, SC, GA	non-nested RUM	big game ($37.89) bottomfish ($4.91 to $9.39) flatfish ($27.63 to $31.18) small game ($10.31 to $13.72) snapper and grouper ($5.41) no target ($7.41 to $19.73)
U.S. EPA (2004d)	13	FL, AL, MS, LA	non-nested RUM	big game ($30.48) bottomfish ($2.21 to $7.23) flatfish ($9.41 to $16.62) seatrout ($10.14 to $13.85) small game ($12.85 to $15.64) snapper and grouper ($11.27 to $11.47)

Table A5-1: Select Characteristics of Recreational Angling Valuation Studies Used in the Meta-Analysis[a]

Author and Year	Number of Observations	State(s)	Study Methodology/ Elicitation Format	Marginal Value per Fish[b]
				no target ($5.35 to $6.36)
Vaughan and Russell (1982)	2	USA	travel cost	trout ($1.14) catfish ($0.78)
Whitehead and Haab (1999)	1	NC, SC, GA, FL, AL, MI, LA	non-nested RUM	small game ($4.32)
Whitehead and Aiken (2000)	6	USA	CV (dichotomous choice)	bass ($4.60 to $10.37)
Williams and Bettoli (2003)	8	TN	CV (dichotomous choice)	trout ($0.62 to $9.43)

[a] Where multiple observations are available from a given study, state, study methodology/elicitation format, and species may take on different values for different observations from that study.
[b] The marginal values per fish presented here represent the highest and lowest values from the study for the specified species or group of species. Italicized values in this column indicate that EPA calculated the marginal value per fish from information in the study. All values are presented in June 2003$.

Source: U.S. EPA analysis for this report.

From these 48 studies, the Agency compiled a data set for the meta-analysis of marginal values per fish. The following section describes the estimation of this model and its application to the proposed section 316(b) rule for Phase III facilities.

A5-3 Meta-Analysis of Recreational Fishing Studies: Regression Model

EPA estimated a meta-analysis model based on 391 estimates of the value anglers place on catching an additional fish, derived from 48 original studies. The meta-data, model specification, model results, and interpretation of those results are discussed in sections A5-3.1 through A5-3.3.

In a frequently cited work, Glass (1976) characterizes meta-analysis as "the statistical analysis of a large collection of results for individual studies for the purposes of integrating the findings. It provides a rigorous alternative to the casual, narrative discussion of research studies which is commonly used to make some sense of the rapidly expanding research literature" [p. 3; cited in Poe et al. (2001), p. 138]. Meta-analysis is being increasingly explored as a potential means to estimate resource values in cases where original targeted research is impractical, or as a means to reveal systematic components of WTP (Johnston et al., 2003; Smith and Osborne, 1996; Santos, 1998; Rosenberger and Loomis, 2000a; Poe et al., 2001; Woodward and Wui, 2001; Bateman and Jones, 2003). While the literature urges caution in the use and interpretation of benefit transfers for direct policy application (e.g., Desvousges et al., 1998; Poe et al., 2001), such methods are "widely used in the United States by government agencies to facilitate benefit-cost analysis of public policies and projects affecting natural resources" (Bergstrom and De Civita, 1999). Transfers based on meta-analysis are likewise common in both the United States and Canada (Bergstrom and De Civita, 1999).

Depending on the suitability of available data, meta-analysis can provide a superior alternative to the calculation and use of a simple arithmetic mean WTP over the available observations, as it allows estimation of the systematic influence of study methodology, sample characteristics, and natural resource attributes on WTP (Johnston et al., 2003). The primary advantage of a regression-based (statistical) approach is that it accounts for differences among study characteristics that may contribute to changes in WTP, to the extent permitted by available data. An additional advantage is that meta-analysis can reveal systematic factors influencing WTP, allowing assessments of whether, for example, WTP estimates are (on average) sensitive to the baseline resource conditions (Smith and Osborne, 1996).

A5-3.1 Meta-Data

Meta-analysis is largely an empirical, data-driven process, but one in which variable and model selection is guided by theory. Given a reliance on information available from the underlying studies that comprise the meta-data, meta-analysis models most often represent a middle ground between model specifications that would be most theoretically appropriate and those specifications that are possible given available data. Smith and Osborne (1996), Rosenberger and Loomis (2000a), Poe et al. (2001), Bateman and Jones (2003), Dalhuisen et al. (2003), and others provide insight into the mechanics of specifying and estimating meta-equations in resource economics applications.

To guide development of variable specifications, EPA relied upon a set of general principles. These principles are designed to help prevent excessive data manipulations and other factors that may lead to misleading model results. The general principles include, all else being equal:

- models should attempt to capture elements of scale of resource changes;
- models should focus on distinguishing marginal values associated with different types of species in different regions, particularly where relevant to the policy question at hand;
- in the absence of overriding theoretical considerations, continuous variables are generally preferred to discrete variables derived from underlying continuous distributions; and

- where possible, exogenous constraints should be avoided in favor of "letting the data speak for themselves."

Based on these criteria, EPA selected a set of variables believed to have a potential influence on the estimated WTP per additional fish caught. Variable selection was guided primarily by prior findings in the literature, and constrained by information available from the original studies that comprise the meta-data. The dependent variable chosen for the meta-analysis is the natural logarithm of WTP per fish, as reported in each original study or as calculated by EPA from information provided by the studies. EPA chose to use the natural log of the dependent variable instead of the linear form, based on (1) data fit, (2) the intuitive nature of results, and (3) the common use of this functional form in the meta-analysis literature (e.g., Smith and Osborne, 1996; Santos, 1998). Section A5-3.2 discusses this decision in greater detail. Per fish values were adjusted to June 2003$ based on the relative change in the consumer price index (CPI) from the study year to June of 2003. The real value per fish over the sample ranged from 4.8 cents to $612.79, with a mean value of $16.82 and a median value of $5.83.

The independent variables included in the meta-analysis characterize the species being valued, study location, baseline catch rate, elicitation and survey methods, demographics of survey respondents, and other specifics of each study. All independent variables are linear. For ease of exposition, these variables are categorized into those characterizing 1) study methodology, 2) sample characteristics, 3) species targeted, and 4) angling quality. Variables included in each category are summarized below.

Study methodology variables characterize such features as:

- the valuation method (e.g., stated preference, travel cost, or random utility model);
- the year in which a study was conducted;
- the survey administration method; and
- reported survey response rates.

Sample characteristics variables characterize such features as:

- the average income of respondents;
- the demographic composition of respondents; and
- the number of fishing trips taken each year by respondents.

Species targeted variables characterize such features as:

- the species targeted by anglers; and
- the geographic region in which the species was targeted.

Angling quality variables characterize such features as:

- the baseline catch rate; and
- the fishing mode (e.g., shore or boat).

Although the interpretation and calculation of most variables is relatively straightforward, a few variables require additional explanation. In particular, the calculation of the dependent variable requires more explanation.[3] The majority of studies provide estimates of WTP per fish, but some studies do not provide estimates of marginal value. In these cases, EPA calculated WTP per fish in one of two ways. The Agency's preferred approach was to use the regression coefficients from the equation presented in the study to calculate the marginal value per fish. For example, a simple linear travel cost model might express the number of trips (*Trips*) taken by a respondent as a function of travel cost (*TC*), the catch rate for salmon (*CR*), and whether or not the respondent owns a boat (*B*):

[3] All calculations used by EPA to estimate marginal values are documented in DCN 7-4922.

$$Trips = \alpha + \beta TC + \chi CR + \delta B \quad [A5\text{-}1]$$

The marginal value per fish is then calculated as follows:

$$\frac{\partial TC}{\partial CR} = \frac{\chi}{\beta} \quad [A5\text{-}2]$$

In the case of RUM studies, the deterministic part of the utility function (V) is in general expressed as a function of travel cost (TC), historic catch rates for various fish species (CR), and a vector of other site attributes (X):

$$V(j) = f(TC_j, CR_{j,s}, X_j) \quad [A5\text{-}3]$$

where:

V (j)	=	the expected utility of fishing at site j;
TC_j	=	travel cost to site j ; and
CR (j,s)	=	historic catch rate for species s at site j;

Angler willingness-to-pay for catching an additional fish can be calculated as a ratio of the first derivative of the utility function with respect to the travel cost and catch rate variables. This is interpreted as the change in travel cost (TC_j) that is just sufficient to return a representative angler to a baseline level of utility, subsequent to a one-fish increase in catch rate that results in an increase in utility above the baseline. Formally, marginal WTP per fish may be expressed as:

$$WTP_{fish} = -\frac{\partial V(\cdot)/\partial CR}{\partial V(\cdot)/\partial TC} \quad [A5\text{-}4]$$

where the numerator and denominator of A5-4 are directly revealed by statistical model coefficients. Equation A5-4 expresses the rate at which anglers are willing to exchange a unit increase in catch rates for a unit increase in the costs of travel.

In cases when EPA was not able to calculate marginal willingness-to-pay per fish from the regression coefficients due to insufficient information, the Agency used linear extrapolation to approximate marginal values. In most cases, this involved calculating average WTP per fish for some specified increase in catch rates. For example, if a study reports that the average respondent is willing to pay ten dollars per trip to catch an additional two fish per trip, then EPA calculated average marginal WTP per fish to be ten dollars divided by two fish, or five dollars per fish.

Another set of variables that requires explanation are the variables that characterize the fish species targeted by anglers. The original studies value a large variety of species. To reduce the number of species variables to a manageable number, and to reduce the number of times in which a species-specific dummy variable distinguishes only a single study, EPA assigned each species to an aggregate species group. These assignments were based on the angling, biological, and regional characteristics of each species. The groups include four saltwater species groups (big game, small game, flatfish, and other saltwater fish), two anadromous species groups (salmon and steelhead trout), and five freshwater species groups (panfish, bass, walleye/pike, rainbow trout, and other trout).[4] The other saltwater group includes bottomfish species, species caught by anglers not targeting any particular species, and species that did not clearly fit in one of the other groups. The panfish group includes freshwater species such as yellow perch, catfish, sunfish, and other warmwater species. Some species groups were further subdivided on the basis of regional differences. Table A5-2 shows the species assigned to each aggregate species group.

Table A5-2: Aggregate Species Groups

Aggregate Group	Number of Observations	Species Included[a]
Big Game	30	billfish family, dogfish, rays, sharks, skates, sturgeon, swordfish, tarpon family, tuna, other big game
Small Game	74	barracuda, bluefish, bonito, cobia, dolly varden, dolphinfish, jacks, mackerel, red drum, seatrout, striped bass, weakfish, other small game
Flatfish	46	halibut, sanddab, summer flounder, winter flounder, other flatfish
Other Saltwater	89	banded drum, black drum, chubbyu, cod family, cow cod, croaker, grouper, grunion, grunt, high-hat, kingfish, lingcod, other drum, perch, porgy, rockfish, sablefish, sand drum, sculpin, sea bass, smelt, snapper, spot, spotted drum, star drum, white sea bass, wreckfish, other bottom species, other coastal pelagics, “no target” saltwater species
Salmon	44	Atlantic salmon, Chinook salmon, coho salmon, other salmon
Steelhead	14	steelhead trout
Walleye/Pike	12	northern pike, walleye
Bass	14	largemouth bass, smallmouth bass
Panfish	11	catfish, carp, yellow perch, other panfish, “general” and “no target” freshwater species
Rainbow Trout	4	rainbow trout
Other Trout	56	brown trout, lake trout, other trout

[a] Some studies evaluated WTP for groups of species that did not fit cleanly into one of the aggregate species groups established by EPA. In those cases, the groups of species from the study were assigned to the aggregate species group with which they shared the most species.

Source: U.S. EPA analysis for this report.

The final set of variables that require additional explanation are the catch rate variables. In general, studies express catch rates in fish per hour, fish per day, fish per trip, or fish per year. Rather than include four separate catch rate variables, EPA combined per hour, per day, and per trip catch rates in a normalized variable called *cr_nonyear*. This variable expresses catch rates in per day units. Because most of the studies focused on single-day trips, EPA included per trip catch rates in this variable without normalization.[5] Per hour catch rates were

[4] The small game group includes some anadromous species such as striped bass that spawn in tidal rivers.

[5] Although some studies included both multiple and single day trips the average angling trip length was often not provided. However, the majority of recreational angling trips are single-day trips. According to the 2001 National Survey of Hunting, Fishing, and Wildlife-Associated Recreation (U.S. FWS, 2002), the average angling trip length was

converted to per day catch rates by multiplying by the number of hours fished per day, as provided in the study. In cases where the study does not provide information on fishing day length, EPA assumed that the average fishing day lasts four hours. EPA included per year catch rates in a separate variable, *cr_year*.

Variables incorporated in the final model are listed and described in Table A5-3.

Table A5-3: Variables and Descriptive Statistics for the Regression Model

Variable[a]	Description	Units (Range)	Mean (Std. Dev.)
log_WTP	Natural log of the marginal value per fish.	Natural log of dollars (-3.0260 to 6.4180)	1.8419 (1.3165)
SP_conjoint	Binary (dummy) variable indicating that the study used a conjoint analysis stated preference methodology.	Binary variable (0 to 1)	0.0435 (0.2042)
SP_dichot	Binary (dummy) variable indicating that the study used a stated preference methodology with a dichotomous choice elicitation format.	Binary variable (0 to 1)	0.1739 (0.3795)
TC_individual	Binary (dummy) variable indicating that the study used a travel cost model based on trip data for each individual in the survey, as opposed to aggregated data.	Binary variable (0 to 1)	0.1074 (0.3100)
TC_zonal	Binary (dummy) variable indicating that the study used a zonal travel cost model based on data aggregated for all respondents from each location in the sample.	Binary variable (0 to 1)	0.0409 (0.1984)
RUM_nest	Binary (dummy) variable indicating that the study used a nested random utility model.	Binary variable (0 to 1)	0.2353 (0.4247)
RUM_nonnest	Binary (dummy) variable indicating that the study used a non-nested random utility model.	Binary variable (0 to 1)	0.3043 (0.4607)
sp_year	If the study uses a stated preference methodology, this variable represents the year in which the study was conducted, converted to an index by subtracting 1,976; otherwise, this variable is set to zero.	Year index (0 to 25)	4.6036 (7.3592)
tc_year	If the study uses a travel cost methodology, this variable represents the year in which the study was conducted, converted to an index by subtracting 1,976; otherwise, this variable is set to zero.	Year index (0 to 18)	0.7315 (2.1914)
RUM_year	If the study uses a RUM methodology, this variable represents the year in which the study was conducted, converted to an index by subtracting 1,976; otherwise, this variable is set to zero.	Year index (0 to 25)	9.3734 (9.7162)
sp_mail	Binary (dummy) variable indicating that the study was a stated preference study that was administered by mail.	Binary variable (0 to 1)	0.0512 (0.2206)
high_resp_rate	Binary (dummy) variable indicating that the sample response rate was greater than 50%.	Binary variable (0 to 1)	0.3581 (0.4800)
inc_thou	Household income of survey respondents in 1,000's of	1,000's of June	46.7008

1.27 days.

Table A5-3: Variables and Descriptive Statistics for the Regression Model

Variable[a]	Description	Units (Range)	Mean (Std. Dev.)
	dollars. If the study does not list income values, *inc_thou* was imputed from Census data.	2003$ (21.990 to 70.610)	(10.2017)
gender	The percentage of sample respondents that were male.	Percentage (0 to 98)	34.6427 (43.6581)
spec_gender	Binary (dummy) variable indicating that the study presented information on the percentage of sample respondents that were male.	Binary variable (0 to 1)	0.3887 (0.4881)
age	The mean age of sample respondents.	Years (0 to 51)	16.0232 (21.0539)
spec_age	Binary (dummy) variable indicating that the study provided information on the mean age of sample respondents.	Binary variable (0 to 1)	0.3683 (0.4830)
trips	The mean number of fishing trips taken each year by sample respondents.	Fishing trips (0 to 56.4)	13.1562 (16.8113)
spec_trips	Binary (dummy) variable indicating that the study provided information on the mean number of fishing trips taken each year by sample respondents.	Binary variable (0 to 1)	0.4450 (0.4976)
nonlocal	Binary (dummy) variable indicating that no respondents in the sample were local residents.	Binary variable (0 to 1)	0.0051 (0.0714)
big_game_natl	Binary (dummy) variable indicating that the target species was big game in the North Atlantic or Mid-Atlantic regions.	Binary variable (0 to 1)	0.0486 (0.2153)
big_game_satl	Binary (dummy) variable indicating that the target species was big game in the South Atlantic or Gulf of Mexico regions.	Binary variable (0 to 1)	0.0205 (0.1418)
big_game_pac	Binary (dummy) variable indicating that the target species was big game in the California or Pacific Northwest regions.	Binary variable (0 to 1)	0.0077 (0.0874)
small_game_atl	Binary (dummy) variable indicating that the target species was small game in the North Atlantic, Mid-Atlantic, South Atlantic, or Gulf of Mexico regions.	Binary variable (0 to 1)	0.1611 (0.3681)
small_game_pac	Binary (dummy) variable indicating that the target species was small game in the California or Pacific Northwest regions.	Binary variable (0 to 1)	0.0281 (0.1656)
flatfish_atl	Binary (dummy) variable indicating that the target species was flatfish in the North Atlantic, Mid-Atlantic, South Atlantic, or Gulf of Mexico regions.	Binary variable (0 to 1)	0.0997 (0.3000)
flatfish_pac	Binary (dummy) variable indicating that the target species was flatfish in the California or Pacific Northwest regions.	Binary variable (0 to 1)	0.0179 (0.1328)
other_sw	Binary (dummy) variable indicating that the target species was bottomfish or other saltwater species.	Binary variable (0 to 1)	0.2276 (0.4198)
pike_walleye	Binary (dummy) variable indicating that the target	Binary variable	0.0307

Table A5-3: Variables and Descriptive Statistics for the Regression Model

Variable[a]	Description	Units (Range)	Mean (Std. Dev.)
	species was northern pike or walleye.	(0 to 1)	(0.1727)
bass_fw	Binary (dummy) variable indicating that the target species was largemouth bass or smallmouth bass.	Binary variable (0 to 1)	0.0358 (0.1860)
trout_rainbow	Binary (dummy) variable indicating that the target species was rainbow trout.	Binary variable (0 to 1)	0.0102 (0.1008)
trout_atlantic	Binary (dummy) variable indicating that the target species was trout (including rainbow trout) in states on the eastern side of the U.S.	Binary variable (0 to 1)	0.0332 (0.1795)
trout_GL	Binary (dummy) variable indicating that the target species was trout (including rainbow trout) in the Great Lakes region.	Binary variable (0 to 1)	0.0179 (0.1328)
trout_mountain	Binary (dummy) variable indicating that the target species was trout (including rainbow trout) in the U.S. FWS Mountain Trout region.	Binary variable (0 to 1)	0.0742 (0.2624)
trout_pacific	Binary (dummy) variable indicating that the target species was trout (including rainbow trout) in the U.S. FWS Western Trout region.	Binary variable (0 to 1)	0.0153 (0.1231)
trout_other	Binary (dummy) variable indicating that the target species was trout (including rainbow trout) in fee-fishing establishments across the U.S.	Binary variable (0 to 1)	0.0026 (0.0506)
salmon_atlantic	Binary (dummy) variable indicating that the target species was salmon on the Atlantic coast.	Binary variable (0 to 1)	0.0051 (0.0714)
salmon_GL	Binary (dummy) variable indicating that the target species was salmon in the Great Lakes.	Binary variable (0 to 1)	0.0230 (0.1502)
salmon_pacific	Binary (dummy) variable indicating that the target species was salmon on the Pacific coast.	Binary variable (0 to 1)	0.0844 (0.2783)
steelhead	Binary (dummy) variable indicating that the target species was steelhead.	Binary variable (0 to 1)	0.0358 (0.1860)
cr_nonyear	For studies that present catch rate on a per hour, per day, or per trip basis, this variable represents the baseline catch rate for the target species, expressed in fish per day or fish per trip; otherwise this variable is set to zero.	Fish per day (0 to 14.0000)	1.6088 (1.9948)
cr_year	For studies that present catch rate on a per year basis, this variable represents the baseline catch rate for the target species, expressed in fish per year; otherwise this variable is set to zero.	Fish per year (0 to 67.3800)	1.3707 (8.5833)

Table A5-3: Variables and Descriptive Statistics for the Regression Model

Variable[a]	Description	Units (Range)	Mean (Std. Dev.)
spec_cr	Binary (dummy) variable indicating that the study presents information on the baseline catch rate.	Binary variable (0 to 1)	0.8440 (0.3633)
shore	Binary (dummy) variable indicating that all respondents in the sample fished from shore.	Binary variable (0 to 1)	0.1458 (0.3633)

[a] The default variable values are:
- A zero value for all of the study methodology variables (*SP_conjoint*, *SP_dichot*, *TC_individual*, *TC_zonal*, *RUM_nested*, and *RUM_nonnested*) indicates that the study used a stated preference methodology with an open-ended, iterative bidding, or payment card elicitation format.
- A zero value for *sp_mail* indicates that if the study was a stated preference study and it was administered by phone or in person.
- A zero value for *nonlocal* indicates that the survey included local anglers or a mix of local and nonlocal anglers.
- A zero value for all of the species variables indicates that the target species was panfish.
- A zero value for *shore* indicates that survey respondents fished from boats or from both the shore and from boats.

Source: U.S. EPA analysis for this report.

A5-3.2 Model and Results

a. Model

Past meta-analyses have incorporated a range of different statistical methods, with none universally accepted as superior (e.g., Santos, 1998; Poole and Greenland, 1999; Poe et al., 2001; Bateman and Jones, 2003). Nonetheless, there is general consensus that certain statistical issues should be addressed during model development. For example, many researchers agree that models must somehow address potential correlation among observations provided by like authors or studies and the related potential for heteroskedasticity (Johnston et al. 2003; Rosenberger and Loomis, 2000b; Bateman and Jones, 2003). This meta-analysis model is estimated following standard methods illustrated in the most recent literature, recognizing that there are some areas in which the literature provides mixed guidance (e.g., the use of weighting).

EPA followed recent work by Bateman and Jones (2003) in applying a multilevel model specification to the meta-data to address potential correlation among observations gathered from single studies. Multilevel (or hierarchical) models may be estimated as either random-effects or random-coefficients models, and are described in detail elsewhere (Goldstein, 1995; Singer, 1998). The fundamental distinction between these models and classical linear models is the two-part modeling of the equation error to account for hierarchical data. Here, the meta-data are comprised of multiple observations per valuation survey (i.e., all observations from studies that were based on a common survey), and there is a corresponding possibility of correlated errors among observations that share a common survey.[6] The common approach to modeling such potential correlation is to divide the residual variance of estimates into two parts: a random error that is independently and identically distributed (iid) across all observations, and a random effect that represents systematic variation related to each survey. The model is estimated as a two-level hierarchy, with level one corresponding to marginal value per fish estimates (individual observations), and level two corresponding to individual surveys. The random effect may be interpreted as a deviation from the mean equation intercept associated with individual surveys (Bateman and Jones, 2003). The model is estimated using a maximum likelihood estimator (MLE), based on the assumption that random effects

[6] EPA chose to group observations by valuation survey rather than by study or author because in a number of cases, studies based on the same survey produce similar results, even if written by different authors.

are distributed multivariate normal. Following the arguments of Bateman and Jones (2003), observations are unweighted. Also following prior work (e.g., Smith and Osborne, 1996; Poe et al., 2001), covariances are obtained using the Huber-White covariance estimator. As described by Smith and Osborne (1996, p. 293), “this approach treats each study as the equivalent of a sample cluster with the potential for heteroskedasticity…across clusters.” (Smith and Osborne, 1996).

Random effects models such as the multilevel model applied here are increasingly becoming standard in resource economics applications, and are estimable using a variety of readily available software packages. For comparison, models were also estimated using both ordinary least squares (OLS) and weighted least squares (WLS) with robust variance estimation and multilevel models with standard (non-robust) variance estimation. None of these models outperformed the illustrated model in terms of overall model significance and fit, or statistical significance of individual coefficients.

As noted in section A5-3.1, the dependent variable in the regression is the log of WTP per fish, and the independent variables are all linear, resulting in a semi-log functional form. This functional form has advantages because of: 1) its fit to the data, 2) the intuitive results provided by the functional form, and 3) the common use of this functional form in the meta-analysis literature (e.g., Smith and Osborne, 1996; Santos, 1998). While linear forms are also common in the literature (Rosenberger and Loomis, 2000a,b; Poe et al., 2001; Bateman and Jones, 2003), specifications requiring more intensive data transformations (e.g., Box-Cox, log-log) are less common. Given questions about *a priori* restrictions on the functional form, final decisions regarding functional forms were made based on a combination of general principles and empirical performance. The semi-log model was chosen over the linear model based on the ability of the semi-log form to capture curvature in the valuation function and its improved fit to the data. It also allows independent variables to influence WTP (after transformation from its natural log) in a multiplicative rather than additive manner.

❖ **A note on model specification**

Following standard econometric practice, the final model is specified based on guidance from theory and prior literature. For example, Arrow et al. (1993) make a fundamental distinction between discrete choice and open-ended payment mechanisms (where open-ended include iterative bidding, payment cards, etc.). Hence, this is the distinction made in the final model (i.e., including the variables *SP_conjoint* and *SP_dichot*). Similarly, other methodology variables in the model were chosen based on theoretical considerations and prior findings in the literature (e.g., nested RUM vs. non-nested RUM; mail surveys vs. phone and in-person surveys).

As is common in meta-analysis, some variables were excluded from the model because sufficient data were incomplete or missing from most studies in the meta-data. For example, a variable characterizing the average number of years respondents had been fishing was excluded because too few observations were available. Some other variables were also excluded because of a clear lack of statistical significance in all estimated models. For example, if there was no overriding theoretical or other rationale for retaining the variable in the model, and the variable was clearly insignificant, EPA excluded the variable from the model. For example, variables representing survey size and estimate size were dropped because they added no significant explanatory power to the model. However, certain variables were retained in the model for theoretical reasons, even if significance levels were low. Such specification of meta-analysis models using a combination of theoretical guidance and empirical considerations is standard in modeling efforts.

b. Results

Table A5-4 presents the results of the model.

Table A5-4: Estimated Multilevel Model Results: Marginal Value per Fish

Variable	Parameter Estimate	Standard Error	t Value	Prob > |t|
Intercept	-2.9751	1.2243	-2.43	0.0205
SP_conjoint	-0.2755	0.4781	-0.58	0.5649
SP_dichot	0.07965	0.3218	0.25	0.8047
TC_individual	2.2848	0.7083	3.23	0.0014
TC_zonal	3.2700	0.7005	4.67	<.0001
RUM_nest	2.2061	0.8792	2.51	0.0126
RUM_nonnest	2.7158	0.7916	3.43	0.0007
sp_year	0.1474	0.02966	4.97	<.0001
tc_year	-0.03301	0.02662	-1.24	0.2159
RUM_year	-0.00844	0.02790	-0.30	0.7626
sp_mail	-0.02076	0.3294	-0.06	0.9498
high_resp_rate	-0.6542	0.3160	-2.07	0.0393
inc_thou	0.02032	0.01052	1.93	0.0543
gender	-0.08744	0.01980	-4.42	<.0001
spec_gender	7.4801	1.7406	4.30	<.0001
age	-0.06713	0.06412	-1.05	0.2960
spec_age	3.2152	2.6241	1.23	0.2214
trips	-0.02307	0.01440	-1.60	0.1102
spec_trips	0.7151	0.3307	2.16	0.0314
nonlocal	3.5050	0.3496	10.02	<.0001
big_game_natl	1.7843	0.5357	3.33	0.0010
big_game_satl	2.7266	0.5952	4.58	<.0001
big_game_pac	2.7002	0.5074	5.32	<.0001
small_game_atl	1.6177	0.7217	2.24	0.0257
small_game_pac	2.0459	0.4551	4.50	<.0001
flatfish_atl	1.6407	0.4184	3.92	0.0001
flatfish_pac	2.2373	0.5431	4.12	<.0001
other_sw	1.0323	0.4540	2.27	0.0237
pike_walleye	1.3790	0.3216	4.29	<.0001
bass_fw	1.6356	0.4733	3.46	0.0006
trout_rainbow	0.6093	0.1123	5.43	<.0001
trout_atlantic	1.1187	0.4016	2.79	0.0057
trout_GL	1.9356	0.3337	5.80	<.0001
trout_mountain	1.0592	0.5220	2.03	0.0433

Table A5-4: Estimated Multilevel Model Results: Marginal Value per Fish

Variable	Parameter Estimate	Standard Error	t Value	Prob > |t|
trout_pacific	0.6630	0.5296	1.25	0.2115
trout_other	-0.7536	0.4723	-1.60	0.1116
salmon_atlantic	5.7740	0.5143	11.23	<.0001
salmon_GL	2.2719	0.3134	7.25	<.0001
salmon_pacific	2.9182	0.5441	5.36	<.0001
steelhead	3.1772	0.7428	4.28	<.0001
cr_nonyear	-0.07350	0.07411	-0.99	0.3221
cr_year	-0.03335	0.01095	-3.05	0.0025
spec_cr	0.4949	0.2833	1.75	0.0816
shore	-0.2291	0.1953	-1.17	0.2416
	Full Model	*Random Effects*		
-2 Log Likelihood	951.5	1177.8		
Chi-square	12.29	145.77		
Prob > Chi-square	0.0005	<0.0001		
Covariance Factors:				
Study Level (σ_u)	0.1618			
Residual (σ_e)	0.6039			
Source: U.S. EPA analysis for this report.				

A5-3.3 Interpretation of Regression Analysis Results

The analysis finds both statistically significant and intuitive patterns that influence marginal WTP for catching an additional fish. In general, the statistical fit of the equation is good; there is a strong systematic element to WTP variation that allows forecasting of WTP based on species and study characteristics. The model as a whole is statistically significant at $p<0.0005$. Of the 44 independent variables in the model (not including the intercept), 32 are statistically significant at the 10% level, and most of those are statistically significant at the 1% level. Signs of significant parameter estimates generally correspond with intuition, where prior expectations exist. As shown in Table A5-4, the random effects are statistically significant, indicating that study level heterogeneity has a statistically significant impact on the model.

a. Source study methodology effects

Eleven variables characterize source study methodology. Many of these variables have coefficients that are consistent with prior expectations of sign and relative magnitude. Others have results that are less intuitively clear. For example, interpretation of the parameter estimates of the year variables is not straightforward. Model results show that the *tc_year* and *RUM_year* both have negative but insignificant parameter estimates. These insignificant parameter estimates may indicate that study year has no significant impact on estimated WTP. Alternatively, it may result from a lack of variability in the meta-data for certain variables (e.g., *tc_year*) or from correlation with other model variables. Of slightly more concern is the parameter estimate for *sp_year*, which is positive and significant. This finding is counterintuitive. Since the focus of survey design over time has often been on the reduction of survey biases that would otherwise result in an overstatement of WTP, WTP per fish might be expected to decrease over time (Arrow et al., 1993). Although the reason for this pattern is unknown, EPA believes that results for this variable should be interpreted with caution.

Of the revealed preference methodology variables, *RUM_nest* has the smallest coefficient, followed by *TC_individual*, *RUM_nonnest*, and *TC_zonal*. Although theory does not provide unambiguous guidance regarding expected magnitude of these variables, nested RUM models account for substitution effects across different fish species. Hence, one might expect these models to produce lower WTP values per fish compared to the non-nested RUM models and travel cost models. Given that random utility models explicitly take into account the presence of substitute sites, they might also be expected to produce lower WTP estimates for accessing a given recreational site compared to the travel cost models. However, there is no clear theoretical reason to expect non-nested RUM models to produce lower WTP per marginal fish compared to individual (non-RUM) travel cost models.

The stated preference dummy variables (*SP_conjoint*, *SP_dichot*, and the default value, *SP_other*) have much lower coefficients than the travel cost and random utility model variables. This finding is consistent with past research by Cameron (1992) and others, who demonstrate that stated preference methods can produce lower estimates of direct use values for the same quality change than revealed preference methods. However, interpretation of the methodology variables associated with the stated preference approaches is confounded by the large positive coefficient on *sp_year*, which indicates that among more recent studies, revealed preference methods may produce higher estimates of WTP per additional fish.

Of the remaining two methodology variables, one is significant. *Sp_mail* was retained in the meta-analysis for theoretical reasons, despite its lack of statistical significance. The parameter estimate of the binary variable *high_response_rate* is negative and significant ($p<0.05$), a finding consistent with prior expectations.

b. Sample characteristics effects

Eight variables characterize demographic and economic attributes. All associated parameter estimates have expected signs, and five are statistically significant at $p<0.10$.

Model results show that respondents with higher incomes (*Inc_thou*) are willing to pay more to catch an additional fish per trip – an expected result. The negative parameter estimate for the *age* variable suggests that older anglers are willing to pay less for catching an additional fish. Insofar as *age* is correlated with experience, the negative coefficient on *age* may capture the effects of increased angler experience. EPA notes that anglers with more experience are likely to have better success rates, and thus might not be willing to pay as much to catch additional fish, due to diminishing marginal WTP per fish caught. The parameter estimate on *gender* is negative and significant($p<0.0001$), indicating that women are willing to pay more to catch an additional fish per trip.

Model results reveal that anglers who take more fishing trips (*trips*) per year (and who presumably catch more fish during the fishing season) have lower marginal values per fish than anglers who take fewer trips per year. This is not surprising, since catching an additional fish during a single trip increases total seasonal catch for avid anglers by a smaller percentage than for anglers who fish less often. Moreover, those taking a greater number of trips, and presumably catching more fish, might be expected to have a somewhat diminished WTP for an additional fish, again based on the concept of diminishing marginal utility.

The parameter estimate for the *nonlocal* variable is positive and significant ($p<0.0001$) indicating that anglers who travel out of state to fish are willing to pay much more to catch additional fish than local residents. However, this effect should be interpreted in the context of the underlying data. This variable is based on only two observations and reflects values of anglers who travel long distances (e.g., visit Alaska) to their fishing destinations.[7] Hence, EPA suggests that results for this variable may not be readily generalizable.

[7] In alternative model specifications, EPA was not able to find a statistically significant difference between the variables *local* (representing survey samples that included only local residents) and *local_nonlocal* (representing

c. Species targeted effects

The model includes 21 binary variables that characterize the target species and region in which the species was targeted. All but two of these variables have coefficients that are significant at $p<0.05$. The variables can be divided into three general groups: marine species, freshwater species, and salmonoids. In general, the sign and magnitude of the coefficients of most of the variables are consistent with prior expectations regarding both the relative worth of different species and the relative worth of individual species in different geographic regions. However, unlike other variables, these expectations are based on existing literature, prior empirical results, and anecdotal evidence, rather than economic theory.

Of the marine species variables, *big_game_satl* and *big_game_pac* have the largest magnitude. *Big_game_natl* has a somewhat lower coefficient, which is likely due to a somewhat different species composition in the big game category in the North Atlantic and Mid-Atlantic regions. *Small_game_atl* has a slightly smaller coefficient than *small_game_pac*, and *flatfish_atl* has a lower coefficient than *flatfish_pac*, but these differences are not statistically significant. As expected, the *other_sw* variable, which includes bottomfish, smelt, grunion, and other miscellaneous saltwater species, has a relatively small coefficient compared to the other marine species.

Results for the freshwater variables also meet prior expectations. Among warmwater species, *bass_fw* has the highest coefficient, followed by *pike_walleye*. The default value for the regression includes species such as panfish, catfish, and perch. Thus, the value of catching additional panfish or perch is significantly lower than most of the other species. Regression results indicate that the value of catching additional trout varies significantly across geographic regions and trout species. The trout regional dummy variables indicate that anglers are willing to pay more to catch additional trout in the Great Lakes (*trout_GL*), and are willing to pay less in other regions, particularly near the Pacific coast (*trout_pacific*). It is not possible to tell from the regression results whether these regional differences in WTP are due to regional differences in the biology of species (size, fighting ability, taste), or regional differences in angler avidity and economic characteristics. The *trout_other* variable, which has a negative coefficient, represents one study that surveyed trout fee-fishing establishments across the U.S. Hence, this variable is most appropriately characterized as a study-specific dummy variable, and hence should be interpreted with caution. The *trout_rainbow* variable (which is additive with the trout regional dummy variables) has a positive and significant coefficient, indicating that anglers may value rainbow trout more highly than other species of trout.

The coefficients of the salmon variables and the *steelhead* variable are fairly large. These findings are consistent with the popularity of salmonoids as game fish. *Salmon_atlantic* has a very large coefficient, but this variable is again based on observations from only one study – hence results for this variable should be interpreted accordingly.[8] *Salmon_GL* has a lower coefficient than *salmon_pacific*, which is consistent with the larger size of Pacific salmon. *Steelhead* has a higher coefficient than either *salmon_GL* or *salmon_pacific*.

d. Angling characteristics

The angling characteristics variables include two catch rate variables (*cr_nonyear* and *cr_year*) and a fishing mode variable (*shore*). The negative parameter estimates on both *cr_nonyear* and *cr_year* indicate that anglers' WTP for catching an additional fish per trip decreases as the number of fish already caught increases.[9] This result is consistent with both economic theory and prior expectations. The parameter estimate on the shore variable is negative but insignificant.

---

survey samples that included a mix of local and nonlocal residents).

[8] The study was based on Atlantic salmon fishing in Maine in 1988. Angling for Atlantic salmon is currently illegal in Maine (MaineToday.com, 2003).

[9] Although cr_nonyear lacks significance ($p<0.32$), this variable is consistently negative across a variety of model specifications.

e. Model limitations

Although the meta-analysis results presented in the previous section indicate that the model's statistical fit is quite good, EPA notes that there are a number of limitations and uncertainties involved in the estimation and results of the model. These limitations stem largely from the quality and quantity of information available from the original studies, and from the statistical methods used to estimate the model.

First of all, regardless of the explanatory power of the meta-analysis regression equation, the model is only as good as the data upon which it is based. EPA believes that WTP per fish estimates from the 24 peer-reviewed journal articles are based on careful, high quality research. The data set also includes estimates from 24 reports, dissertations, academic working papers, and books, which are not always subject to the same academic scrutiny and quality standards. Nonetheless, based on EPA's review of these documents, the Agency believes that all of the estimates included in the data set are of reasonable academic quality.

Another limitation of the data is that some demographic and other variables are present for only a subset of the meta-observations. For example, the variables *gender*, *age*, and *trips* have a large number of missing observations, indicating that the original studies do not always provide detailed demographic data. By including dummy variables to indicate missing observations (*spec_gender*, *spec_age*, and *spec_trips*), EPA was able to control for the missing data. This specification presumes that a fixed shift in intercept (i.e., using a dummy variable) is sufficient to control for systematic differences associated with the lack of data for specific variables – an unverifiable assumption. Moreover, the significance of these variables would be clearer if more observations were available.

A third limitation of the data, related to variable specification, is the imperfect match between the aggregate species variables specified in the model and the species evaluated in each individual study. Although in most cases the match was good, some studies provided WTP per fish estimates for very broad categories of species, such as "bottomfish (flounder family, cod family, snapper, grouper, jack, grunt, sea bass, porgy, wreckfish)" (Schuhmann, 1997). EPA assigned these estimates to the aggregate species group variable that most closely matched the largest number of species from the list provided in the study, but the Agency acknowledges that this process introduces uncertainty into the analysis.

Another source of uncertainty related to the species groupings is that creating variables for aggregate species groups reduces the precision of the resulting benefit estimates. By aggregating species into categories, EPA was able to improve the fit of the meta-analysis model, but this aggregation also results in a lower of level of detail in the values that can be predicted. In particular, the panfish category and other saltwater category include relatively diverse species.

Model results are also subject to choices regarding functional form and statistical approach, although many of the primary model effects are robust to reasonable changes in functional form and/or statistical methods. The rationale for the specific functional form and model structure chosen is detailed above in section A5-3.2a. In general, meta-analysis may provide a superior alternative to the calculation and use of a simple arithmetic mean, as it allows WTP to be adjusted to account for the characteristics of the transfer site. The model's ability to adjust WTP appropriately is suggested by the many systematic (statistically significant) patterns revealed by the meta-analysis regression. Nonetheless, the use and interpretation of meta-analysis models for benefit transfer, and the use of benefit transfer in general, are subject to the constraints and concerns expressed elsewhere in the literature (e.g., Desvousges et al., 1998; Poe et al., 2001; Vandenberg et al., 2001).

A5-4 Application of the Meta-Analysis Results to the Analysis of Recreational Benefits of the Proposed Section 316(b) Rule for Phase III Facilities

The results of the meta-analysis in conjunction with information specific to the resource users and populations of species that will benefit from reduced I&E can be used to estimate the recreational welfare gain associated with the proposed section 316(b) rule for Phase III facilities. This analysis involves the following steps:

- estimating the marginal recreational value per fish for each species affected by the 316(b) regulation in each region;
- calculating the recreational fishing benefits from eliminating baseline I&E losses, by multiplying the marginal value per fish by the number of recreational fish species currently lost to I&E that would otherwise be caught by recreational anglers; and
- calculating the recreational fishing benefits from the proposed section 316(b) regulation for Phase III facilities, by multiplying the marginal value per fish by the number of additional fish that would be caught by recreational anglers because of reduced I&E losses of recreational fish species.

A5-4.1 Estimating Marginal Value per Fish

EPA used the estimated meta-regression to estimate marginal values per fish for the species affected by I&E at Phase III facilities. To calculate the marginal value per fish for the affected species, EPA chose input values for the independent variables based on differences in the affected species characteristics, study regions, and demographic characteristics of the affected angling populations. The study design variables were selected based on current economic literature. Tables A5-5 summarizes the input values for each of the variables in the model.

Table A5-5: Independent Variable Assignments for Regression Equation

Variable	Coefficient	Assigned Value	Explanation
Intercept	-2.9751	1	The equation intercept was set to one by default.
SP_conjoint	-0.2755	0	Current academic literature suggests that nested RUM models produce the most accurate valuation results, so *RUM_nest* was set to one, and the other study methodology variables were set to zero.
SP_dichot	0.07965	0	
TC_individual	2.2848	0	
TC_zonal	3.2700	0	
RUM_nest	2.2061	1	
RUM_nonnest	2.7158	0	
sp_year	0.1474	0	Because more recent studies are expected to be more accurate, *RUM_year* was set equal to 24 (equivalent to 2000 minus 1976).
tc_year	-0.03301	0	
RUM_year	-0.00844	24	
sp_mail	-0.02076	0	Since the *RUM_nest* was the model chosen, *sp_mail* was set to zero.
high_resp_rate	-0.6542	1	High survey response rates are desirable because they may provide more accurate estimates, so *high_response_rate* was set to one.
inc_thou	0.02032	varies	*Inc_thou* was set to the median income for each study region evaluated, based on U.S. Census data.

Table A5-5: Independent Variable Assignments for Regression Equation

Variable	Coefficient	Assigned Value	Explanation
gender	-0.08744	89.11	*Age* and *gender* were set to their sample means, and *spec_age* and *spec_gender* were set to one.
spec_gender	7.4801	1	
age	-0.06713	43.51	
spec_age	3.2152	1	
trips	-0.02307	varies	The variable *trips* was assigned region-specific values based on NMFS (1994, 1997, 2000) and U.S. FWS survey data (2002), and *spec_trips* was set to one.
spec_trips	0.7151	1	
nonlocal	3.5050	0	Because the default (zero) value for the *nonlocal* dummy variable represents a combination of local and nonlocal anglers, *nonlocal* was set to zero.
big_game_natl	1.7843	varies	Species targeted variables were assigned input values based on characteristics of the species affected by I&E and the study region. In general, the match between the affected species and the variables in the meta-analysis equation was good.
big_game_satl	2.7266	varies	
big_game_pac	2.7002	varies	
small_game_atl	1.6177	varies	
small_game_pac	2.0459	varies	
flatfish_atl	1.6407	varies	
flatfish_pac	2.2373	varies	
other_sw	1.0323	varies	
pike_walleye	1.3790	varies	
bass_fw	1.6356	varies	
trout_rainbow	0.6093	varies	
trout_atlantic	1.1187	varies	
trout_GL	1.9356	varies	
trout_mountain	1.0592	varies	
trout_pacific	0.6630	varies	
trout_other	-0.7536	varies	
salmon_atlantic	5.7740	varies	
salmon_GL	2.2719	varies	
salmon_pacific	2.9182	varies	
steelhead	3.1772	varies	

Table A5-5: Independent Variable Assignments for Regression Equation

Variable	Coefficient	Assigned Value	Explanation
cr_nonyear	-0.07350	varies	The variable *cr_nonyear* was assigned species and region-specific values for the coastal and Great Lakes regions based on catch rates data provided by NMFS (1994, 1997, 2000) and MDNR (2002). For the Inland region, EPA assigned values to the *cr_nonyear* variable based on the average values for each species from the studies. The variable *spec_cr* was set to one. *Cr_year* was set to zero, since catch per trip and catch per day are more common measures of angling quality.
cr_year	-0.03335	0	
spec_cr	0.4949	1	
shore	-0.2291	varies	*Shore* was assigned values based on NMFS (1994, 1997, 2000) and FWS (2002) survey data indicating the average percentage of anglers who fish from shore in each region.

Source: U.S. EPA analysis for this report.

Table A5-6 presents region- and species-specific values for the input variables that vary across regions.

Table A5-6: Region- and Species-Specific Variable Assignments for Regression Equation

Variable		Region						
		California	**North Atlantic**	**Mid-Atlantic**	**South Atlantic**	**Gulf of Mexico**	**Great Lakes**	**Inland**
inc_thou		54.385	55.000	51.846	40.730	36.641	44.519	58.240
trips		3.2	7.2	9.3	7.8	7.3	9.0	13.0
shore		24.0	24.0	23.1	30.0	25.0	48.0	57.0
Species	**Species Type Dummy Variable**[a]	**Baseline Catch Rate, Expressed in Fish per Day** (*cr_nonyear*)						
Small game[b]	*small_game_atl*, *small_game_pac*	2.7	1.6	1.6	2.2	2.2		2.1
Flatfish[c]	*flatfish_atl*, *flatfish_pac*	1.3	1.0	1.0	1.5			
Other saltwater	*other_sw*	1.7	1.7	1.7	1.7	1.7		
Salmon	*salmon_GL*						0.2	
Walleye/Pike	*pike_walleye*						0.8	0.8
Bass	*bass_fw*						0.2	0.2
Panfish[d]							4.7	4.7

[a] This column indicates which species type dummy variable was set to one to represent each species.
[b] For small game in the North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, and Inland regions, *small_game_atl* was set to one. For small game in the California region, *small_game_pac* was set to one.
[c] For flatfish in the North Atlantic, Mid-Atlantic, South Atlantic, Gulf of Mexico, Great Lakes, and Inland regions, *flatfish_atl* was set to one. For flatfish in the California region, *flatfish_pac* was set to one.
[d] To indicate that the target species was panfish, all species type dummy variables were set to zero.

Source: U.S. EPA analysis for this report.

EPA decided not to include the error term when using the regression equation to predict marginal values per fish. Bockstael and Strand (1987) argue that if the source of econometric error in an equation is primarily due to omitted variables, the error term should be included, but if the error is primarily due to random preferences, it should be excluded. Because the error term is positive, the empirical effect of including this term is to increase the predicted marginal values. Therefore, EPA's approach results in more conservative estimates. The Agency also notes that when the error term is excluded, the values predicted by the regression equation are more consistent with those from the underlying studies.

Table A5-7 presents the estimated marginal value per fish for all species that were affected by I&E in each region.

Table A5-7: Marginal Recreational Value per Fish, by Region and Species[a]

Species	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland
Small game	$12.57	$7.64	$6.87	$5.65	$5.32		$7.38
Flatfish	$15.61	$8.06	$6.91	$5.84			
Other saltwater	$4.52	$4.20	$3.73	$3.09	$2.88		
Salmon						$11.19	
Walleye/pike						$4.58	$5.15
Bass						$5.90	$6.96
Panfish						$1.06	$0.97

[a] All monetary values are expressed in June 2003$.

Source: U.S. EPA analysis for this report.

A5-4.2 Calculating Recreational Benefits

EPA estimated the recreational welfare gain from eliminating current I&E losses and the recreational welfare gain from the proposed rule by combining estimates of the marginal value per fish with estimates of the baseline level of I&E and the reduction in recreational fishing losses from I&E attributable to the proposed rule. To calculate the recreational welfare gain from eliminating current I&E losses, EPA multiplied the marginal value per fish by the number of fish that are currently lost due to I&E that would otherwise be caught by recreational anglers. To calculate the recreational welfare gain from the proposed regulation, EPA multiplied the marginal value per fish by the additional number of fish caught by recreational anglers that would have been impinged or entrained in the absence of the regulation. In these calculations, recreational fish losses are expressed as the number of mature, catchable adults, not as age-1 equivalents. The results of these calculations are presented in detail in Chapters B4 through G4 of this report.

A5-5 Limitations and Uncertainties

A number of issues are common to all benefit transfers. Benefit transfer involves adapting research conducted for another purpose to address the policy questions at hand. Because benefits analysis of environmental regulations rarely affords sufficient time to develop original stated preference surveys that are specific to the policy effects, benefit transfer is often the only option to inform a policy decision. Specific issues associated with the estimated regression model and the underlying studies are discussed in section A5-3.3. Additional limitations and uncertainties associated with implementation of the meta-analysis approach are addressed below.

A5-5.1 Sensitivity Analysis Based on Krinsky and Robb (1986) Approach

The meta-analysis model presented above can be used to predict mean WTP for catching an additional fish. However, estimates derived from regression models are subject to some degree of error and uncertainty. To better characterize the uncertainty or error bounds around predicted WTP, EPA adapted the statistical procedure described by Krinsky and Robb in their 1986 *Review of Economics and Statistics* paper "Approximating the Statistical Property of Elasticities." The procedure involves sampling from the variance-covariance matrix and means of the estimated coefficients, both of which are standard output from the statistical package used to estimate the meta-model. WTP values are then calculated for each drawing from the variance covariance matrix, and an empirical distribution of WTP values is constructed. By varying the number of drawings, it is possible to generate an empirical distribution with a desired degree of accuracy (Krinsky and Robb, 1986). The lower or upper bound of WTP values can then be identified based on the 5th and 95th percentile of WTP values from the empirical distribution. These bounds may help decision-makers understand the uncertainty associated with the benefit results.

The results of EPA's calculations are shown in Table A5-8. The table presents 95% upper confidence bounds and 5% lower confidence bounds for the marginal value per fish for each species in each region. These bounds can be used to estimate upper and lower confidence bounds for the welfare gain from eliminating baseline I&E losses or reducing I&E losses under the proposed regulation. Refer to the regional recreational results chapters for detail on the specific calculations.

Table A5-8: Confidence Bounds on Marginal Recreational Value per Fish, Based on the Krinsky and Robb Approach[a]

Species	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland
5% Lower Confidence Bound[b]							
Small game	$7.18	$3.53	$3.39	$2.91	$2.79		$3.75
Flatfish	$8.12	$4.39	$3.84	$3.05			
Other saltwater	$2.35	$2.31	$2.12	$1.70	$1.57		
Salmon						$8.48	
Walleye/pike						$3.13	$3.25
Bass						$4.00	$4.28
Panfish						$0.68	$0.60
95% Upper Confidence Bounds[b]							
Small game	$22.21	$16.59	$14.07	$11.08	$10.25		$14.62
Flatfish	$30.37	$14.76	$12.38	$11.19			
Other saltwater	$8.82	$7.70	$6.60	$5.63	$5.30		
Salmon						$17.31	
Walleye/pike						$7.82	$8.29
Bass						$10.42	$11.63
Panfish						$1.94	$1.60

[a] All values are in June 2003$.
[b] Upper and lower confidence bounds based on results of the Krinsky and Robb (1986) approach.

Source: U.S. EPA analysis for this report.

A5-5.2 Variable Assignments for Independent Regressors

The per fish values estimated from the model depend on the values of the input variables in the meta-analysis. EPA assigned values to the input variables based on established economic theory and characteristics of the affected species and regions. However, because the input values for some variables are uncertain, the resulting per fish values and benefits estimates also include some degree of uncertainty.

A5-5.3 Other Limitations and Uncertainties

In addition to the limitations and uncertainties involved with the study data and model estimation, which are discussed in section A5-3.3e, there are limitations and uncertainties involved with the calculation of per fish values from the model, and with the use of those values to estimate the welfare gain resulting from the 316(b) regulation. These issues pertain to the appropriateness of the benefit transfer and the estimation of the level of current and post-regulatory recreational losses. This section discusses each of these problems in greater detail.

The validity and reliability of benefit transfer — including that based on meta-analysis — depends on a variety of factors. While benefit transfer can provide valid measures of use benefits, tests of its performance have provided mixed results (e.g., Desvousges et al., 1998; Vandenberg et al., 2001; Smith et al., 2002). Nonetheless, benefit transfers are increasingly applied as a core component of benefit cost analyses conducted by EPA and other government agencies (Bergstrom and De Civita, 1999; Griffiths, *undated*). Smith et al. (2002, p. 134) state that "nearly all benefit cost analyses rely on benefit transfers, whether they acknowledge it or not." Given the increasing (or as Smith et al. (2002) might argue, universal) use of benefit transfers, an increasing focus is on the empirical properties of applied transfer methods and models.

An important factor in any benefit transfer is the ability of the study site or estimated valuation equation to approximate the resource and context under which benefit estimates are desired. As is common, the meta-analysis model presented here provides a close but not perfect match to the context in which values are desired. For example, although most of the Inland studies take place in the Great Lakes region, the proposed rule affects sites all across the Inland region. However, EPA believes that regional differences in per fish values for specific Inland species are relatively small.

The final area of uncertainty related to the use of the regression results to calculate regulatory benefits is uncertainty in the estimates of I&E. There are a number of reasons why recreational losses due to I&E may be higher or lower than expected. Projected changes in recreational catch may be underestimated because cumulative impacts of I&E over time are not considered. In particular, I&E estimates include only individuals directly lost to I&E, not their progeny. Additionally, the interaction of I&E with other stressors may have either a positive or negative effect on recreational catch. Finally, in estimating recreational fishery losses, EPA used I&E data provided by facilities, which in some case are more than 20 years old. While EPA used the most current data available, they may not reflect current conditions.

Chapter A6: Qualitative Assessment of Non-Use Benefits

Introduction

Chapter Contents

Comprehensive, appropriate estimates of total resource value include both use and non-use values, such that the resulting total value estimates may be compared to total social cost. “Non-use values, like use values, have their basis in the theory of individual preferences and the measurement of welfare changes. According to theory, use values and non-use values are additive” (Freeman, 1993).[1] Therefore, use values alone may seriously understate total social values. Recent economic literature provides substantial support for the hypothesis that non-use values are greater than zero. Moreover, when small per capita non-use values are held by a substantial fraction of the population, they can be very large in the aggregate. As stated by Freeman (1993), “... there is a real possibility that ignoring non-use values could result in serious misallocation of resources.”

Given that aquatic species without any direct uses account for the majority of cooling water intake structure losses, a comprehensive estimate of the welfare gain from reduced impingement and entrainment (I&E) losses requires an estimate of non-use benefits.[2] Stated preference methods, or benefit transfers based on stated preference studies, are the generally accepted techniques for estimating non-use values. Stated preference methods rely on surveys that assess individuals’ stated willingness-to-pay (WTP) for specific ecological improvements, such as increased protection of fishery resources. Benefit transfer involves adapting research conducted for another purpose in the available literature to address the policy questions in hand (Bergstrom and De Civita, 1999). Because benefit-cost analysis of environmental regulations rarely affords sufficient time to develop original stated preference surveys specific to policy effects, benefit transfer is often the only remaining option for providing information to inform policy decisions.

The Agency has begun the preliminary development of a stated preference survey that would measure non-use benefits from reduced I&E attributable to the section 316(b) regulation for Phase III facilities. This stated preference study is expected to be completed for the final regulation for Phase III facilities. Because developing an original stated preference survey specific to the proposed regulation was not feasible due to the time constraints, EPA explored several benefit transfer approaches for analyzing national level non-use benefits of the proposed regulation. EPA, however, did not include the results of these approaches in the benefit analysis because of limitations and uncertainties associated with estimation of non-use benefits on a national scale. For further discussion of the benefit transfer methods considered for this analysis, refer to DCN 7-5133.

To assess the public policy significance or importance of the ecological gains from the proposed regulation for Phase III facilities, EPA collected and developed relevant information to enable the Agency to consider non-use benefits qualitatively. This assessment is discussed below.

---

[1] According to Freeman (1993), this additive property holds under traditional conditions related to resource levels and prices for substitute goods in the household production model.

[2] For detail on the number and percentage of fish directly valued, see Section A3-4.1 of this report.

A6-1 Public Policy Significance of Ecological Improvements from the Proposed Regulation for Phase III Facilities

Changes in cooling water intake system (CWIS) design or operations resulting from the section 316(b) regulations for Phase III facilities are expected to reduce I&E losses of fish, shellfish, and other aquatic organisms and, as a result, are expected to increase the numbers of individuals present and benefit local and regional fishery populations. Depending on the nature of the reduced losses and on the conditions at the site, this may ultimately contribute to the enhanced environmental functioning of affected waterbodies (rivers, lakes, estuaries, and oceans) and associated ecosystems. Specific ecological benefits that may occur due to enhanced environmental functioning of affected waterbodies resulting from the proposed regulation for Phase III facilities are described in sections A6-1.1 and A6-1.2.

A6-1.1 Effects on Depleted Fish Populations

EPA believes that reducing fish mortality from I&E would contribute to the health and sustainability of the affected fish populations by lowering the overall level of mortality for these populations. Fish populations suffer from numerous sources of mortality; some are natural and others are anthropogenic. Natural sources include weather, predation by other fish, and the availability of food. Human impacts that affect fish populations include fishing, pollution, habitat changes, and I&E losses at CWIS. Fish populations decline when they are unable to sufficiently compensate for their overall level of mortality. Lowering the overall mortality level increases the probability that a population will be able to compensate for mortality at a level sufficient to maintain the long-term health of the population. In some cases, I&E losses may be a significant source of anthropogenic mortality to depleted fish stocks. For example, damaged saltwater fish stocks affected by I&E include winter flounder, red drum, and rockfishes (NMFS, 2003). I&E also affects species native to the Great Lakes such as lake whitefish and yellow perch whose populations have dramatically declined in recent years (U.S. Department of the Interior, 2004; Wisconsin DNR, 2003).

The public importance of restoring healthy fisheries is reflected in actions taken by the Federal and State Agencies to reduce fishing pressure on these fish stocks. Actions taken by the Federal and regional government agencies include buying fishing licenses and fishing vessels at substantial public expense and imposing restrictions on commercial and recreational catch. Fishing restrictions impose limitations on those who make a living from fishing or participate in recreational fishing. These actions reflect the public importance of achieving recovery of depleted fish stocks. Another example of the public value of fishery resources is a large-scale ecosystem restoration program that includes the native species recovery in the Great Lakes Basin (U.S. Department of the Interior, 2004).[3]

EPA was unable to estimate changes in future fish population resulting from reduced mortality from I&E from the proposed regulation for Phase III facilities due to unavoidable uncertainty in predicting the trajectory of future fish populations and significant data gaps. The Agency, however, believes that reducing fish mortality from I&E along with other measures would contribute to recovery of the damaged fish populations.

A6-1.2 Ecosystem Effects

The aquatic resources affected by cooling water intake structures provide a wide range of services. Ecosystem services are the physical, chemical, and biological functions performed by natural resources and the human benefits derived from those functions, including both ecological and human use services (Daily, 1997; Daily et al., 1997). Scientific and public interest in protecting ecosystem services is increasing with the recognition that these services are vulnerable to a wide range of human activities and are difficult, if not impossible, to replace with human technologies (Meffe, 1992).

[3] Habitat restoration activities can be targeted to achieve ecological benefits at either the community or individual species level and are critical for preserving aquatic biodiversity throughout the Great Lakes.

In addition to their importance in providing food and other goods of direct use to humans, the organisms lost to I&E may be critical to the continued functioning of the ecosystems of which they are a part. Fish are essential for energy transfer in aquatic food webs, regulation of food web structure, nutrient cycling, maintenance of sediment processes, redistribution of bottom substrates, regulation of carbon fluxes from water to the atmosphere, and maintenance of aquatic biodiversity (Peterson and Lubchenco, 1997; Postel and Carpenter, 1997; Holmlund and Hammer, 1999; Wilson and Carpenter, 1999). Examples of ecological services that may be disrupted by I&E include:

- decreased numbers of ecological keystone, rare, sensitive, or threatened and endangered species;
- decreased numbers of popular commercial and recreational fish species that are not fished, perhaps because the fishery is closed;
- increased numbers of exotic or disruptive species that compete well in the absence of species lost to I&E (I&E may also help remove some exotic or disruptive organisms);
- disruption of ecological niches and ecological strategies used by aquatic species;
- disruption of energy transfer through the food web;
- decreased local biodiversity;
- disruption of predator-prey relationships;
- disruption of age class structures of species;
- disruption of natural succession processes.

Many of these services can only be maintained by the continued presence of all life stages of fish and other aquatic species in their natural habitats. Reducing I&E losses could to contribute to restoring (or preserving) the biological integrity of the ecosystems of substantial national importance.

a. Effects on saltwater ecosystems

In the 1987 amendments to the CWA, Congress established the National Estuary Program because the “Nation’s estuaries are of great importance to fish and wildlife resources and recreation and economic opportunity... [, and to] maintain the health and ecological integrity of these estuaries is in the national interest” (Water Quality Act of 1987). So far, there are 28 estuaries designated under the National Estuary Program (NEP). In addition, the largest estuary in the United States, Chesapeake Bay, is protected under its own federally mandated program, separate but related to NEP. Table A6-1 shows estuaries from which the sample Phase III facilities draw water. Of the 16 estuaries affected by the sample Phase III facilities, 12 are nationally significant estuaries designated under NEP or the Chesapeake Bay Program.

Table A6-1: Estuaries Affected by Phase III Facilities[a]

Region	Affected Estuary	Designated under NEP or the Chesapeake Bay Program[a]
California	San Francisco Bay	✓
	Santa Monica Bay	✓
Gulf of Mexico	Calcasieu Estuary	
	Galveston Bay	✓
	Matagorda Bay	
Mid-Atlantic	Barnegat Bay	✓
	Chesapeake Bay	✓
	Delaware Estuary	✓
	Delaware Inland Bays	✓
	Long Island Sound[b]	✓
	New York/New Jersey Harbor	✓
North Atlantic	Long Island Sound[b]	✓
	Massachusetts Bays	✓
	New Hampshire Estuaries	✓
	Penobscot Estuary	
South Atlantic	Savannah River Estuary	

a. Based on estuaries included in EPA's National Estuary Program and the Chesapeake Bay Program.
b. Affected by the sample facilities located in the Mid-Atlantic and North Atlantic regions. EPA notes that although additional estuaries are likely to be affected by Phase III facilities, specific locations and thus waterbodies affected by the facilities represented by the sample Phase III facilities are unknown.

Source: U.S. EPA, 2004a.

Substantial federal and state resources have been directed to NEP to enhance conservation of and knowledge about the estuaries designated under this program. Since 1998, more than $95 million has been devoted to NEP to benefit the health of the nationally significant estuaries (NEP, 2004; U.S. EPA, 2004c). These expenditures reflect high public values for restoring (or protecting) the biological integrity of the ecosystems of substantial national importance.

b. Effects on freshwater ecosystems

Reducing I&E at Phase III facilities may also benefit freshwater ecosystems of national significance, including the Great Lakes Basin, Mississippi River, and Columbia River. These waterbodies are subject to large-scale ecosystem restoration efforts that are good indicators of great public importance of restoring the ecological health of these ecosystems (U.S. Fish and Wildlife Service, 2004; U.S. Department of the Interior, 2004; Northeast Midwest Institute, 2004; The Upper Mississippi River Basin Association, 2004). The ecosystem restoration efforts focus on many issues, including coastal habitat restoration, protection of fish species, conservation of migratory birds and endangered species. For example, between 1992 and 2001, more than $17 million was devoted to projects to restore and conserve the Great Lakes ecosystem; $102 million was spent on improving the Mississippi River ecosystem (U.S. EPA, 2004b, and Brescia, 2002). Reducing I&E of aquatic organisms may improve the quality of aquatic habitat and contribute to improvement of the biological integrity and health of these ecosystems.

Finally, reducing I&E in waterbodies that do not have a national significance may contribute to restoration or protection of ecosystems of regional or local importance.

A6-2 Findings from Focus Group Meetings

To assist in the development of a stated preference survey, EPA conducted several focus groups meetings. Focus groups are often described as "informal sessions in which a skilled moderator leads a group of individuals through a discussion of specific topics to discover their attitudes and opinions" (Desvousges et al., 1984, p. 2-1, cited in Johnston et al., 1995 p. 56). Focus groups are among the most significant qualitative research tools used in social sciences (Bateman et al., 2002); observations from focus groups or similar qualitative tools may provide information allowing one to interpret or validate previously obtained quantitative results (Responsive Management, 1992).

Based on the focus groups conducted during the preliminary development of a stated preferences survey, the Agency found that (1) both user and non-users of the affected aquatic resources are likely to hold values for reducing I&E mortality of the affected fish species; (2) the main motives for reducing I&E mortality are bequest and existence values; (3) focus group participants agreed that all fish species (including forage fish) play an important role in the affected ecosystems and thus also have significant values; and (4) saltwater fishery resources are likely to have higher values compared to freshwater fishery resources. The Focus Group Report (DCN 7-5180) provides detail on EPA's findings from the focus group meetings.

Chapter A7: Entrainment Survival

Introduction

To calculate benefits associated with entrainment reduction, EPA used the assumption that all organisms passing through a facility's cooling water system would experience 100% mortality. This assumption was recommended in EPA's 1977 Guidance for Evaluating the Adverse Environmental Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500 (U.S. EPA, 1977). This is also the basic assumption currently used in the permitting programs for section 316(b) in Arizona, California, Hawaii, Louisiana, Maine, Maryland, Massachusetts, Minnesota, Nevada, New Hampshire, Ohio, and Rhode Island (personal communication, I. Chen, U.S. EPA Region 6, 2002; personal communication, P. Colarusso, U.S. EPA Region 1, 2002; personal communication, G. Kimball, 2002; personal communication, M. McCullough, Ohio EPA, 2002; McLean and Dieter, 2002; personal communication, R. Stuber, U.S. EPA Region 9, 2002).

Chapter Contents

EPA obtained 37 entrainment survival studies conducted at 22 individual power producing facilities and conducted a detailed review. EPA also reviewed a report prepared for the Electric Power Research Institute (EPRI) (EA Engineering, Science, and Technology, 2000) which summarized the results of 36 entrainment studies, 31 of which were the same studies reviewed by EPA. The intent of EPA's review was to determine the soundness of the findings behind the entrainment survival studies and to evaluate whether the assumption of 100% entrainment mortality is appropriate for use in the national benefits assessment for the proposed section 316(b) rule for Phase III facilities to compare to the costs of installing the best technology available for minimizing adverse environmental impact.

A7-1 The Causes of Entrainment Mortality

A7-1.1 Fragility of Entrained Organisms

Cooling water intake structures entrain many species of fish, shellfish, and macroinvertebrates. These species are most commonly entrained during their early life stages, as eggs, yolk-sac larvae (YSL), post yolk-sac larvae (PYSL), and juveniles, because of their small size and limited swimming ability. In addition to having limited or no mobility, these early life stages are very fragile and thus susceptible to injury and mortality from a wide range of factors (Marcy, 1975). For these reasons, entrained eggs and larvae experience high mortality rates as a result of entrainment. The three primary factors contributing to the mortality of organisms entrained in cooling water systems are thermal stress, mechanical stress, and chemical stress (Marcy, 1975). The relative contribution of each of these factors to the rate of mortality of entrained organisms can vary among facilities, based on the nature of their design and operations as well as the sensitivity of the species entrained (Marcy, 1975; Beck and the Committee on Entrainment, 1978; Ulanowicz and Kinsman, 1978). These three primary factors are discussed in more detail below.

A7-1.2 Thermal Stress

Facilities use cooling water as a means of disposing of waste heat from facility operations. Thus, organisms present in the cooling water are exposed to rapid increases in temperatures above ambient conditions when passing through the cooling water system. This thermal shock causes mortality or sublethal effects that affect further growth and development of entrained eggs and larvae (Schubel et al., 1978; Stauffer, 1980). The magnitude of thermal stress experienced by organisms passing through a facility's cooling system depends on facility-specific parameters such as intake temperature, maximum temperature, discharge temperature, duration of exposure to elevated temperatures through the facility and in the mixing zone of the discharge canal, the critical thermal maxima of the species, and delta T (ΔT, i.e., the difference between ambient water temperature and maximum water temperature within the cooling system) (Marcy, 1975; Schubel et al., 1978). The extent of the effect of thermal stress can also vary among the species and life stages of entrained organisms (Schubel et al., 1978; Stauffer, 1980).

A7-1.3 Mechanical Stress

Entrained organisms are also exposed to significant mechanical stress during passage through a cooling system, which also causes mortality. Types of mechanical stress include effects from turbulence, buffeting, velocity changes, pressure changes, and abrasion from contact with the interior surfaces of the cooling water intake structure (Marcy, 1973; Marcy et al., 1978). The extent of the effect of mechanical stress depends on the design of the facility's cooling water intake structure and the capacity utilization of operation. Some studies have suggested that mechanical stress may be the dominant cause of entrainment mortality at many facilities (Marcy, 1973; Marcy et al., 1978). For this reason, it has been suggested that the only effective method of minimizing adverse effects to entrained organisms is to reduce the intake of water (Marcy, 1975).

A7-1.4 Chemical Stress

Chemical biocides are occasionally used within cooling water intake structures to remove biofouling organisms. Chlorine is the active component of the most commonly used biocides (Morgan and Carpenter, 1978; Morgan, 1980). These biocides are used in concentrations sufficient to kill organisms fouling the cooling system structures, and thus cause mortality to the organisms entrained during biocide application. The extent of the effect of chemical stress depends on the concentration of biocide and the timing of its application. Eggs may be less susceptible to biocides than larvae (Lauer et al., 1974; Morgan and Carpenter, 1978). Tolerance to biocides may also vary according to species. However, most species have been shown to be affected at low concentrations, < 0.5 ppm, of residual chlorine (Morgan and Carpenter, 1978).

A7-2 Factors Affecting the Determination of Entrainment Survival

There are many challenges that must be overcome in the design of a sampling program intended to accurately establish the magnitude of entrainment survival (Lauer et al., 1974; Marcy, 1975; Coutant and Bevelhimer, 2001). Samples are almost certain not to be fully representative of the community of organisms experiencing entrainment. Some species are extremely fragile and disintegrate during collection or when preserved, and are thus not documented when samples are processed (Boreman and Goodyear, 1981). This is particularly true for the most fragile life stages, such as eggs and yolk-sac larvae of many species. All sampling devices are selective for a certain size range of organisms, so a number of sampling methods would have to be employed to accurately sample the broad size range of organisms subject to entrainment. The relative ability of different organisms to avoid sampling devices also determines abundance and species composition estimated from samples (Boreman and Goodyear, 1981). This avoidance ability varies with the size, motility, and condition of the organisms. If dead or dying organisms tend to settle out, then sampling will be selective for the live, healthy specimens (Marcy, 1975). If, on the other hand, the healthy, more motile specimens are able to avoid sampling gear, the sampling will tend to be selective for dead or stunned specimens. The patchy distribution of many species (Day et al., 1989; Valiela, 1995) creates difficulties in developing precise estimates of organism densities (Boreman and Goodyear, 1981). The patchier the distribution, the greater the number of samples required to reduce the uncertainty associated with the density estimates to an acceptable level.

The factors just discussed affect the ability to accurately establish the type and abundance of organisms present at the intake and discharge of a cooling water system. A second suite of factors, superimposed on the first, affects the ability to estimate the percentages of those organisms that are alive and dead at those two locations. The greatest challenge to be overcome is posed by the fragility of the organisms being studied. The early life stages of most species are so fragile that they may experience substantial mortality simply due to being sampled, both from contact with the sampling gear and in being handled for subsequent evaluation. For example, Marcy (1973) reported on the effects of current velocity on percent mortality of ichthyoplankton taken in plankton nets, and found sampling mortality of 18% at velocities of 0.3 to 0.6 m/sec. The loss or damage of organisms beyond identification during plant passage causes overestimations of the true fraction of live organisms in the discharge samples, because the disintegrated organisms are extruded from the sampling device (Boreman and Goodyear, 1981).

The entrainment survival studies addressed in this review quantified survival by estimating the percentage of organisms categorized as alive, stunned, or dead present in samples collected at the intake and discharge locations of a facility. In the studies reviewed, a variety of methods were used to determine the physiological state of sampled organisms, ranging from placing the sampled organisms in various types of holding containers for observation to the use of devices specifically designed for assessment of larval survival, such as a larval table. A variety of criteria was also used in these studies to categorize the physiological status of the organisms, such as opacity as an indicator of a dead egg, and movement of a larva in response to being touched as an indicator of being alive or stunned. The lack of standardized procedures applied for assessing physiological condition in all of the studies reviewed made comparisons of the study findings difficult.

When quantifying entrainment survival, these studies used the estimates of the percentage dead from samples collected at the intake as controls to correct the samples at the discharge for mortality associated with natural causes and with sampling and handling stress. The use of intake samples as controls requires the assumption that sampling- and handling-induced mortality rates be the same at the intake and discharge, which, in turn, requires that sampling methods and conditions be nearly identical in both locations (Marcy, 1973). This requirement is difficult to meet at most facilities because of the differences in the physical structures and hydrodynamic conditions at intakes and discharges (e.g., frequently high velocity, turbulent flow at discharges versus lower velocity, laminar flows at intakes). In many cases, the location and design of the cooling water intake and discharge structures may preclude use of the same type of sampling gear in both locations. Another assumption implicit in this approach is that mortality due to entrainment is entirely independent of mortality due to sampling and handling and that there is no interaction between these stresses, an assumption that is acknowledged but never proven in the studies reviewed.

The percent alive in the intake control is frequently well below 100% because these fragile organisms experience substantial mortality from stresses caused by being collected. An additional factor contributing to the less than 100% alive in intake samples is that some dead organisms may be present in the water column being sampled because of natural mortality or recirculation of water discharged from the cooling system. In many studies, the survival in the intake sample is extremely low; for example, the intake survival for bay anchovy was 0% in studies conducted at Bowline (Ecological Analysts Inc., 1978a), Brayton Point (Lawler, Matusky & Skelly Engineers, 1999), and Indian Point (Ecological Analysts Inc., 1978c; EA Engineering, Science, and Technology, 1989). The studies reviewed corrected their discharge survival estimates to account for the control sample mortality by using the percent alive in the intake control samples in the following manner. First, the proportion initially alive at the intake (P_I) and discharge (P_D) samples was determined, for each species in most cases, using the following equation:

$$P_I \text{ or } P_D = \frac{\text{Number of alive and stunned organisms}}{\text{Total number of organisms collected}}$$

Using the intake proportion as the control, initial percent entrainment survival (S_I) was then calculated using the following equation:

$$S_I = \left[\frac{P_D}{P_I}\right] \times 100$$

When latent mortality was studied, a sample of the alive and stunned organisms from the initial entrainment survival determination was observed for a given period of time. The latent survival rate calculated is the proportion of those that remained alive after a given period of time from only those that survived initially and not the total number sampled. The latent percent survival (S_L) was determined using the following equation:

$$S_L = 100 \times \left[\frac{\dfrac{\#\ \text{of alive organisms after a given time from discharge samples}}{\#\ \text{of organisms initially sampled alive or stunned indischarge samples}}}{\dfrac{\#\ \text{of alive organisms after a given time from intake samples}}{\#\ \text{of organisms initially sampled alive or stunned in intake samples}}}\right]$$

Entrainment survival was then calculated by adjusting the initial entrainment survival with latent entrainment survival using the following equation:

$$\text{Entrainment Survival (\%)} = S_I \times S_L$$

A variation of this formula, specifically Abbott's formula, is used for acute toxicity testing in the Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms (U.S. EPA, 2002; EPA-821-R-02-012) and in testing of pesticides and toxic substances in Product Performance Test Guidelines OPPTS 810.3500 Premises Treatments (U.S. EPA, 1998; EPA-712-C-98-413), to adjust mortality for the possibility of natural deaths occurring during a test. This formula is intended to account for acceptable levels of unavoidable control mortality in the range of 5 to 10% (Newman, 1995). Abbott's formula is as follows:

$$\text{Corrected mortality} = 1 - \left[\frac{1 - \text{proportion dead in treatment}}{1 - \text{proportion dead in control}}\right]$$

This method of correcting for control mortality is often used in toxicological experiments in which organisms in concurrent control and experimental samples experience identical conditions except for the stressor that is the subject of study, and, as already noted, this method is applied when control mortalities, from stress due to holding or sampling and from natural causes, are generally low (less than 10%). In entrainment survival studies, sampling conditions at the intake and discharge are seldom identical. Also, the initial mortalities in the intake samples are often much higher than 5 or 10% and sometimes higher than the mortality in the discharge samples.

In addition, the assumption that mortality due to entrainment is entirely independent of mortality due to sampling and handling with no interaction between these stresses is not true. The dead organisms observed in the intake samples comprise organisms that died before sampling from natural conditions, organisms that died from the stress of sampling and sorting, and possibly organisms that died from previous passages through the cooling water system at facilities where water is recirculated. The dead organisms observed in the discharge samples comprise organisms that died before passage through the facility from natural conditions, organisms that died from the stresses associated with entrainment as described above, and organisms that died from the stress of sampling and sorting. The fundamental difference between the extent of the effect of sampling stress in the intake and the discharge samples is that the discharge samples are exposed to sampling stress after they have been exposed to entrainment stress. Thus the most vulnerable organisms have already died because of entrainment and would not be alive at the time of sampling to die from that stress. By correcting discharge samples for sampling and natural deaths using the intake results, the assumption is made that the mortality in the discharge sample is the result of the same probability of death due to sampling as in the intake sample and only the additional mortality is due to the stress of entrainment. When intake survival (P_I) is less than discharge survival (P_D), the use of the equation for entrainment survival (S_I) results in a calculation of 100% survival even though the majority of organisms may be dead in both samples (EA Engineering, Science, and Technology, 2000). However, in the intake sample, much of the mortality may be due to sampling stress, whereas in the discharge sample, much of the mortality may be due to entrainment stress. Additionally, the initial survival estimates may be overestimations of survival due to the disintegration of entrained organisms and their subsequent extrusion through the sampling gear (Boreman and Goodyear, 1981). For all of the reasons described above, the applicability of this equation for determining entrainment survival by correcting discharge survival with intake survival is questionable. Also, the statistical attributes of these calculated mortality proportions are often not addressed. The higher and more variable the intake sample mortality percentages, the greater the degree of uncertainty that would be expected to be associated with the resultant entrainment survival estimates.

An additional factor that was not accounted for in all the studies reviewed was the fate of organisms discharged into receiving waters after passage through the cooling system. Latent mortality studies were intended to document delayed mortality of organisms that were lethally injured or stressed during entrainment but were not killed immediately. Some studies (e.g., Lauer et al., 1974) also reported that some fish larvae surviving entrainment behaved normally when maintained in laboratory conditions for extended periods of time, eating and growing normally. However, larvae that did not experience immediate mortality from lethal stresses were discharged into receiving waters under conditions substantially altered from the normal environment in which they were present before entrainment and under conditions very dissimilar to those experienced under laboratory conditions. Any naturally occurring vertical positioning of the organisms within the water column would be disrupted (Day et al., 1989), and the turbulence and velocities present in discharge locations would be unlike the environmental conditions they experienced before entrainment. Under such altered conditions, their normal ability to feed or escape predation is compromised. In addition, thermal shock can disrupt further development of eggs and larvae even if they survive entrainment (Schubel et al., 1978). The potential for such phenomena to occur and the magnitude the effect may have on any possible survival of entrained organisms would be nearly impossible to confirm or refute through field studies. However, were these phenomena to occur, they would result in mortalities beyond and in addition to the initial and latent mortalities that were calculated in the studies reviewed.

The factors discussed above served as the basis for EPA’s review of the entrainment survival studies. Table A7-1 presents summary information collected directly from each of the original studies reviewed.

Table A7-1: Summary of Entrainment Survival Study Results

Facility	Sampling Period	Number of Samples and Days	Species	Number Sampled at Intake	Number Sampled at Discharge	Survival Study	Initial Discharge Survival	Latent Discharge Survival	Study Survival Estimate
Anclote	September-November 1985	120 samples, 8 days	Fish larvae	109	474	Initial and 24 hour latent	8-47%	-	27-62%
			Amphipods	5,185	4,662		29-58%	-	49-73%
			Chaetognatha	1,549	1,927		28-35%	-	67-72%
			Crab larvae	3,007	6,145		74-80%	-	21-100%
			Caridean shrimp	2,728	1,766		45-66%	-	64-81%
Bergum Power Station	April-June 1976	Unknown #, 6 days	Smelt	Unknown	322	Initial	10-28%	-	10-41%
			Perches	Unknown	826		32-74%	-	39-82%

Table A7-1: Summary of Entrainment Survival Study Results

Facility	Sampling Period	Number of Samples and Days	Species	Number Sampled at Intake	Number Sampled at Discharge	Survival Study	Initial Discharge Survival	Latent Discharge Survival	Study Survival Estimate
Bowline Point	June-July 1975	Unknown #, unknown days	Striped bass White perch Bay anchovy	141 122 2,134	111 168 1,317	Initial and 96 hour latent	74% 68% 2%	23% 26% 0%	70% 100% 22%
Bowline Point	May-July 1976	Unknown #, 10 days	Striped bass PYSL White perch PYSL Bay anchovy PYSL Herrings PYSL Atlantic tomcod PYSL	118 54 148 46 54	207 42 1,120 83 17	Initial and 96 hour latent	54% 33% 0% 20% 29%	23% 21% 0% 1% 12%	26-77% 13-84% - 0-80% 54%
Bowline Point	March-July 1977	736 samples, 46 days	Striped bass larvae White perch PYSL Bay anchovy larvae Herrings PYSL Silverside PYSL	228 26 634 37 24	452 38 1,524 22 56	Initial and 96 hour latent	71-72% 34% 0-2% 23% 16%	55-66% 69% 0% 5% 0%	41-100% 16-62% - 51% -
Bowline Point	March-October 1978	609 samples, 40 days	Striped bass PYSL White perch PYSL Bay anchovy PYSL Herrings PYSL	646 190 325 271	792 301 763 51	Initial and 96 hour latent	52-63% 19% 0-3% 23-63%	5-46% 0-5% 0% 0%	76-100% 52-68% - -
Bowline Point	May-June 1979	435 samples, 19 days	Striped bass PYSL White perch PYSL Bay anchovy PYSL Herrings PYSL	77 205 181 63	155 191 89 92	Initial and 96 hour latent	35-41% 26-35% 0-4% 30-31%	8-20% 5-8% 0% 0-3%	24-42% 32% - 0-58%
Braidwood Nuclear	June-July 1988	68 samples, 3 days	All species combined	191	103	Initial	59%	-	100%
Brayton Point	April-August 1997 February-July 1998	6,829 samples, 41 days	Winter flounder Tautog Windowpane flounder Bay anchovy American sand lance	49 34 58 539 1,091	965 401 58 15,896 2,941	Initial and 96 hour latent	30-38% 4% 29-30% 0% 0%	- - - - -	90-100% 98-100% 65-67% 0% 100%
Cayuga Generating Plant	May-June 1979	80 samples, 24 days	Suckers Carps and minnows Perches	984 466 108	649 192 66	Initial and 48 hour latent	75-92% 12-74 % 43-69%	93-98% 45-100% 44-61%	87-98% 25-86% 19-59%
Connecticut Yankee	June-July 1970	102 samples, 7 days	Alewife Blueback herring	Unknown	unknown	Initial	0-8%	-	0-25%
Connecticut Yankee	June-July 1971 and 1972	30 samples, 2 days	Alewife Blueback herring	273	795	Initial	0-24%	-	0-26%
Contra Costa	April-July 1976	Unknown #, 7 days	Striped bass	637	329	Initial	0-50%	-	0-95%

Table A7-1: Summary of Entrainment Survival Study Results

Facility	Sampling Period	Number of Samples and Days	Species	Number Sampled at Intake	Number Sampled at Discharge	Survival Study	Initial Discharge Survival	Latent Discharge Survival	Study Survival Estimate
Danskammer Point Generating Station	May-November 1975	372 samples, 29 days	Striped bass PYSL White perch PYSL Herrings PYSL	54 36 200	61 55 326	Initial and 96 hour latent	39% 38% 20%	3% 4% 0%	95% 100% 80-87%
Fort Calhoun	October 1973 - June 1977	Unknown #, 89 days	Ephemeroptera Hydropsychidae Chironomidae	2,221 3,690 2,646	2,220 4,964 2,925	initial	18-32% 47-56% 43-66%	- - -	92% 92% 84%
Ginna Generating Station	June and August 1980	255 samples, 20 days	Alewife larvae Rainbow smelt larvae	54 31	95 17	Initial and 48 hour latent	0% 0%	- -	- 0%
Indian Point	June and July 1977	Unknown #, 7 days	Striped bass PYSL White perch PYSL Bay anchovy PYSL Herrings PYSL	806 158 1,254 100	518 67 704 65	Initial and 96 hour latent	45-52% 15-43% 3-4% 10-11%	29-36% 15-30% 0% 0%	85-87% 73-89% 18-36% 40%
Indian Point	May-July 1978	Unknown #, 22 days	Striped bass PYSL White perch PYSL Bay anchovy PYSL Herrings PYSL	447 227 500 1,046	1,102 392 820 1,104	Initial and 96 hour latent	0-34% 0-37% 0% 0-8%	0-19% 6-15% 0% 0%	0-82% 0-58% 0% 0%
Indian Point Generating Station	March-August 1979	Unknown #, 40 days	Atlantic tomcod Striped bass White perch Herrings Bay anchovy	266 127 195 254 457	212 153 147 186 485	Initial and 96 hour latent	14-46% 62-77% 24-70% 28% 6%	15-75% 4-21% 18% 13% 4%	11-64% 59-75% 29-32% 22-31% 3-7%
Indian Point Generating Station	April-July 1980	Unknown #, 44 days	Striped bass Bay anchovy White perch	227 260 113	248 588 176	Initial and 96 hour latent	50-81% 0-4% 0-90%	60-72% 0% 73%	55-81% 2-4% 50-90%
Indian Point Generating Station	May-June 1985	Unknown #, 49 days	Bay anchovy PYSL	106	274	Initial and 48 hour latent	6%	0%	0-24.3%
Indian Point Generating Station	June 1988	Unknown #, 13 days	Striped bass larvae Bay anchovy larvae	353 633	2,710 7,391	Initial and 24 hour latent	62-68% 0-2%	24-44% 0%	60-79% 0-25%
Indian River Power Plant	July 1975 - December 1976	46 samples, 27 days	Bay anchovy Atlantic croaker Spot Atlantic menhaden Atlantic silverside	Unknown	Unknown	Initial and 96 hour latent	Unknown	Unknown	0-100% 0-100% 25-100% 0-100% 0-100%
Muskingum River Plant	1979	No samples	None specified	0	0	None	Intermediate to high potential	-	-

Table A7-1: Summary of Entrainment Survival Study Results

Facility	Sampling Period	Number of Samples and Days	Species	Number Sampled at Intake	Number Sampled at Discharge	Survival Study	Initial Discharge Survival	Latent Discharge Survival	Study Survival Estimate
Northport Generating Station	April and July 1980	162 samples, 20 days	American sand lance Winter flounder Bay anchovy	29 13 7	782 17 11	Initial and 48 hour latent	17% 35% 0%	2% 17% 0%	2% 10% -
Oyster Creek Nuclear Generating Station	February-August 1985	28 samples, 20 days	Bay anchovy larvae Winter flounder larvae	3,396 3,935	3,474 2,999	Initial and 96 hour latent	0-71% 32-92%	0% 6-66%	0-68% 15-84%
Pittsburg Power Plant	April-July 1976	Unknown #, 7 days	Striped bass	196	266	Initial	8-87%	-	12-94%
Port Jefferson	April 1978	94 samples, 5 days	Winter flounder Sand lance Fourbeard rockling American eel Sculpin	36 249 216 107 22	26 191 144 96 17	Initial and 96 hour latent	0-23% 12-40% 19-21% 94-96% 88%	50% 0-10% - 71-96% -	65% 25-86% 73-100% 100% 75%
PG&E Potrero	January 1979	25 samples	Pacific herring	546	716	Initial and 96 hour latent	16%	-	70%
Quad Cities Nuclear Station	June 1978	Unknown #, 5 days	Freshwater drum Minnows	378 278	916 307	Initial and 24 hour latent	0-71% 2-75%	- -	2-62% 7-63%
Quad Cities Nuclear Station	April-June 1984	Unknown #, 8 days	Freshwater drum Carp Buffalo	Unknown Unknown Unknown	Unknown Unknown Unknown	Initial and 24 hour latent	Unknown Unknown Unknown	- - -	63% 92-97% 94%
Roseton Generating Station	May-November 1975	672 samples, 41 days	Striped bass PYSL White perch PYSL Herrings PYSL	100 77 471	172 97 833	Initial and 96 hour latent	62% 29% 26%	6% 1% 0%	38% - -
Roseton Generating Station	June-July 1976	Unknown #, 27 days	Striped bass PYSL White perch PYSL Herring PYSL	93 401 1,054	80 349 645	Initial and 96 hour latent	14-43% 6-42% 5-29%	- - 0%	19-58% 11-79% 10-59%
Roseton Generating Station	March May-July 1977	Unknown #, unknown days	Striped bass PYSL White perch PYSL Herring PYSL Atlantic tomcod YSL	427 251 880 1,178	765 266 1,344 1,345	Initial and 96 hour latent	3-29% 0-17% 0-5% 16%	18% 27% 0% 40%	6-58% 0-52% 0-19% 41%
Roseton Generating Station	March July-July 1978	256 samples, 30 days	Striped bass PYSL White perch PYSL Herring PYSL Atlantic tomcod PYSL	123 395 1,274 83	211 459 1,089 153	Initial and 96 hour latent	27-50% 0-35% 0-10% 33-45%	18% 10% 0% 36%	46% 56-96% 0% 39%

Table A7-1: Summary of Entrainment Survival Study Results

Facility	Sampling Period	Number of Samples and Days	Species	Number Sampled at Intake	Number Sampled at Discharge	Survival Study	Initial Discharge Survival	Latent Discharge Survival	Study Survival Estimate
Roseton Generating Station	May-July 1980	1,431 samples, 42 days	Striped bass PYSL	245	425	Initial and 48 hour latent	46-61%	48-56%	88%
			White perch PYSL	194	366		30-59%	27-62%	67%
			Herring PYSL	812	1252		7-31%	1-3%	23%
Salem Generating Station	1977-1982	640 samples, 38 days	Spot	66	130	Onsite and simulated studies	74.1	-	0-76%
			Herrings	8	14		7.1	0	2-74%
			Atlantic croaker	-	-		-	-	0-60%
			Striped bass	-	-		-	-	32-46%
			White perch	-	-		-	-	30-70%
			Bay anchovy	-	-		-	-	2-3%
			Weakfish	-	-		-	-	14-56%

A review of the data in Table A7-1 shows that the majority of the studies were conducted at facilities located in a limited geographical region of the country: 24 of the studies were conducted in the northeastern region of the United States. This may explain why these studies provide entrainment survival estimates for relatively few, only 24, species or families of fish. The majority of survival estimates in these studies were for striped bass, white perch, bay anchovy, and herrings. Also, the majority of these studies are over 20 years old, with 25 of the studies conducted in the 1970s. Thus, the results on species composition and abundance are not necessarily indicative of current conditions, with improved water quality due to the enactment of the Clean Water Act in 1972. Entrainment survival in these studies was also estimated with relatively short sampling periods, with the 15 studies using sampling periods of approximately two months long. Also, the sampling periods did not always correspond to peak egg and larval abundance in the waterbody. Twelve of these studies determined that sample sizes of fewer than 100 individuals for a particular species at the discharge station were sufficient to give an accurate estimation of entrainment survival. These small sample sizes are not be sufficient to provide accurate estimates of entrainment survival given that these facilities entrain organisms on the order of millions to billions per year. Also, small sample sizes in conjunction with the high variability of entrainment survival increase the uncertainty associated with these estimations. The small sample sizes allowed for limited study of latent survival, and no facility attempted to study latent physiological effects of entrainment on a species, such as the possible effects on growth rates, maturation, fertility, and vulnerability to natural mortality. The nature of the equation for entrainment survival results in estimates substantially higher than the proportion of survival in the discharge samples because of its use of a correction for mortality in the intake samples, which is often quite high. The fact that the existing studies are characterized by high uncertainty, high variability, and the potential for high bias (Boreman and Goodyear, 1981) complicates efforts to synthesize the various results in a manner that would provide useful generalizations of the results or application to other particular facilities. For these reasons, EPA believes that the reported results do not provide a clear indication as to the extent of entrainment survival significantly above 0% to be used as a defensible assumption to calculate benefits for this rule.

A7-3 Detailed Analysis of Entrainment Survival Studies Reviewed

The summary tables at the end of this chapter provide detailed summary descriptions of each of the 37 studies reviewed. EPA reviewed these studies to determine if they were conducted in a manner that provides adequate representation of the current probability of entrainment survival at the facility. The criteria EPA used to evaluate the studies focused on three main themes: the sampling effort of the study, the operating conditions of the facility during the study, and the survival estimates determined as the result of the study. Specifically, EPA asked the following questions:

Sampling:

- When were samples collected?
- With what frequency were samples collected?
- Were samples collected when organisms were spawning, or at peak abundance?
- What time of day were samples collected?
- What was the number of replicates per sampling date?
- Were the intake and discharge samples collected at the same time so the results can be compared?
- How long was each sample collected?
- What method was used to collect samples?
- At what depth were samples collected?
- What was the location of the samples collected at the intake and discharge?
- Which water quality parameters were measured?
- Were dissolved organic carbon (DOC) and particulate organic carbon (POC) measured?
- What was the velocity at the intake and at the discharge?

Operating conditions during sampling:

- How many generating units at the facility were in operation?
- How many pumps at the facility were in operation?
- What was the intake temperature range, the discharge temperature range, and the ΔT range to which organisms were exposed?
- Were biocides in use?

Survival estimation:

- How many sampling events occurred?
- What was the total number of samples collected?
- What was the total number of organisms collected?
- How many organisms are entrained each year at this facility?
- Did the study take into account fragmented organisms?
- Were the number of organisms collected at the intake and at the discharge comparable?
- What were the most abundant species collected?
- Were stunned larvae included with live larvae in survival estimates?
- Did the facility omit dead and opaque organisms from the count of dead organisms?
- How was latent survival studied?
- Were data sampled from all times and operating conditions combined to determine entrainment survival?
- What were the controls for the study?
- What was the range of intake survival determined by the study?
- What was the range of discharge survival determined by the study?
- How was entrainment survival calculated?
- Were confidence intervals or standard errors calculated?
- Were significant differences tested between intake and discharge survival?
- Was entrainment survival calculated for species with low sample sizes, such as fewer than 100 organisms?
- Was egg survival studied?
- Was there any trend evident in larval survival?
- Were the raw data provided to verify results?
- What was the trend of survival with regard to temperature?
- What was the extent of mechanical mortality?
- What quality control procedures were used?
- Was the study peer reviewed?

A7-4 Discussion of Review Criteria

In this section, the criteria EPA used to review the entrainment survival studies are discussed in depth to give a better indication of the soundness of the science behind a facility's estimate of potential survival.

A7-4.1 Sampling Design and Method

These aspects of the sampling effort are relevant to whether the samples collected are representative of all organisms experiencing entrainment with regard to taxa and size classes, whether the estimates of densities and numbers are accurate and precise, and whether the survival estimates for the intake and discharge can be validly compared (Marcy, 1975; Boreman and Goodyear, 1981). Sampling should be carefully planned to minimize any potential bias (Marcy, 1975; Boreman and Goodyear, 1981). Studies should be conducted throughout the parts of the year when substantial numbers of organisms are entrained. Any possible survival may vary with factors that change seasonally, such as organism size and life stage and ambient water temperature. Most studies attempted to collect samples during times of peak abundance, although the sampling frequency may not have been sufficient to fully capture peak densities. Of those reviewed by EPA, six studies did not correspond with the timing of peak densities at that location.

Even if a study is limited to the early life stages of particular fish or shellfish, survival differences among sizes and life stages and seasonal or temperature-related changes in entrainment survival must be quantified. The timing of the sample collection for an entrainment survival study can influence results in a number of ways, such that results from studies collected during one period may not be representative of potential effects during other periods. For instance, samples collected when the intake temperatures are low or late in a spawning season when larvae are larger can produce estimates of entrainment survival that may be higher than at other times. Thus, studies need to be conducted throughout the entire spawning season to accurately characterize overall entrainment mortality if entrainment survival is found to vary with life stage or size of each species entrained. For the same reason, it may not be appropriate to develop average survival estimates from samples collected under different environmental conditions (in particular under different temperature regimes) and from only parts of a spawning period for a particular species. This was done in almost all the studies reviewed by EPA, which causes their results to be of questionable value. This also makes it difficult for EPA to synthesize the results of these studies into a meaningful average value of entrainment survival to be used in a national benefits assessment.

Many studies collected samples at night to ensure high numbers of organisms in their samples because larvae rise to the surface at night to feed and avoid predation (Marcy, 1975; Day et al., 1989). This practice will bias results because the samples will contain a disproportionate number of live organisms than that which is actually present in the water column. There is evidence that dead organisms will sink to the bottom of the water column after entrainment (Marcy, 1975). Twenty-four studies indicated that most sampling took place at night. For many studies, the depth of sampling is not noted and thus it is unclear whether the samples were collected near the surface, at mid-depth, or near the bottom of the water column. Any potential for bias due to a higher percentage of alive organisms present near the surface could not be assessed.

The method of sampling should be selected to cause the least amount of mortality possible and the mesh size should be fine enough to capture disintegrated or fragmented organisms. Many studies sampled organisms using sampling instruments with mesh size greater than or equal to 500 μm. This may not be fine enough to capture disintegrated or fragmented organisms in the discharge. Attention should be given to the mesh size of sampling instruments to be sure that the targeted sample is not extruded through the mesh.

Intake and discharge sampling should be paired to be sure that the same population of organisms is sampled and subsequently compared. In 12 studies examined, it is unknown if the samples at the intake and discharge were paired. In some studies, samples were not collected at all locations during all sampling events. In other studies, twice as many samples were collected at the discharge than at the intake. Also, in many instances, the intake samples were collected at different generating units of the facility than the discharge samples. Average elapsed times for sample collection were given, and it is unclear if the same elapsed time was used at both locations to give an accurate depiction of organismal densities. The time elapsed during sample collection or the volume of water sampled should be identical in the paired intake and discharge samples to ensure valid comparisons of samples. It was not indicated in any of the studies reviewed whether the same volume of water was sampled in all the intake and discharge samples. If intake samples are to be compared to discharge samples, consistent sampling methods must be used at the two locations so that the samples contain the same density of organisms.

The location of the intake sampling is important because it may contain organisms that already died because of the changes in velocity near the intake. Two studies reviewed collected intake samples after the water had entered the cooling system. The location of the discharge sampling is also important. Samples collected from the end of the discharge canal may not contain organisms that died from passage through the facility because of the tendency of dead organisms to settle out of the water column in the discharge canal. Samples collected from the discharge pipe may not contain organisms that died from thermal effects of entrainment because the samples are collected before the full effects of thermal exposure were experienced. Fourteen studies reviewed collected discharge samples from the discharge pipe. It is also unknown if the samples collected in the discharge canal or from the receiving water contained organisms in the dilution water that bypassed the cooling water system. Five studies reviewed collected discharge samples in the receiving water downstream from the discharge canal, which can result in samples containing organisms that never passed through the cooling water system. The velocity at the intake and discharge should also be recorded to determine the potential to cause mortality. Fourteen of the studies noted the velocity at the intake, at the discharge, or both. For the ones that did not give both intake and discharge velocities, it is unknown whether the velocities at the two sampling sites were comparable, and thus whether the mortalities due to velocity-related sampling stress were comparable at the two locations.

Water chemistry conditions also need to be recorded to be sure conditions are similar at all sampling locations. Water quality parameters include measurements of dissolved oxygen, pH, and conductivity in the through-plant water, at the discharge point, and in the containers or impoundments in which the entrained organism are kept when determining latent mortality. Eighteen studies reviewed gave some indication that water quality parameters were measured. However, it is unclear whether measurements were collected at both the intake and the discharge, and only one study reviewed indicated that water quality parameters were measured in latent mortality studies (EA Engineering, Science, and Technology, 1986).

A7-4.2 Operating Conditions During Sampling

Mortality due to entrainment stress is affected by the operating characteristics of the power facility. The conditions under which the samples are collected are extremely important and, therefore, the results can be assumed to represent possible survival only when the facility is operating under those same conditions and at that time of year, and may not represent any potential for survival at all times. For example, results of studies conducted when the plant was not generating power (and thus not transferring heat to the cooling water) would not be applicable to impacts when it was in full operation. The magnitude of mechanical stress is dependent on the design of the facility's cooling water intake structure. The physical and operating conditions of the facility must be recorded to determine the effect on entrainment survival. The percentage of the maximum load at which the facility is operating must be recorded at the time of sampling to indicate the extent to which organisms are exposed to stress. The number of generating units was highly variable or unknown in many of the studies reviewed. Only one study indicated that the facility operated at peak load to maximize temperature stress during the time of sampling. Eight studies indicated that power was generated during only a portion of time in the sampling period. To fully account for the effects of mechanical stressors on entrainment survival, the study must reflect the speed and pressure changes within the condenser, the number of pumps in operation, the occurrence of abrasive surfaces, and the turbulence within the condenser. In addition, it is important to note the number and arrangement of generating units, parallel or in sequence, which may expose organisms to entrainment in multiple structures. Survival should be studied under the range of facility conditions that may influence survival, for example, intake flow or capacity utilization and ambient (intake) water temperature and ΔT.

The effect of temperature can be species-specific since different fishes have different critical thermal maxima. The maximum temperature to which organisms may be exposed while passing through the facility may cause instant death in some species but not others. To assess the effect of thermal stressors on entrainment survival, the study must determine the temperature regime of the facility. Specifically, the study must record the temperature at both the intake and the discharge point for each component of the facilities system: temperature changes within the system, including the inflow temperature; maximum temperature; ΔT; rate of temperature change; and the temperature of the water to which the organisms are discharged. It is also important to measure the duration of time an organism is entrained and thus exposed to the thermal conditions within the condenser and in the mixing zone of the discharge canal. This information was not provided in the studies reviewed by EPA. Also, in those studies that attempted to relate survival to temperature stress, too few samples were collected at different temperature ranges to give an adequate representation of survival in that range. The EPRI report sorted larval entrainment survival data by discharge temperature and concluded that survivability decreased as the discharge temperature increased (EA Engineering, Science, and Technology, 2000). The lowest probability of larval survival occurred at temperatures greater than 33 °C. In the studies reviewed by EPA, a noticeable decline in survival estimates occurred at discharge temperatures above 30 °C. The amount of time that a facility discharges water in different temperature ranges and survival estimates at that temperature range should be weighted when attempting to determine the survival estimate throughout the year, rather than using an average survival during the sampling period, which may not adequately reflect operating conditions throughout the year.

To properly account for chemical stressors, the timing, frequency, methods, concentrations, and duration of biocide use for the control of biofouling must be determined. The extent to which biocides are routinely used is unknown. The studies reviewed by EPA were all conducted at times when biocides were not in use because the biocide use would be expected to kill all organisms. Thus, the results of these studies do not account for biocide impacts and only reflect other times when biocides are not in use at the particular facility. A reduced survival estimate for the proportion of time when biocides were in use would have to be incorporated into any estimation of annual mean entrainment mortality value for a facility for that estimate to be valid.

A7-4.3 Survival Estimates

Many of the entrainment survival studies reviewed did not account for the extent to which the fragile life stages are fragmented and disintegrated by both sampling and entrainment. Only six of the studies acknowledged that the entrainment survival estimates were indicative only of alive and stunned identifiable organisms out of all those sampled and enumerated that were at least 50% intact. In such circumstances, an important proportion of entrained dead (fragmented) organisms is omitted from the calculated estimate of survival. Entrainment survival studies should not limit their estimates of survival to include only those organisms that are either whole or 50% whole in the sample. For those studies that did not discuss the issue of fragmented organisms, it is unclear how the issue was treated. Several studies indicated that the majority of the sample was mangled or unidentifiable. There is potential for an extremely large number of dead organisms to be excluded from entrainment survival estimates because they are fragmented to the point of being unidentifiable. Studies should account for this fragmentation of organisms by measuring unidentifiable biomass in the samples from the intake and discharge stations. Without taking these organisms into account, entrainment survival estimates will be biased and the results will be higher than that which actually occurs. There are indications that the number of fragmented organisms, which are generally not included in survival estimates, may be high which results in an overestimation of entrainment survival if these fragmented organisms are more prevalent in the discharge. In the proceedings of a conference held in Providence, RI, on January 6, 1972, entitled *Pollution of the Interstate Waters of Mount Hope Bay and its Tributaries in the States of Massachusetts and Rhode Island*, the following regarding fragmentation was quoted "...in 1970 when we observed many small transparent larval menhaden in the intake. They were most readily noted by their black eyes. But in the effluent, all we found were eyes. They were torn to pieces" (U.S. EPA, 1972). Foam observed in the discharge (Thomas, 2002) may indicate that fragmentation is substantial. The data summary in Jinks et al. (1981) suggests that a substantial number of fish larvae may be fragmented by mechanical forces and become unrecognizable, contributing to a bias in estimates of survival. Ten of the studies reviewed by EPA reported finding fragmented organisms; others did not quantify evidence of disintegrated organisms. High rates of physical damage and abundant larval fish fragments were reported by Stevens and Finlayson (1978) at the Pittsburg and Contra Costa power plant discharges. Such losses can contribute to a bias (overestimation) of entrainment survival because the number of dead organisms are not properly enumerated. In addition, the low numbers of organisms sampled in the studies in relation to the high annual entrainment numbers give further indication that the sampling effort may not result in an adequate representation of the organisms entrained and therefore the survival estimates may not be representative of what occurs.

Including stunned larvae in the initial survival estimates also results in overestimations of survival, since the majority of these organisms died in the laboratory latent survival studies and even more will die in the natural conditions of the discharge canal because of predation or disrupted growth and development. Twenty-nine studies reviewed included stunned larvae in their initial survival estimates, and only a few of these indicated that this method will overestimate initial survival. The remainder of the studies reviewed did not discuss the treatment of stunned larvae. Many studies reviewed reported only initial acute mortality. Both initial mortality and extended or latent (96 hour) mortality should be studied and reported.

Dead and opaque organisms that may have died before entrainment should not be excluded from the enumeration of dead organisms. Several studies reviewed by EPA noted that dead organisms can turn opaque within an hour. This is the same amount of time that can elapse during sampling collection and sorting. Also, zero dead and opaque organisms were collected in the samples of one study when the facility was not generating power. Three studies omitted dead and opaque organisms from the dead classification used to estimate survival. This resulted in an elimination of up to 99% of the organisms in the samples of one study. Alternatively, one study counted only those organisms that were opaque as dead.

The study design should support unbiased estimation of survival, taking into account pertinent factors and the changing relative abundances of species and life stages. Because entrainment mortality changes with ambient and operating conditions, and because the numbers of various species and life stages entrained also change diurnally and seasonally, use of an average value for entrainment survival could be misleading. Organisms should be counted and sorted by species, life stage, and size. Entrainment survival should then be calculated separately for each life stage of each species. Entrainment survival estimates appears to vary markedly with fish larval size (EA Engineering, Science, and Technology, 1989); estimates of mortality are often higher for smaller larvae and lower for larger ones. Thus, survival measured for a heterogeneous mixture of sizes will apply only to that mixture under the same conditions, and cannot be used to accurately estimate survival for the species over the course of even part of a season. The approach of modeling survival in relation to size may be more promising (EA Engineering, Science, and Technology, 1989). The implication is that accurate assessment of entrainment survival requires frequent samples throughout a season, to reflect the changing size and species composition of the ichthyoplankton. In most of the studies all data from all samples collected under varied times and conditions were combined to give an average entrainment survival. However, bias could be introduced when a disproportionate number of samples are taken under a specific set of conditions that may not accurately reflect conditions throughout the year. Only 16 of the 37 studies reviewed estimated entrainment survival by sampling reported standard deviations or confidence intervals for the survival estimates. The apparent precision of estimates based on hundreds of organisms, and the estimates themselves, are deceptive. Such estimates are based on aggregated numbers that vary in size; however, larval fish survival is dependent on size (EA Engineering, Science, and Technology, 1989).

The volume of water sampled should always be reported with the number of organisms counted in the sampled volume. This allows estimates of the densities of organisms in the intake and the discharge water. Density estimates provide an important check on assumptions. When organism densities cannot be measured accurately, a useful check on disintegration of organisms that are never counted cannot be performed. Another check on loss of organisms by disintegration is a count of body parts, which was done in only one of the studies reviewed, but this will not account for organisms rendered unidentifiable or disintegrated. In some studies, the numbers of organisms in discharge samples were many times greater than the numbers of organisms in intake samples using the same sampling methods. In other studies, there were many times more organisms collected in the intake samples than in the discharge samples. Such large differences raise concerns about sampling methods and possible sources of bias that would need to be investigated.

Control samples taken to test the mortality associated with sampling gear should be taken as far away from the intake as possible. This will ensure that the rates of mortality determined will be solely from natural causes or sampling damage and not from potential damage due to increased velocity and turbulence near the intake. Sampling mortality should be reduced to the maximum extent possible, using modern sampling techniques (EA Engineering, Science, and Technology, 2000). When control survival is less than discharge survival, no attempts should be made to calculate entrainment survival; this would give an erroneous survival result of greater than 100%. That some studies reported entrainment survival estimates greater than 100% indicates that these studies' methods of calculating entrainment survival were flawed by methodological biases.

Calculating survival from the ratio of the fraction alive in discharge samples to the fraction alive in intake samples requires assumptions not supported by the same studies. These assumptions are that (1) no organisms are lost to counting by destruction in the cooling water system, in other words, the same density of organisms (dead or alive) is observed in the discharge as in the intake; and that (2) the sampling method causes the same rate of mortality in the discharge sample as in the intake sample. The first assumption is without doubt violated for many species and life stages. The second assumption is also questionable, because any organisms alive in the discharge have survived entrainment and may be more resistant to sampling-related mortality. Because the loss of organisms by disintegration is not measured, if a substantial number of organisms are destroyed and thus are not counted in the discharge, it is more likely that entrainment survival will be overestimated. The second assumption can be minimized if methods of sampling are used that reduce sampling mortality to a minimum (EA Engineering, Science, and Technology, 2000); such methods (e.g., rear-draw pumping methods, pumpless flume) were used in only 5 of the 37 studies reviewed. The formula commonly used (EA Engineering, Science, and Technology, 2000) to estimate entrainment survival, $S_I = P_{D\,/}\,P_I$, is appropriate in experimental situations in which the number of organisms at risk is verified to equal the number counted (alive and dead) at the end of the study. It can be applied in observational studies when it is known that the number at risk is conserved (i.e., no organisms are lost in sampling or destroyed so they cannot be counted). The biases that result from loss via sampling or destruction, and other causes, were illustrated by Boreman and Goodyear (1981). If Abbott's correction for control mortality is applied, it requires the assumption that sampling mortality rate is the same for the intake and discharge samples. This source of bias was also considered by Boreman and Goodyear (1981). Abbott's correction may contribute to overestimation of entrainment survival because it attributes to entrainment only that mortality in excess of the mortality attributed to sampling. This may overestimate entrainment survival for two reasons: it is likely that sampling mortality and entrainment mortality are not entirely additive, and, as noted above, it is quite possible that the sampling mortality rate is less in the discharge sample than in the intake sample used as the control.

A7-5 Applicability of Entrainment Survival Studies to Other Facilities

Because of many factors, any potential for entrainment survival is most likely facility-specific. Therefore, EPA does not suggest that entrainment survival estimates be applied to other facilities, as was done in the Muskingum River Plant study (Ecological Analysts Inc., 1979a). To correctly transfer the results, the physical attributes of facilities would need to be identical. Specifically, the facilities would need to have similar numbers of cooling water flow routes; similar lengths of flow routes in terms of time and linear distance; similar mechanical features in terms of abrasive surfaces, pressure changes, and turbulence; and similar number and types of pumps used. In addition, there would need to be similarity and constancy of the flow rates, transit times, thermal regimes, and biocide regimes. The ecological characteristics of the environment around the facility would also need to be similar in terms of ambient water temperature, dissolved oxygen level, and the species and life stage of organisms present. Similarities or differences in these aspects may profoundly affect the applicability of the study across facilities. The studies reviewed by EPA were unsuitable for developing unbiased estimates of entrainment survival over the pertinent courses of time (diel and seasonal) and the typical environmental and operating conditions at the facilities conducting the studies, and thus cannot be used to estimate entrainment survival at section 316(b) facilities nationwide.

A7-6 Conclusions

EPA's review of the 37 entrainment survival studies revealed a number of limitations that challenge their use in assessing the benefits of the proposed section 316(b) rule for Phase III facilities. The primary issue with regard to these studies is whether their results can support a defensible estimate of survival substantially different from the value of 0% survival assumed by EPA in assessing benefits of the rule. Given that live organisms can be found in the discharge canals of many cooling water intake systems, it may be true that not all organisms are necessarily killed as they pass through the cooling systems of all facilities under all operating conditions. However, the results of the 37 studies, summarized in Table A7-1, suggest that the proportion alive in the samples is highly variable and unpredictable among species and among facilities. The studies document that some species (e.g., herrings, bay anchovy) are very sensitive to entrainment and experience 0% survival with calculated mortality rates of 100% at most facilities. Other species (e.g., striped bass) may be more resistant to entrainment effects. However, even for these apparently hardy species, some studies yielded ranges of entrainment survival estimates that included zero and latent survival values very close to zero. Multiple studies at the same facility (e.g., Bowline Point, Indian Point) yielded survival values for some species (e.g., striped bass) that varied substantially among years, most likely due to a combination of changes in environmental conditions, changes in plant operations, and changes in sampling and testing procedures. The studies indicate that any survival is dependent on temperature, but the effect may vary greatly depending on intake water temperature, plant design, fish species, and life stages. Few of the studies could conclusively document and quantify the specific stressors causing the observed mortalities, and no rigorous, validated method or model was put forward that would allow survival rates to be accurately predicted. Another major constraint on the use of these findings in this rulemaking process is that they cover very few species, and primarily in a single geographical region of the country, thus providing no basis for prediction or projection of effects to other species in other parts of the country. These studies as well as other literature also show that findings from one facility cannot be considered to be valid for another facility, since many site-specific and facility-specific factors may affect the magnitude of mortality that occurs. The current state of knowledge would not support predictions of entrainment survival for the range of species, life stages, regions, and facilities involved in EPA's benefits estimates.

The potential usefulness of the findings of the studies reviewed is further compromised by the numerous factors that can influence the representativeness, accuracy, and precision of the survival estimates presented, and that are often not rigorously accounted for in the studies reviewed. These factors are described in section A7-2, and some of the deficiencies of the studies with regard to these factors are elaborated in section A7-3. The most frequent and serious deficiencies noted (e.g., high control mortalities, omission of fragmented or unidentifiable organisms, and uncertainty regarding post-discharge survival) compromise the accuracy and precision of the survival estimates. In many of the studies reviewed, the precision of the survival estimates was not rigorously assessed, and thus the uncertainty associated with the estimates is not known. If the factors addressed in this review were taken into account in an entrainment survival study, EPA believes that the estimates of survival that would result would not be substantially different from zero.

EPA acknowledges that some of the studies performed at some facilities were designed in a more rigorous manner than others in order to minimize the influence of factors that could compromise findings (e.g., the use of a larval table for assessing physiological condition) and included comprehensive sampling in an attempt to enhance the accuracy and precision of the survival estimates. However, while such studies may have provided estimates for the facility studied under the environmental and operational conditions that occurred at the time the study was performed, these studies do not provide a basis for generalizing specific survival rates for all or even the same species at other facilities or at the same facility in other years. In addition, there exists the possibility of additional post-discharge (latent) mortality when entrained organisms are returned to the receiving waterbody. Overall, the unreliability, variability, and unpredictability of entrainment survival estimates evident from EPA's review of the entrainment survival studies support the use of the assumption of 0% survival in the benefits assessment because there is no clear indication of any defensible estimate of survival substantially different from 0% to use to calculate benefits for this rule.

Summary Tables of Entrainment Survival Studies

Anclote Power Plant

Anclote River, FL

1985 Study

CCI Environmental Services, 1996

Sampling: Dates: Sept. 25 - 29, October 9 - 11, and November 1-2
Samples collection frequency: a few days per month
Times of peak abundance: autumn months when densities maybe not the highest
Time: mostly at night, some late afternoon to evening
Number of replicates: varied between 5 - 25 per month
Intake and discharge sampling: paired number, timing unknown
Elapsed collection time: 20 - 30 minutes
Method: 400 μm mesh net with 1 m diameter and 5 gallon plastic bucket with 500 μm mesh side panels
Depth: mid-depth and surface
Intake location: unknown
Discharge location: condenser discharge and point of discharge in canal
Water quality parameters measured: pH, DO, salinity
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: operated at peak load to maximize ΔT, 1 - 2 Units
Number of pumps in operation: varied due to sampling location, 0- 4 pumps
Temperature: Discharge temperature: 28.8 - 38.3 °C
ΔT average: 5.4 - 7.3 °C
Biocide use was not noted

Survival Estimation:
Number of sampling events: 8
Total number of samples collected: 120
Total number of organisms collected: 41,196
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: approx. equal
Most abundant species: not classified to species level
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 24 hours
In several replicates, more organisms were counted after 24 hours in jar
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 64% for fish larvae; 73% for Amphipoda
44% for Chaetognatha; 72% for crab larvae
72% for Caridean shrimp
Initial discharge survival range: 8 - 47% for fish larvae; 29 - 58% for Amphipoda
28 - 35% for Chaetognatha; 74 - 80% for crab larvae
45 - 66% for Caridean shrimp
Calculation of Entrainment Survival: Discharge survival / Intake survival
Mean survival for each replicate was reported as survival estimate per species
Confidence intervals (95%) and standard deviations were calculated
Significant differences were tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: none collected
Larval survival: decreased markedly within hours of collection
Raw data: were provided to verify results
Temperature effects: unknown
Mechanical effects: unknown
Quality control: QA/QC officer oversaw sorting and sample handling
Peer review: not mentioned, study was conducted for the facility

Bergum Power Station

Bergumermeer, Netherlands

1976 Study

Hadderingh, 1978

Sampling: Dates: April 27 - June 1
Samples collection frequency: approximately once per week
Times of peak abundance: coincided with abundance of larvae and juveniles
Time: unknown
Number of replicates: unknown
Intake and discharge sampling: unclear if paired sampling
Elapsed collection time: 3 minutes
Method: conical net with 0.5 mm mesh and 0.5 m diameter
Depth: unknown
Intake location: unknown
Discharge location: in outlet before weir
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: 40 cm/sec

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: Intake temperature: 10.8 - 21.6
Discharge temperature: 16.7 - 24.6 °C
ΔT ranged from 2.4 - 8.0 °C
Biocide use was not noted

Survival Estimation:
Number of sampling events: 6
Total number of samples collected: unknown
Total number of organisms collected: unknown at intake, 1148 at discharge
Number of organisms entrained per year: unknown
approximately 10 million organisms entrained per day in May
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: unknown
Most abundant species: smelt, perches
Stunned larvae: unknown if included in survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in floating buckets in the outlet canal for 24 hours
5 - 50% appeared to be dead in buckets floating in outlet canal
However, latent survival was not explicitly studied
Data: survival by sampling date and then averaged
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 54 - 100% for smelt
81 - 96% for perches
Initial discharge survival range: 10 - 28% for smelt
32 - 74% for perches
Calculation of Entrainment Survival: Discharge survival / Intake survival
Confidence intervals and standard deviations were not presented.
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: no eggs collected
Larval survival: increased in samples later in year, may be due to larger sized
Raw data: were not provided to verify results
Temperature effects: not discussed
Mechanical effects: not discussed
Quality control: not discussed
Peer review: work done for facility, published in Applied Limnology

Bowline Point Generating Station

Hudson River, NY

1975 Study

Ecological Analysts Inc., 1976a

Sampling: Dates: June 3 - July date unknown
Samples collection frequency: 1 - 4 times per week
Times of peak abundance: sampling intended to coincide with peak densities
Time: day or night
Number of replicates: unknown
Intake and discharge sampling: unknown if paired
Elapsed collection time: 15 minutes
Method: larval collection tables
Depth: unknown
Intake location: in front of intake
Discharge location: from standpipe connected to discharge pipe of Unit 2
Water quality parameters measured: conductivity, DO, pH
DOC and POC measured: no
Intake and discharge velocity: intake: 1.5 - 2 m/sec, discharge 2- 4.6 m/sec

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: ΔT range: 0.5 - 12.1 °C
Biocide use was not noted

Survival Estimation:
Number of sampling events: 37
Total number of samples collected: 400
Total number of organisms collected: 4643
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: no, more at intake
Higher percentage of larvae were collected at the discharge station in the later weeks of the collection period. Conversely, a higher percentage of larvae were collected at the intake at the beginning weeks of the collection period. This discrepancy in larval collection combined with higher survival rates later in the spawning season accounts for the bias which results in higher survival rates at the discharge station. The study acknowledges this bias and concludes that it is responsible for the higher discharge survival estimates
Most abundant species: striped bass, white perch and bay anchovy
Stunned larvae: included in initial survival proportion; most died within hours
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 96 hours
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 81% for striped bass
56% for white perch
9% for bay anchovy
Initial discharge survival range: 74% for striped bass
68% for white perch
2% for bay anchovy
Calculation of Entrainment Survival: Discharge survival / Intake survival
Confidence intervals (95%) were presented
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: no
Egg survival: not studied
Larval survival: decreased markedly within 3 hours of collection.
Raw data: were not provided to verify results
Temperature effects: too few samples collected to establish relationship
Mechanical effects: extent was not discussed
Quality control: color coded labeling, routine checks on sorting accuracy
Peer review: not mentioned, study was conducted for the facility

Bowline Point Generating Station

Hudson River, NY

1976 Study

Ecological Analysts Inc., 1977

Sampling: Dates: May 18 - July 26
Samples collection frequency: approx. 4 nights per week
Times of peak abundance: for all species except Atlantic tomcod
Time: at night
Number of replicates: stated average of 10 per sampling trip
Intake and discharge sampling: sorted simultaneously
Elapsed collection time: 15 minutes
Method: larval collection table with 4 inch diameter trash pump
Depth: unknown
Intake location: in front of Unit 1 trash racks
Discharge location: from standpipes of discharge at Units 1 or 2
Water quality parameters measured: conductivity, pH, and DO
DOC and POC measured: no
Intake and discharge velocity: intake: 0.11 - 3 m/sec, discharge: 3 - 4.6 m/sec

Operating Conditions During Sampling:
Number of units in operation: varied between 1 and 2
Number of pumps in operation: unknown
Temperature: discharge range: 29.0 - 35.9 °C
Biocide use was not noted

Survival Estimation:
Number of sampling events: 39
Total number of samples collected: 688
Total number of organisms collected: 2795
Number of organisms entrained per year: unknown
Fragmented organisms: only included in count if >50% was present
Equal number of organisms collected at intake and discharge: no, very different
Most abundant species: striped bass, white perch, atlantic tomcod, bay anchovy, herrings
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 96 hours
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 81 - 90% for striped bass
62% for white perch
54 - 82% for Atlantic tomcod
7 - 53% for bay anchovy
35% for herrings
Initial discharge survival range: 0 - 54% for striped bass
0 - 33% for white perch
29 - 94% for Atlantic tomcod
0 - 10% for bay anchovy
20% for herrings
Calculation of Entrainment Survival: Discharge survival / intake survival
Confidence intervals (95%) were presented
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Larval survival: decreased markedly within 12 hours of collection.
Raw data: were not provided to verify results.
Temperature effects: trend of decreasing survival when temperatures > 30 °C
Mechanical effects: unknown extent
Quality control: color coded labels, immediate checks of sorted samples, SOPs
Peer review: not mentioned, study was conducted for the facility

Bowline Point Generating Station

Hudson River, NY

1977 Study

Ecological Analysts Inc., 1978a

Sampling: Dates: March 7 - July 15
Samples collection frequency: 5 nights per week
Times of peak abundance: covered of peak densities of most targeted species
Time: at night
Number of replicates: varied between 2 and 10 per site
Intake and discharge sampling: paired
Elapsed collection time: 15 minutes
Method: larval table with pump, 2 pumps at intake; 2 tables at discharge
ambient water injection system added to reduce prolonged temp. exposure
Depth: middle to bottom at intake, at standpipes for discharge
Intake location: in front of Unit 1 trash rack
Discharge location from standpipes of either Unit 1 or 2, depending on operation
Water quality parameters measured: conductivity, pH and DO
DOC and POC measured: no
Intake and discharge velocity: intake: 0.11- 2 m/sec; discharge 3 - 4.6 m/sec

Operating Conditions During Sampling:
Number of units in operation: varied between 1 and 2
Number of pumps in operation: 2 pumps throttled or 2 pumps full
Temperature: Intake range: 3.7 - 27 °C
ΔT range: not provided
Biocide use was not noted

Survival Estimation:
Number of sampling events: 46
Total number of samples collected: 736
Total number of organisms collected: 4071
Number of organisms entrained per year: unknown
Fragmented organisms: included in count if > 50% of organism was present
Equal number of organisms collected at intake and discharge: no, very different
Most abundant species: striped bass, white perch, bay anchovy, herrings and silversides
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 96 hours
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 74% for striped bass
69% for white perch
0 - 16% for bay anchovy
54% for herrings
37% for silversides
Initial discharge survival range: 71 - 72% for striped bass
34% for white perch
0 - 2% for bay anchovy
23% for herrings
16% for silversides
Calculation of Entrainment Survival: Discharge survival / Intake survival
Standard errors were presented
Significant differences were tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Larval survival: survival increased with larval length
Raw data: were not provided to verify results.
Temperature effects: decreased survival > 33 °C
Mechanical effects: unknown
Quality control: color coded labels, checks of sorting efficiency
Peer review: not mentioned, study was conducted for the facility

Bowline Point Generating Station

Hudson River, NY

1978 Study

Ecological Analysts Inc., 1979b

Sampling: Dates: March 13 - October 16
Samples collection frequency: 1 - 5 times per week
Times of peak abundance: majority of samples in June and July
Time: at night
Number of replicates: varied between 1 - 10 per sampling date.
Intake and discharge sampling: mostly paired, not all sites sampled all dates
Elapsed collection time: 15 minutes
Method: pump/larval table combination; also floating larval table
Depth: at bottom for intake and unspecified for discharge
Intake location: in front of trash racks of Unit 1 or 2
Discharge location: at either Unit 1 or 2 in standpipes from discharge pipe
floating larval table used for sampling at point of discharge
Water quality parameters measured: salinity, pH, DO, conductivity
DOC and POC measured: no
Intake and discharge velocity: intake: 0.15 - 0.23 m/s

Operating Conditions During Sampling:
Number of units in operation: varied between 1 and 2
Number of pumps in operation: unknown
Temperature: unknown
Biocide use was not noted

Survival Estimation:
Number of sampling events: 40
Total number of samples collected:609
Total number of organisms collected: unknown
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: varied
Most abundant species: striped bass, bay anchovy, white perch and herrings
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in holding jars for 96 hours
Data: was summarized and averaged over the entire sampling period.
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 48 - 49% for striped bass
39% for white perch
4% for bay anchovy
19% for herrings
Initial discharge survival range: 51 - 63% for striped bass
19% for white perch
0% for bay anchovy
23% for herrings
Calculation of Entrainment Survival: Discharge survival / Intake survival
Standard error were presented
Significant differences were tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Larval survival: decreased markedly within 12 hours of collection
Survival increased with larval length
Raw data: were not provided to verify results
Temperature effects: no survival for YSL for any species at temps. > 30 °C
no survival for PYSL for any species at temps. > 33 °C
majority of samples collected at temperatures < 30 °C
Mechanical effects: recirculation of water occurs
Quality control: color coded labels, double checks, sorting efficiency checks
Peer review: not mentioned, study was conducted for the facility

Bowline Point Generating Station

Hudson River, NY

1979 Study

Ecological Analysts Inc., 1981a

Sampling: Dates: May 23 - June 27
Samples collection frequency: 3 - 5 days per week
Times of peak abundance: timed to coincide with peak densities
Time: 1400 to 2200 hours
Number of replicates: varied between 0 - 9 per sampling date, generally 7
Intake and discharge sampling: mostly paired, initiated simultaneously
Elapsed collection time: 15 minutes
Method: intake: floating larval table or rear draw sampling flume
discharge: pumpless plankton sampling flume or pumped larval table
Depth: intake: mid-depth (4.6 m); discharge: 2 m below surface
Intake location: in front of trash racks
Discharge location: at standpipe and diffuser
Water quality parameters measured: conductivity, pH, DO
DOC and POC measured: no
Intake and discharge velocity: intake: 1.5 - 3.0 m/sec; discharge 3 - 4.6m/sec

Operating Conditions During Sampling:
Number of units in operation: varied, power generated on only 5 sampling dates
Number of pumps in operation: operated through sampling
Temperature: ΔT range: not provided
Biocide use was not noted

Survival Estimation:
Number of sampling events: 19
Total number of samples collected: 435
Total number of organisms collected:1212
Number of organisms entrained per year: estimated 1.5 million striped bass
2.7 million white perch
Fragmented organisms: included in count if 50%of organism was present
Equal number of organisms collected at intake and discharge: approx. equal
Most abundant species: white perch, bay anchovy, striped bass, herrings
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 96 hours.
Data: was summarized and averaged over the entire sampling period.
Controls: Survival in the intake samples was considered to be the control.
Initial intake survival range: 63 - 71% for striped bass; 39 - 63% for white perch
4 - 14% for bay anchovy; 56 - 61% for herrings
Initial discharge survival range: 35 - 41% for striped bass; 26 - 35% for white perch
0 - 4% for bay anchovy; 30 - 31% for herrings
Calculation of Entrainment Survival: Discharge survival / Intake survival
Standard errors were presented.
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: determined by translucency and hatching success
Larval survival: decreased markedly within 12 hours of collection.
Raw data: were not provided to verify results.
Temperature effects: little survival at discharge temperatures > 30 °C
Mechanical effects: due to no power generation on the majority of sampling dates, results give indication of extent of mechanical induced mortality
This study included analysis of diel patterns of ichthyoplankton abundance in comparison to diel patterns of plant generation. Facility tends to operate at 85 to 95% of capacity in the mid-afternoon hours which results in higher ΔT's and discharge temperatures. Facility tends to operate at minimum level, 20 to 30% capacity, in early morning when larval abundance is high and entrainment survival samples collected. Sample collection during the hours when the facility is operating at minimum levels of percent capacity, and at times with correspondingly lower ΔT's and discharge temperatures, may add bias to the results since more organisms will be exposed to lower levels of temperature stress. The peak abundance for each species is only slightly higher than abundance throughout the day. Thus, collectively, more organisms may be exposed to higher temperatures and have higher mortality rates but are not reflected in samples collected at night.
Quality control: color coded labels, check of sorting efficiency, SOPs
Peer review: not mentioned, study was conducted for the facility

Braidwood Nuclear Station

Kankakee River, IL

1988 Study

EA Science and Technology, 1990

Sampling: Dates: June 1 - July 5
Samples collection frequency: 3 samples taken in 35 days
Times of peak abundance: peak densities of eggs and larvae were found in May
Time: varied; day and night at intake, only day at discharge
Number of replicates: varied, 8 - 14 per sampling date
Intake and discharge sampling: more discharge replicates, not always same day
Elapsed collection time: 2 minutes
Method: plankton net with 1.0 m opening, net rinsed out in bucket
Depth: unknown
Intake location: in holding pond into which river water was pumped
Discharge location: downstream of outfall in discharge canal
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: 0.4 - 0.6 ft/sec

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: not given
Biocide use was not noted

Survival Estimation:
Number of sampling events: 3
Total number of samples collected: 62
Total number of organisms collected: 294
Samples, which were collected after peak densities, contained fewer and larger organism which may in turn have higher survival rates.
Number of organisms entrained per year: estimate 5.8 - 11.2 million eggs/larvae
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: more at intake
Most abundant species: minnows and sunfish
Stunned larvae: included in survival proportion
Dead and opaque organisms: were omitted from all calculations of survival
Thus 67% of those dead in the intake samples and 21% of those dead in the discharge samples were omitted from the survival proportions
Latent survival: not studied
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control.
Initial intake survival range: 60% for minnows (17% including dead-opaque)
78% for sunfish (54% including dead-opaque)
Initial discharge survival range: no minnows collected
80% for sunfish (76% including dead-opaque)
Calculation of Entrainment Survival: Discharge survival / Intake survival
Survival proportions calculated by dividing number of live larvae by number of live plus dead-transparent larvae
Confidence intervals / standard deviations: were not presented.
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: data not given
Larval survival: not studied
Raw data: were not provided to verify results.
Temperature effects: not studied
Mechanical effects: not studied
Quality control: not discussed
Peer review: not mentioned, study was conducted for the facility

.

Brayton Point

Mount Hope Bay, MA

1997-1998 Study

Lawler, Matusky & Skelly Engineers, 1999

Sampling: Dates: April 30 - August 27, 1997 and February 26 - July 29, 1998
Samples collection frequency: weekly
Times of peak abundance: not discussed specifically
Time: varied, day or night
Number of replicates: varied between 14 and 77
Intake and discharge sampling: not paired, 2 tables located in discharge canal
Elapsed collection time: 15 minutes
Method: pump/larval table combination
Depth: mid-depth for intake, 2 - 4 m below surface at discharge
Intake location: directly in front of Unit 3 intake screens
Discharge location: middle of discharge canal or from Unit 4 discharge pipe
Water quality parameters measured: conductance and salinity periodically
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: intake range: 4.5 - 28.0 °C
discharge range: 11 - 45 °C
ΔT data not provided
Biocide use: samples collected when not in use

Survival Estimation:
Number of sampling events: 41
Total number of samples collected: 2692 in 1997; 4137 in 1998
Total number of organisms collected: 2256 in intake; 27,574 in discharge
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal no. of organisms collected at intake and discharge: 4 - 79X more in discharge
Most abundant species: bay anchovy, American sand lance
Stunned larvae: assumed stunned larvae did not survive due to increased predation risk
Dead and opaque organisms: not discussed
Latent survival: observed in holding cups in aquarium racks for 96 hours
Data: was summarized and averaged with both sampling years combined
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 0% for American sand lance
4% for tautog
0% for bay anchovy
44 - 46% for windowpane flounder
32% for winter flounder
Initial discharge survival range: 0% for American sand lance
4% for tautog
0% for bay anchovy
29 - 30% for windowpane flounder
33 - 38% for winter flounder
Calculation of Entrainment Survival: discharge survival / intake survival
Standard errors were presented
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Larval survival: survival increased with larval length,
decreased markedly within 4 hours of holding in latent studies
Raw data: were provided by species and not by sample to verify results
Temperature effects: survival decrease markedly at temps > 20 °C
Mechanical effects: unknown extent
Quality control: continuous sampling plan which included reanalysis of samples
Peer review: not mentioned, study was conducted for the facility

Cayuga Generating Plant

Wabash River, IN

1979 Study

Ecological Analysts Inc., 1980a

Sampling: Dates: May 17 - 31 and June 8 - 22
Samples collection frequency: daily
Times of peak abundance: highest average densities sampled were June 8 - 10
Time: 1900 to 0300 hours
Number of replicates: varied between 0 - 6 per sampling date.
Intake and discharge sampling: simultaneous sampling, transit time = 36 mins
Elapsed collection time: 15 minutes
Method: pump / larval table collection system
Depth: intake: 2 and 5 m below surface, discharge: 3 - 4 m below surface
Intake location: in front of intake structure
Discharge location: where discharge of Units 1 and 2 enter canal
also cooling tower discharge in discharge canal
Water quality parameters measured: DO
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: varied, 2 - 4
Temperature: intake range: 17.6 - 24.3 °C
discharge range: 29.4 - 33.3 °C
ΔT ranged from 8.4 - 11.8 °C
Biocide use: occurs daily, but ceased at least 2 hours before sampling

Survival Estimation:
Number of sampling events: 24
Total number of samples collected: 80
Total number of organisms collected: 2556
Number of organisms entrained per year: unknown
Fragmented organisms: 13 - 14.6% were damaged
Equal number of organisms collected at intake and discharge: more at intake
Most abundant species: suckers, perches, carps, temperate basses
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: 48 hour observation in aerated glass jars of filtered river water
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 86 - 98% for suckers
28 - 92% for carps and minnows
50 - 86% for perches
Initial discharge survival range: 75 - 92% for suckers
12 - 74% for carps and minnows
43 - 69% for perches
Calculation of Entrainment Survival: Discharge survival/ Intake survival
Confidence intervals: were not presented; standard errors were calculated
standard error sometime as high as survival
Significant differences were tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Larval survival: latent effects were not seen until 48 hours after collection
Raw data: were provided to verify results
Temperature effects: lower survival for all species at temperatures above 30 ˚C
Mechanical effects: survival decreased when number of pumps increased
Quality control: sorting efficiency checks and color coded labels
Peer review: not mentioned, study was conducted for the facility

Connecticut Yankee Atomic Power Company

Connecticut River, CT

1970 Study

Marcy, 1971

Sampling: Dates: June 30 - July 29
Samples collection frequency: weekly
Times of peak abundance: sampling dates were estimated times of peak larvae
Time: varied throughout day to avoid biocide application
Number of replicates: sampled in triplicate, data from replicates combined
Intake and discharge sampling: samples taken successively
not all sites sampled on all dates
Elapsed collection time: 5 minutes
Method: conical nylon plankton net with 1 L plastic bucket attached to cod end
portable water table for maintaining temperature during counting
Depth: median depth at intake; surface, middle and bottom of discharge
because dead fish in canal may sink or float due to immobility or
changes in specific gravity of water, thus giving inconsistent results
Intake location: unknown
Discharge location: outfall weir and 3 location in discharge canal
Water quality parameters measured: DO
DOC and POC measured: no
Intake and discharge velocity: 1 - 2 ft/sec, may approach 8 ft/sec

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: Discharge temperature: 28.2 - 41 °C
ΔT ranged from 6 - 12.1 °C
Biocide use: sampling avoided daily application of 13% sodium hydrochlorite

Survival Estimation:
Number of sampling events: 7
Total number of samples collected: 102
Total number of organisms collected: 2681
Number of organisms entrained per year: unknown
Fragmented organisms: majority of dead fish were mangled
Equal number of organisms collected at intake and discharge: unknown
Most abundant species: alewife and blueback herring
Stunned larvae: not discussed
Dead and opaque organisms: not discussed
Latent survival: not studied
Data: all data for all species combined, survival calculated for each date
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 29 - 100% for all species combined
Initial discharge survival range: 0 - 7.5% for all species combined
Calculation of Entrainment Survival: number live per cubic meter in each
discharge sample/ number live per cubic meter in intake for each day
Confidence intervals and standard deviations: were not presented
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: July 29
Egg survival: not sampled
Larval survival: no organisms were found alive at end of discharge canal at
temperatures > 30 °C
Raw data: were not provided to verify results
Temperature effects: at discharge temp. > 33.5 °C, no living organisms sampled
Mechanical effects: not discussed
Quality control: not discussed
Peer review: published in notes of Journal Fisheries Research Board of Canada

Connecticut Yankee Atomic Power Company

Connecticut River, CT

1971-1972 Study

Marcy, 1973

Sampling: Dates: June 2 - 24, 1971 and June 27 - July 13, 1972 (mechanical only)
Samples collection frequency: approximately once per week
Times of peak abundance: unknown
Time: afternoons and evenings
Number of replicates: three at each station although at three different depths
data were combined for each station
Intake and discharge sampling: collected successively at the 5 sites
Elapsed collection time: 5 minutes
Method: conical nylon plankton net with 0.39 mm mesh and 1L plastic bucket
Depth: surface, middle, and bottom
Intake location: unknown
Discharge location: below weir and 3 points along discharge canal
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: 0.3 - 0.6 m/sec, may approach 2.4 m/sec

Operating Conditions During Sampling:
Number of units in operation: unknown in 1971, no power generation in 1972
Number of pumps in operation: unknown
Temperature: Intake temperature: 16 - 26 °C (1971); 19.9 - 28 °C (1972)
Discharge temperature: 29 - 35 °C (1971 only)
ΔT ranged from 9-13 °C (1971 only)
Biocide use: 1972 study, chemical mortality indistinguishable from mechanical

Survival Estimation:
Number of sampling events: 2 (1971) and 7 (1972)
Total number of samples collected: 30 (1971) and 246 (1972)
often 2-3 times as many samples collected at discharge
Total number of organisms collected: 1068 (1971) and 10,271 (1972)
Number of organisms entrained per year: unknown,
estimated entrainment is 1.7 - 5.8% of nonscreenable fish which pass facility
Fragmented organisms: not discussed
Equal no. of organisms collected at intake and discharge: 4X more in discharge
lower numbers collected at end of canal may be due to dead fish settling out of water column
Most abundant species: alewife and blueback herring
Stunned larvae: were included as live unless they had begun to turn opaque
Dead and opaque organisms: only opaque organisms were counted as dead
Latent survival: not studied
Data: replicate data combined; survival calculated per sampling day
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 64 - 100% for all species sampled (1971)
Initial discharge survival range: 0% for all species sampled (1971)
Calculation of Entrainment Survival: number live per cubic meter in each discharge sample/ number live per cubic meter in intake for each day
Confidence intervals and standard deviations were not presented.
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: none sampled
Larval survival: no survival anywhere in discharge at temperatures > 29 °C
Raw data: were not provided to verify results
Temperature effects: organisms exposed to elevated temp. for 50 - 100 min
estimated as causing 20% of mortality
most fish are dead at the end of the 1.14 mile canal
Mechanical effects: 1972 study indicated that 72 - 87% is mechanical mortality
Quality control: not discussed
Peer review: published in Journal Fisheries Research Board of Canada

Contra Costa Power Plant

San Joaquin River, CA

1976 Study

Stevens and Finlayson, 1978

Sampling: Dates: April 28 - July 10
Samples collection frequency: once per week
Times of peak abundance: unknown
Time: varied, about 25% of all samples collected at night
Number of replicates: typically 3
Intake and discharge sampling: paired at closest time and temperature
Elapsed collection time: 1 - 2 minutes
Method: 505 micron mech conical nylon plankton net with 0.58 m plastic collecting tubes on cod end; towed net on boat at 0.6 ft/sec
Depth: mid-depth
Intake location: at intake for units 6 and 7
Discharge location: at discharge for units 1 - 5 and units 6-7
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: Intake temperature: 19 - 30 °C
Discharge temperature 19 - 38 °C
Biocide use was not noted

Survival Estimation:
Number of sampling events: 6
Total number of samples collected: unknown
Total number of organisms collected: 966 (1606 at north shore control)
Number of organisms entrained per year: unknown
Fragmented organisms: enumerated in one replicate tow
higher proportion of unidentifiable fragments in discharge
Equal number of organisms collected at intake and discharge: more at intake
Most abundant species: striped bass
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: not studied
Data: was summarized by mean larval length
Controls: survival in the intake samples was considered to be the control
additional control on north shore to determine background mortality
control site at north shore away from intake had lower mortality rates
Initial intake survival range: 33-90% for striped bass
recirculated water may be cause of some intake mortality
Initial discharge survival range: 0 - 50% for striped bass
Calculation of Entrainment Survival: paired discharge survival divided by paired intake survival
Confidence intervals and standard deviations were not presented.
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Larval survival: increased survival with greater larval length
Raw data: were not provided to verify results
Temperature effects: mortality increased with increase in discharge temperature
higher mortality with discharge temp. > 31 and ΔT > 7 °C
linear regression showed that half died at temps >33.3 °C
0% survival at temperatures of 38 °C
Mechanical effects: stated not as much of an effects as temperature
Quality control: not discussed
Peer review: study conducted by California Fish and Game with funds provided by facility

Danskammer Point Generating Station

Hudson River, NY

1975 Study

Ecological Analysts Inc., 1976b

Sampling: Dates: May 29 - November 18
Samples collection frequency: varied from once every 2 weeks to 4 times per week
Times of peak abundance: increased frequency during spawning
Time: varied, generally overnight
Number of replicates: varied, ranged from 1 to 12
Intake and discharge sampling: usually paired
Elapsed collection time: unknown
Method: pump/larval table
Depth: mid-depth for intake, unspecified for discharge
Intake location: in canal in front of traveling screens
Discharge location: outlet of Unit 3 to Hudson River
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: varied between 1 and 2
Temperature: Intake temperature range: 21 - 26 °C
Discharge temperature range: not provided
ΔT ranged from 0 - 10 °C
Biocide use not used during sampling; noted that chlorination will reduce survival

Survival Estimation:
Number of sampling events: 29
Total number of samples collected: 372
Total number of organisms collected: 1655
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal no. of organisms collected at intake / discharge: up to 2X more in discharge
Most abundant species: herrings, striped bass and white perch
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 96 hours
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 0 - 50% for striped bass
33 - 100% for white perch
63 - 100% for herrings
Initial discharge survival range: 0 - 39% for striped bass
38 - 80% for white perch
20 - 22% for herrings
Calculation of Entrainment Survival: Discharge survival / Intake survival
Confidence intervals and standard deviations: were not presented.
Significant differences were tested between the intake and discharge survival
Significantly lower survival in discharge: herring PYSL
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: none collected
Larval survival: decreased markedly within 3 hours of collection.
Raw data: were not provided to verify results
Temperature effects: significantly lower survival when ΔT > 10 °C and discharge temperature >30 °C
Mechanical effects: not discussed
Quality control: samples double checked and data entry monitored
Peer review: not mentioned, study was conducted for the facility

Fort Calhoun Nuclear Station

Missouri River, NE

1973-1977 study

Carter, 1978

Sampling: Dates: October 1973 - June 1977
Samples collection frequency: 5 - 24 times per year
Times of peak abundance: same frequency all year round
Time: unknown
Number of replicates: unknown
Intake and discharge sampling: unknown if timing was paired
Elapsed collection time: unknown
Method: plankton net with 571 μm mesh and 0.75 m diameter
Depth: unknown
Intake location: in river near intake
Discharge location: near discharge in river immediately downstream of intake
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: varied, 25-97% of full power or shut down
Number of pumps in operation: unknown
Temperature: Discharge temperature: 27.0 - 36.9 °C during summer samples
ΔT ranged from 0.6 - 13.5 °C
Biocide use: unspecified number of samples collected during chlorination

Survival Estimation:
Number of sampling events: 89 (16 when facility was shut down)
Total number of samples collected: unknown
Total number of organisms collected: 24,535 macroinvertebrates
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: no, varied
Most abundant species: Ephemeroptera, Hydropsychidae, Chironomidae
Stunned larvae: macroinvertebrates studied
Dead and opaque organisms: not discussed
Latent survival: not studied
Data: was summarized and averaged over entire sampling period
Controls: Survival in the intake samples was considered to be the control
Initial intake survival range: 12 - 26% for Ephemeroptera
42 - 51% for Hydropsychidae
35 - 60% for Chironomidae
Initial discharge survival range: 18 - 32% for Ephemeroptera
47 - 56% for Hydropsychidae
43 - 66% for Chironomidae
Calculation of Entrainment Survival: Average differential mortality
Confidence intervals / standard deviations: were calculated but not presented
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not collected
Larval survival: macroinvertebrates only were studied
Raw data: were not provided to verify results
Temperature effects: discussed but data not presented
Mechanical effects: studied during 16 dates when facility was shut down
Quality control: unknown
Peer review: not mentioned, study was conducted for the facility

Ginna Generating Station

Lake Ontario, NY

1980 Study

Ecological Analysts Inc., 1981c

Sampling: Dates: June 11 - 24 and August 8 - 21
Samples collection frequency: 5 times per week
Times of peak abundance: to coincide with peak densities of targeted species
Time: late afternoon or early evening
Number of replicates: unknown
Intake and discharge sampling: simultaneous sampling at both sites
Elapsed collection time: 15 minutes
Method: Intake: pump to floating rear-draw sampling flume
Discharge: floating rear-draw pumpless plankton sampling flume
Also used ambient water injection to reduce exposure to high temps.
Depth: unknown
Intake location: at screenhouse intake after flow through 3,100 ft intake tunnel
Discharge location: discharge canal
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: Discharge range: 18.5 - 34.4 °C
ΔT ranged from 8 - 10 °C
Biocide use: sampled 4 hours after routine injections

Survival Estimation:
Number of sampling events: 20
Total number of samples collected: 255
Total number of organisms collected: 664
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: varied
Most abundant species: alewife
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars of filtered water for 48 hours
Data: was summarized and averaged over the sampling month
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 16.3% for alewife eggs
39% for alewife larvae
58-71% for rainbow smelt
Initial discharge survival range: 62.5% for alewife eggs; 16% hatching success
0% for Alewife larvae
0% for rainbow smelt
Calculation of Entrainment Survival: Discharge survival/Intake survival
In June, only one larvae was found alive int the discharge samples
Standard errors were presented
Significant differences were tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Too few of many species were collected at the two sites (only 1 or 2 per site) to provide any reliable estimate of entrainment survival
Egg survival: determined by translucency and hatching success
Raw data: were provided to verify results
Temperature effects: none survived at any temperature
Mechanical effects: none survived at any temperature
Quality control: SOPs, color coded labels, sorting efficiency checks
Peer review: not mentioned, study was conducted for the facility

Indian Point Generating Station

Hudson River, NY

1977 Study

Ecological Analysts Inc., 1978c

Sampling: Dates: Jun 1 - July 15
Samples collection frequency: twice per week
Times of peak abundance: expected to coincide with peak densities
Time: 1800 - 0200 hours
Number of replicates: varied between 5 - 7 per sampling date.
Intake and discharge sampling:
Elapsed collection time: 15 minutes
Method: pump/larval table with ambient water injection to reduce temp. stress
Depth: unknown
Intake location: at intake of Units 2 and 3
Discharge location: discharge for Unit 3 and discharge common to all Units
Water quality parameters measured: DO, pH and conductivity
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: varied between 2 and 3, outage at Unit 2 from 7/4
Number of pumps in operation:6, at or near full capacity
Temperature: Intake range: 18.8 - 26.4 °C
Discharge range: 22.7 - 34.9 °C
ΔT during study not provided
Biocide use: unknown

Survival Estimation:
Number of sampling events: 7
Total number of samples collected: unknown
Total number of organisms collected: 4097
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed specifically, however, there were 115 Morone spp. organisms which could not be further identified to the species level and there were 55 organisms which were mutilated to the point of being unidentifiable to even the family level of organization. Entrainment survival may have been even lower if these mutilated samples were included in the assessment.
Equal number of organisms collected at intake and discharge: more at intake
Most abundant species: striped bass, white perch, bay anchovy and herrings
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: in aerated holding container in ambient water bath for 96 hours
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 0 - 11% for bay anchovy; 60 - 77% striped bass 66% for white perch; 36% for herrings
Initial discharge survival range: 3% for bay anchovy; 29 - 45% for striped bass 15% for white perch; 11% for herrings
Calculation of Entrainment Survival: Discharge survival / Intake survival
Standard errors were presented
Significant differences were tested between the intake and discharge survival
Significantly lower survival in discharge: striped bass YSL and PYSL
white perch PYSL
bay anchovy PYSL
herring PYSL
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Raw data: were not provided to verify results
Temperature effects: no determination that temperature had a significant effect
Mechanical effects: unknown
Quality control: color coded labels and immediate checks of sorted samples
Peer review: not mentioned, study was conducted for the facility

Indian Point Generating Station

Hudson River, NY

1978 Study

Ecological Analysts Inc., 1979c

Sampling: Dates: May 1 - July 12
Samples collection frequency: 2 consecutive days per week
Times of peak abundance: coincided with spawning of targeted species
Time: 1800 - 0200 hours
Number of replicates: approximately 6 per date
Intake and discharge sampling: simultaneous
Elapsed collection time: 15 minutes
Method: pump/ larval table with ambient water injection
Depth: 1 - 3 m below surface, approximately mid-depth
Intake location: Unit 2 and 3 intake
Discharge location: Unit 2 and 3 discharge, discharge point common to all units
Water quality parameters measured: conductivity, pH and DO
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: varied between 1 and 2
Number of pumps in operation: varied between 5 - 11, near full capacity
Temperature: Intake range: 11.2 - 24.3 °C
Discharge range: 19 - 36 °C
ΔT ranged from 9 - 12 °C
Biocide use was not noted

Survival Estimation:
Number of sampling events: 22
Total number of samples collected: unknown
Total number of organisms collected: 4496
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: more at discharge
Most abundant species: striped bass, white perch, bay anchovy and herrings
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 96 hours
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 26 - 48% for striped bass; 15 -48% for white perch
18% for herring; 2% for bay anchovy
Initial discharge survival range: 0 - 34% for striped bass; 0 - 37% for white perch
0 - 8% for herring; 0% for bay anchovy
Calculation of Entrainment Survival: Discharge survival/ Intake survival
Standard errors were presented
Significant differences were tested between the intake and discharge survival
Significantly lower survival at discharge: striped bass YSL, PYSL and juveniles
white perch PYSL
herring PYSL
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: none were alive in either the intake or discharge samples
Larval survival: decreased markedly within 24 hours of collection.
Raw data: were not provided to verify results
Temperature effects: at temps. > 30 °C, no striped bass or white perch survived
also 0% survived when both Unit 2 and 3 were running
Mechanical effects: not discussed
Quality control: sorting efficiency checks, color coded labeling, SOPs
Peer review: not mentioned, study was conducted for the facility

Indian Point Generating Station

Hudson River, NY

1979 Study

Ecological Analysts Inc., 1981d

Sampling: Dates: March 12 -22 and April 30 - August 14
Samples collection frequency: March: 4 times per week,
rest was 2 consecutive days per week
Times of peak abundance: coincided with spawning of targeted species
Time: 1700 to 0200
Number of replicates: unknown
Intake and discharge sampling: simultaneous sampling
Elapsed collection time: 15 minutes
Method: March sampling: two pump/larval table combination
April-August sampling: rear-draw plankton sampling flume at intake
pumpless plankton sampling flume at discharge
Depth: mid-depth for intake, 1 - 5 m below surface for discharge
Intake location: of Units 2 and 3
Discharge location: in discharge canal for Unit 3 and at end of canal
Water quality parameters measured: conductivity, pH and DO
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: one unit not operating March 20 - 26
only one continuously April - August
Number of pumps in operation: varied between 5 and 12
Temperature: Discharge range: 12.0 - 21.9 °C in March; 24 - 32.9 °C
ΔT data not provided
Biocide use was not noted

Survival Estimation:
Number of sampling events: 8 in March; 32 in April - August
Total number of samples collected: unknown
Total number of organisms collected: 478 in March; 2362 April-August
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: varied
Most abundant species: Atlantic tomcod, striped bass, white perch, herring, bay anchovy
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars with filtered water for 96 hours
Data: sorted by discharge temperature in March; combined all April - August
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 43 - 68% for Atlantic tomcod; 39 - 56% for striped bass
13 - 33% for white perch; 23% for herrings
10% for bay anchovy
Initial discharge survival range: 14 - 46% for Atlantic tomcod; 62 - 77% for striped bass
24 - 70% for white perch; 28% for herrings
6% for bay anchovies
Calculation of Entrainment Survival: For the fish larvae samples, a difference in stress associated with the different sampling techniques at the intake and discharge was given as the reason why discharge survival was higher than intake survival for each taxa sampled. Thus, entrainment survival was not calculated.
Standard errors were presented
Significant differences were tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: determined by translucency and hatching success;
33% hatched in discharge samples; 44% in intake samples
Larval survival: decreased markedly within 3 hours of collection.
Raw data: were not provided to verify results.
Temperature effects: no white perch or striped bass survival at temps. > 33 °C
Mechanical effects: unknown extent
Quality control: sorting efficiency checks, color coded labels and SOPs
Peer review: not mentioned, study was conducted for the facility

Indian Point Generating Station

Hudson River, NY

1980 Study

Ecological Analysts Inc., 1982b

Sampling: Dates: April 30 - July 10
Samples collection frequency: 4 consecutive nights per week
Times of peak abundance: coincided with primary spawning of target species
Time: 1600 - 0200 hours
Number of replicates: unknown
Intake and discharge sampling: initiated simultaneously
Elapsed collection time: 15 minutes
Method: intake: rear-draw plankton sampling flume mounted on raft
discharge: pumpless plankton sampling flume mounted on raft
Depth: unknown
Intake location: Unit 3 intake
Discharge location: discharge port number 1
Water quality parameters measured: conductivity, DO, pH
DOC and POC measured: no
Intake and discharge velocity: intake: 0.3 m/sec; discharge 3 m/sec

Operating Conditions During Sampling:
Number of units in operation: varied between 1 and 2, Unit 2 offline June 4-11
Number of pumps in operation: varied between 5 and 11
Temperature: intake range: 11.3 - 25.1 °C
discharge range: 23 - 31 °C
ΔT data not presented
Biocide use was not noted

Survival Estimation:
Number of sampling events: 44
Total number of samples collected: unknown
Total number of organisms collected: 2355
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: more at discharge
Most abundant species: striped bass, white perch, bay anchovies
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 96 hours
Data: combined by discharge temperature
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 95% for striped bass
93% for white perch
32% for bay anchovies
40% recirculation can occur so intake mortality may include organisms which were dead due to a previous passage through the facility
Initial discharge survival range: 50-81% for striped bass
0-90% for white perch
0-4% for bay anchovy
Calculation of Entrainment Survival: Discharge survival / intake survival
Confidence intervals / standard deviations: were not presented.
Significant differences were tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: hatching success: 82% in intake, 47% in discharge
Larval survival: decreased markedly within 3 hours of collection.
Raw data: were not provided to verify results
Temperature effects: little survival at discharge temps > 33 °C
Mechanical effects: unknown
Quality control: sorting efficiency checks, color coded labels and SOPs
Peer review: not mentioned, study was conducted for the facility

Indian Point Generating Station

Hudson River, NY

1985 Study

EA Science and Technology, 1986

Sampling: Dates: May 27 - June 29
Samples collection frequency: daily
Times of peak abundance: sampling did not occur during time of peak densities
Time: daytime, switched to nighttime after June 11 due to low sample sizes
Number of replicates: unknown
Intake and discharge sampling: simultaneous sampling
Elapsed collection time: 13 - 15 minutes (200 m^3)
Method: barrel sampler with 2 coaxial cylinders with 505 μm mesh
one sampler at intake; 2 at discharge
Depth: unknown
Intake location: in front of Unit 2 intake
Discharge location: in discharge canal downstream from Unit 2 discharge
Water quality parameters measured: salinity, DO, pH and conductivity
DOC and POC measured: no
Intake and discharge velocity: discharge: 2.8 - 10 ft/sec

Operating Conditions During Sampling:
Number of units in operation: varied between 1 and 2
Number of pumps in operation: unknown
Temperature: Intake range: 20.3 - 22.9 °C
Discharge range: 26.6 - 30.3 °C
ΔT range: 4.6 - 8.5 °C
Biocide use: residual chlorine not measured

Survival Estimation:
Number of sampling events: 49
Total number of samples collected: unknown
Total number of organisms collected: 457
Cited low efficiency of sampling gear as part of reason for low numbers of organisms sampled
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal no. of organisms collected at intake and discharge: 3X more at discharge
Most abundant species: bay anchovy
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 48 hours
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 23% for bay anchovy
Initial discharge survival range: 6% for bay anchovy
Calculation of Entrainment Survival: Discharge survival / Intake survival
Confidence intervals (95%) were presented
No calculations of significance due to small sample size
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: none collected
Larval survival: decreased markedly within 3 hours of collection.
Raw data: were not provided to verify results
Temperature effects: unknown, too narrow of temperature range sampled
Mechanical effects: New dual-speed pumps installed in Unit 2 in 1984, study was conducted to determine whether extent of mechanical mortality differed from previous studies.
Quality control: SOPs, reanalysis of samples, double keypunch of all data
Peer review: not mentioned, study was conducted for the facility

Indian Point Generating Station

Hudson River, NY

1988 Study

EA Engineering, Science, and Technology, 1989

Sampling: Dates: June 8 - June 30
Samples collection frequency: unclear
Times of peak abundance: sampling not at peak densities for targeted species
Time: afternoon and evening hours
Number of replicates: varied, unknown number per day
Intake and discharge sampling: simultaneous with twice as many at discharge
Elapsed collection time: 15 minutes
Method: rear-draw sampling flumes, 1 at intake and 2 at discharge
Depth: unknown at intake, surface at bottom at discharge
Intake location: on raft in front of Intake 35
Discharge location: downstream from flow of Units 2 and 3
Water quality parameters measured: salinity, DO, pH
DOC and POC measured: no
Intake and discharge velocity: discharge 2.2 - 10.0 ft/sec

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: Intake range: 20.3 - 23.8 °C
ΔT range: not provided
Biocide use: residual chlorine not monitored

Survival Estimation:
Number of sampling events: 13
Total number of samples collected: unknown
Total number of organisms collected: 12,333
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: 10X more in discharge
Most abundant species: bay anchovy, striped bass, white perch
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars for 24 hours
Data: was summarized and averaged over the entire sampling period; discharge survival estimates include data from direct release studies and combined surface and bottom samples
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 0 - 8% for bay anchovy; 86 - 90% for striped bass
Initial discharge survival range: 0 - 2% for bay anchovy; 62 - 68% for striped bass
Calculation of Entrainment Survival: discharge survival / intake survival
Standard errors were presented
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: none survived in intake and discharge samples
Larval survival: decreased markedly within hours of collection
Raw data: were not provided to verify results
Temperature effects: undetermined effect; too narrow range tested
Mechanical effects: study was conducted to determine the effect of the installation of dual speed circulating water pumps in Unit 2 in 1984 and variable speed pumps in Unit 3 in 1985; mechanical effects were determined to be main cause of mortality when discharge temperatures are < 32 °C
Quality control: SOPs, sampling stress evaluation, reanalysis of samples, double keypunch data
Peer review: not mentioned, study was conducted for the facility

Indian River Power Plant

Indian River Estuary

1975-1976 Study

Ecological Analysts Inc., 1978b

Sampling: Dates: July 2, 1975 - December 13, 1976
Samples collection frequency: once or twice monthly
Times of peak abundance: samples not taken frequently enough to detect
Time: mostly at night
Number of replicates: varied
Intake and discharge sampling: not paired
discharge samples not always collected
Elapsed collection time: approximately 5 minutes or until sufficient # collected
Method: 0.5 m diameter plankton sled with 505 μm net
rinsed in 10L of water of unspecified origin
Depth: unknown
Intake location: from foot bridge over intake canal
Discharge location: in discharge canal under roadway bridge
Water quality parameters measured: unknown
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: Intake range: -0.2 - 29.2
Discharge range: 5.4 - 39 °C
ΔT ranged from 5.2 - 9.0 °C
Biocide use was not noted

Survival Estimation:
Number of sampling events: 27
Total number of samples collected: 25 intake and 21 discharge
Total number of organisms collected: unknown
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: unknown
Most abundant species: bay anchovy, Atlantic croaker, spot, weakfish, Atlantic menhaden and Atlantic silversides
Stunned larvae: not discussed
Dead and opaque organisms: not discussed
Latent survival: in holding containers in ambient water baths for 96 hours
Data: sorted based on discharge temperature
Controls: survival in the intake samples was considered to be the control.
Initial intake survival range: not provided
Initial discharge survival range: not provided
Calculation of Entrainment Survival: not all were counted for most abundant species, a random sample was used instead
Confidence intervals / standard deviations: were not presented.
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms: unknown
Egg survival: were alive in either the intake or discharge samples.
Larval survival: unclear trend
Raw data: in Appendix B not available to EPA
Temperature effects: all species had lower survival at discharge temps > 20 ˚C.
only Spot survived above 35 °C though linear regression
Mechanical effects: unknown, however dye studies performed at this facility and recirculation of discharge water has been shown to occur. The extent to which organisms are entrained repeatedly and the effect this has on the number of organisms that were shown to have died through natural causes or from sampling is not known. Thus some intake mortality may be due to the organism's previous passage through the facility.
Quality control: unknown
Peer review: not mentioned, study was conducted for the facility

Muskingum River Plant

Muskingum River, OH

Literature Review

Ecological Analysts Inc., 1979a

Sampling: No on site sampling conducted

Operating Conditions During Sampling:
No sampling conducted

Survival Estimation:
Analyzed pressure regimes in circulating water system
Measured discharge temperature and ΔT at the facility
Determined that pressure regimes were similar to facilities with entrainment survival studies
Determined that low survival occurs at $\Delta T > 7.8$ °C which occurs for a small portion of entrainment season
Reviewed documentation of survival at other steam electric stations
Concluded that potential of survival at this facility was intermediate to high
Peer review: literature review prepared for facility

Northport Generating Station

Long Island Sound, NY

1980 Study

Ecological Analysts Inc., 1981c

Sampling: Dates: April 10 - 22 and July 10 - 23
Samples collection frequency: 5 nights per week
Times of peak abundance: attempted to coincide with peak abundance
Time: 1700 - 0100 hours
Number of replicates: unknown
Intake and discharge sampling: simultaneous
Elapsed collection time: 15 minutes
Method: floating rear-draw sampling flume with 505 μm mesh screens with ambient water injection system
Depth: intake: 2-8 m below surface; discharge: 1.5 m
Intake location: immediately in front of Unit 2 or 3 trash racks
Discharge location: immediately in front of Unit 2 or 3 seal well
Water quality parameters measured: DO, pH, conductivity
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: Discharge range: 15.9 - 35 °C, ave 19.9 in April and 33.6 in July
ΔT ranged from 8.6 - 15.0 °C
Biocide use was not noted

Survival Estimation:
Number of sampling events: 20
Total number of samples collected: 162
Total number of organisms collected: 884 in April and 76 in July
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: more at discharge
Most abundant species: American sand lance, winter flounder, northern pipefish
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated jars of filtered ambient water for 48 hours
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 66% for American sand lance; 85% for winter flounder 28% for bay anchovy
Initial discharge survival range: 17% for American sand lance; 35% for winter flounder 0% for bay anchovy
Calculation of Entrainment Survival: discharge survival / intake survival
Stated that survival estimate based on 4 assumptions: that the survival at the discharge is the product of the probabilities of surviving entrainment and sampling, that the survival at the intake is the probability of surviving sampling, that at the discharge there is no interaction between the two stresses, and each life stage consists of a homogenous population in which all individuals have the same probability of surviving to the next life stage
Standard errors were presented
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: none collected
Larval survival: decreased markedly within 6 hours of collection. American sand lance significantly larger in intake sample
Raw data: were provided to verify results
Temperature effects: not studied
Mechanical effects: not studied
Quality control: SOPs, color coded labels, sorting efficiency checks
Peer review: not mentioned, study was conducted for the facility

Oyster Creek Nuclear Generating Station

Barnegat Bay, NJ

1985 Study

EA Engineering, Science, and Technology, 1986

Sampling: Dates: February - August
- Samples collection frequency: unknown
- Times of peak abundance: smaller samples collected during peak densities
- Time: unknown
- Number of replicates: unknown
- Intake and discharge sampling: discharge collected 2 minutes after intake
- Elapsed collection time: approximately 10 minutes
- Method: barrel sampler with 2 nested cylindrical tanks with 331 mm mesh
- Depth: unknown
- Intake location: northernmost intake groin west of recirculation tunnel
- Discharge location: easternmost condenser discharge point
- Water quality parameters measured: DO, salinity and pH in latent studies
- DOC and POC measured: no
- Intake and discharge velocity: unknown

Operating Conditions During Sampling:
- Number of units in operation: unknown
- Number of pumps in operation: unknown
- Temperature: Discharge range: 13.5 - 39.3 °C
  - ΔT ranged from -0.2 - 12.1 °C
- Biocide use: chlorine concentration was measured, but not detected

Survival Estimation:
- Number of sampling events: 20
- Total number of samples collected: 13 for bay anchovy eggs, 10 for bay anchovy larvae and 5 for winter flounder
- Total number of organisms collected: 60,274
- Number of organisms entrained per year: 619 million to 15.4 billion
- Fragmented organisms: not discussed
- Equal number of organisms collected at intake and discharge: no
- Most abundant species: bay anchovy and winter flounder
- Stunned larvae: included in initial survival proportion; as well as damaged
- Dead and opaque organisms: not discussed
- Latent survival: observed in aerated glass jars in water baths for 96 hours
- Data: grouped by 3 day long sampling events
- Controls: survival in the intake samples was considered to be the control
- Initial intake survival range: 38 - 91% for bay anchovy larvae
  - 77 - 96% for winter flounder larvae
- Initial discharge survival range: 0 - 71% for bay anchovy larvae
  - 32 - 92% for winter flounder larvae
- Calculation of Entrainment Survival: Discharge survival / Intake survival
- Confidence intervals / standard deviations: were not presented
- Significant differences were not tested between the intake and discharge survival
- Survival calculated for species with fewer than 100 organisms collected: no
- Egg survival: based on translucency and hatching success
- Larval survival: decreased markedly within 3 hours of collection
- Raw data: were not provided to verify results
- Temperature effects: no bay anchovy larvae survived at discharge > 35 °C
- Mechanical effects: 18.8% of mortality at discharge temperatures 25.9 - 27.0 °C
- Quality control: unknown
- Peer review: not mentioned, study was conducted for the facility

Pittsburg Power Plant

Suisun Bay, CA

1976 Study

Stevens and Finlayson, 1978

Sampling: Dates: April 28 - July 10
Samples collection frequency: once per week
Times of peak abundance: unknown
Time: varied, about 25% of all samples collected at night
Number of replicates: typically 3
Intake and discharge sampling: paired at closest time and temperature
Elapsed collection time: 1 - 2 minutes
Method: 505 micron mech conical nylon plankton net with 0.58 m plastic collecting tubes on cod end; towed net on boat at 0.6 ft/sec
Depth: mid-depth
Intake location: in river near intake
Discharge location: in river near discharge
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: Intake temperature: 18 - 30 °C
Discharge temperature 27 - 37 °C
Biocide use was not noted

Survival Estimation:
Number of sampling events: 7
Total number of samples collected: unknown
Total number of organisms collected: 462 (585 at north shore control)
Number of organisms entrained per year: unknown
Fragmented organisms: enumerated in one replicate tow
higher proportion of unidentifiable fragments in intake
43% in intake; 19% in discharge
Equal number of organisms collected at intake and discharge: more at intake
Most abundant species: striped bass
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: not studied
Data: was summarized by mean larval length
Controls: survival in the intake samples was considered to be the control
additional controls in center of river and north shore
control site at north shore away from intake had lower mortality rates
Initial intake survival range: 49 - 93% for striped bass
Initial discharge survival range: 8 - 87% for striped bass
Calculation of Entrainment Survival: paired discharge survival divided by paired intake survival
Confidence intervals / standard deviations: were not presented
Significant differences were not tested between the intake and discharge survival
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Larval survival: increased survival with greater larval length
Raw data: were not provided to verify results
Temperature effects: mortality increased with increase in discharge temperature
higher mortality with discharge temp. > 31 and ΔT > 7 °C
linear regression showed that half died at temps >33.3 °C
0% survival at temperatures of 38 °C
Mechanical effects: stated not as much of an effects as temperature;
recirculated water may be cause of some intake mortality
Quality control: not discussed
Peer review: study conducted by California Fish and Game with funds provided by facility

Port Jefferson Generating Station

Long Island Sound, NY

1978 Study

Ecological Analysts Inc., 1978d

Sampling: Dates: April 21 - 26
Samples collection frequency: 4 times in one week
Times of peak abundance: unclear if sampling coincided with peak densities
Time: 1800 - 0200 hours
Number of replicates: varied between 7 - 10 per sampling date.
Intake and discharge sampling: simultaneous collection, equal number at sites
Elapsed collection time: 15 minutes
Method: pump (2 different types) and larval table
Depth: intake: 2 m below mean low water mark
discharge: 1 m below mean low water mark
Intake location: in front of trash racks of intake of Unit 4
Discharge location: in common seal well structure for Units 3 and 4
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: 4
Temperature: Intake range: 7 - 9 °C
Discharge range: 10 - 18 °C
ΔT ranged from 2 - 11 °C
Biocide use: sampling coincided with time of no biocide use

Survival Estimation:
Number of sampling events: 5
Total number of samples collected: 94
Total number of organisms collected: 1104
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: no, quite different
Most abundant species: winter flounder, sand lance, sculpin, American eel, fourbeard rockling eggs
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not discussed
Latent survival: observed in aerated glass jars in water bath for 96 hours
Data: was summarized and averaged over the entire sampling period
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 42 - 60% for winter flounder PYSL;
11 - 67% for sand lance PYSL
33 - 84% sculpin PYSL
25 - 100% American eel juveniles
11 - 26% fourbeard rockling eggs
Initial discharge survival range:0 - 43% for winter flounder PYSL
12 - 40% for sand lance PYSL
88% for sculpin PYSL
94 - 96% for American eel juveniles
19 - 21% fourbeard rockling eggs
Calculation of Entrainment Survival: Discharge survival / intake survival
Confidence intervals / standard deviations: were not presented.
Significant differences were tested between the intake and discharge survival
Significantly lower survival in discharge: winter flounder PYSL
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: classified by observation only, based on transparency
Larval survival: no information given on length or other life stages
Raw data: were provided to verify results
Temperature effects: no apparent relationship temperature and survival; low numbers collected at a narrow range of discharge temperatures
Mechanical effects: assumed cause of all mortality
Quality control: color coded labeling, checks of sorted samples, and SOPs
Peer review: not mentioned, study was conducted for the facility

PG&E Potrero Power Plant

San Francisco Bay, CA

1979 Study

Ecological Analysts Inc., 1980b

Sampling: Dates: January
- Samples collection frequency: unknown
- Times of peak abundance: unclear if sampling corresponded with peak densities
- Time: unknown
- Number of replicates: unknown
- Intake and discharge sampling: equal number but timing unknown
- Elapsed collection time: 15 minutes
- Method: 2 pumps and larval table with filtered ambient temperature water flow
- Depth: mid-depth
- Intake location: directly in front of intake skimmer wall
- Discharge location: at point where discharge enters San Francisco Bay
- Water quality parameters measured: none
- DOC and POC measured: no
- Intake and discharge velocity: unknown

Operating Conditions During Sampling:
- Number of units in operation: unknown
- Number of pumps in operation: unknown
- Temperature: Discharge range: 18 - 19.5 °C
  - ΔT range not presented
- Biocide use: not used during sampling events

Survival Estimation:
- Number of sampling events: 11
- Total number of samples collected: 25
- Total number of organisms collected: 1262
- Number of organisms entrained per year: estimated for Units 1-3: 3 billion
- Fragmented organisms: not discussed
- Equal number of organisms collected at intake and discharge: approx. same
- Most abundant species: Pacific herring
- Stunned larvae: issue of stunned larvae not discussed in study
- Dead and opaque organisms: not discussed
- Latent survival: observed in aerated glass jars in water baths for 96 hours
- Data: was summarized and averaged over the entire sampling period
- Controls: survival in the intake samples was considered to be the control
- Initial intake survival range: 22% for Pacific herring
- Initial discharge survival range: 16% for Pacific herring
- Calculation of Entrainment Survival: Discharge survival/ Intake survival
- Confidence intervals / standard deviations: were not presented.
- Significant differences were not tested between the intake and discharge survival
- Survival calculated for species with fewer than 100 organisms collected: no
- Egg survival: not studied
- Larval survival: Based on results of this study, an estimate of 75% entrainment survival was used for all species and life stages entrained at this facility under all conditions
- Raw data: were not provided to verify results
- Temperature effects: discharge temps < 30 °C over 99.5% of time
- Mechanical effects: most likely cause of mortality due to low temperatures
- Quality control: unknown
- Peer review: not mentioned, study was conducted for the facility

Quad Cities Nuclear Station

Mississippi River, IL

1978 Study

Hazleton Environmental Science Corporation, 1978

Sampling: Dates: June 19 - 28
Samples collection frequency: varied
Times of peak abundance: unknown
Time: afternoon, evening or nighttime hours
Number of replicates: varied
Intake and discharge sampling: unknown if paired
Elapsed collection time: did not exceed 60 seconds
Method: from boat, with 0.75 m conical plankton net with 526 μm mesh and an unscreened 5 L bucket attached
Depth: mid-depth at intake, near surface at discharge
Intake location: intake forebay
Discharge location: in discharge canal common to all units;
held at discharge temp for 8.5 minutes to simulate passage through canal
then cooled to ambient temp. plus 3.5 °C before sorting
Water quality parameters measured: DO
DOC and POC measured: no
Intake and discharge velocity: exceed 1 ft/sec

Operating Conditions During Sampling: completely open cycle mode
Number of units in operation: power output 41 - 99%, Unit 1 offline on June 22
Number of pumps in operation: all 3 regardless of power load
Temperature: Intake range: 21.5 - 26.5 °C
Discharge range: 28.0 - 39.0 °C
ΔT ranged from 5.5 - 14.8 °C
Biocide use: not used during sampling

Survival Estimation:
Number of sampling events: 5
Total number of samples collected: unknown
Total number of organisms collected: 2587
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: more at discharge
Most abundant species: freshwater drum and minnows
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: assumed dead from natural mortality prior to collection and omitted from further analysis; 27% of all sampled
Latent survival: observed in aerated glass jars for 24 hours on June 22-23, 26-27
Data: combined by % power of station operation
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 0 - 80% for all species
0 - 100% for freshwater drum
48 - 100% for minnows
Initial discharge survival range: 0 - 84% for all species
0 - 71% for freshwater drum
2 - 75% for minnows
Calculation of Entrainment Survival: Discharge survival/Intake survival
(minus dead and opaque individuals)
When discharge survival was greater than intake survival, the study indicated that entrainment survival could not be calculated, rather than assume 100% entrainment survival
Confidence intervals / standard deviations: were not presented.
Significant differences were tested between the intake and discharge survival
Significantly lower survival in discharge: throughout study
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not presented
Larval survival: decreased with increasing power output and discharge temperature
3% survival for all species when the facility operated near full capacity
(96-99%) and discharge temperatures exceeded 37.9 ˚C
Raw data: were provided to verify results, however replicate sample data not presented
Temperature effects: lower survival with higher discharge temperatures > 30 °C
Mechanical effects: suggest mechanical effects cause 20 - 25% of mortality
Quality control: not discussed
Peer review: not mentioned, study was conducted for the facility

Quad Cities Nuclear Station

Mississippi River, IL

1984 Study

Lawler, Matusky & Skelly Engineers, 1985

Sampling: Dates: April 25 - June 27
July sampling canceled as 100% mortality was suspected
Samples collection frequency: weekly
Times of peak abundance: unknown
Time: unknown
Number of replicates: unknown
Intake and discharge sampling: unknown if paired
Elapsed collection time: unknown
Method: from boat, with 0.75 m conical plankton net with 526 μm mesh and an unscreened 5 L bucket attached
Depth: 1.5 m for intake, surface for discharge
Intake location: intake forebay
Discharge location: in discharge canal; held at collection temperature for 8.5 min. then cooled to 3.5 °C above ambient temperature with an ice bath, in all held for over 20 minutes before sorting
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: samples collected at < 0.8 ft/sec

Operating Conditions During Sampling: operating at 40.2 to 50.7% capacity
Number of units in operation: Unit 1 offline for refueling; both units offline on May 9
Number of pumps in operation: all 3 on all dates except on May 9
Temperature: Intake range: 11 - 24.4 °C
Discharge range: 12 - 37 °C
ΔT ranged from 9.5 to 14.5 °C; 1 °C on May 9 when offline
Biocide use: not used during sampling

Survival Estimation:
Number of sampling events: 8
Total number of samples collected: unknown
Total number of organisms collected: 3967
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal number of organisms collected at intake and discharge: approx. same total
Most abundant species: freshwater drum, carp and buffalo
Stunned larvae: not discussed
Dead and opaque organisms: omitted from analysis; assumed dead before collection, 2, 979 opaque individuals were collected (75% of total, 87% of all discharge sample. range: 0 to 99% in samples) None were found to be dead and opaque in discharge on May 9 when offline and ΔT was 1˚ C.
Latent survival: not discussed
Data: combined by species and sampling date
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: results not presented, only number alive 10 - 81% were dead and opaque
Initial discharge survival range: results not presented, only number alive 24 - 99% were dead and opaque
Calculation of Entrainment Survival: Discharge survival / Intake survival
Confidence intervals / standard deviations: were not presented.
Significant differences were not tested due to low numbers collected
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Larval survival: too little information to make any assumption of survival
Raw data: were not provided to verify results; totals collected per species not presented; actual numbers of dead and opaque not provided
Temperature effects: no sampling in July when discharge temps > 37 °C
Mechanical effects: not discussed
Quality control: 100% reanalysis quality control
Peer review: not mentioned, study was conducted for the facility

Roseton Generating Station

Hudson River, NY

1975 Study

Ecological Analysts Inc., 1976c

Sampling: Dates: May 29th - November 18th
Collection frequency: varied from 4 times per week to once every 2 weeks.
Times of peak abundance: greater frequency of collection
Time: varied but generally occurred between dusk and dawn
Number of replicates: varied between 3and 14 for each date
Intake and discharge sampling: paired but timing not standardized
Elapsed collection time: not noted
Method: pump/larval table
Depth: mid-depth at both the intake and discharge
Intake location: in front of the trash rack
Discharge location: from the seal well before the end of the discharge pipe
Water quality parameters measured: none mentioned
DOC and POC measured: no
Intake and discharge velocity: not given

Operating Conditions During Sampling:
Number of units in operation: varied between 1 and 2
Number of pumps in operation: varied between 2 and 3
Temperature: ΔT ranged from 3 to 13 °C, intake and discharge T not given
Biocide use: not noted

Survival Estimation:
Number of sampling events: 41
Number of samples: 672
Number of organisms collected: 3,667
Number of organisms entrained per year: not discussed
Fragmented organisms collected: not discussed
Equal number collected from intake and discharge: differed by as much as 3.2X
Most abundant species: striped bass, white perch, alewife and blueback herring
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not mentioned
Latent survival: observed in aerated glass jars for 96 hours.
Data: summarized and averaged over the entire sampling period
Controls: survival in intake sample; no other control
Initial intake survival range: 57 to 80% for striped bass
0 to 71% for white perch
58 to 65% for herrings
Initial discharge survival range: 62% for striped bass
29% for white perch
26% for herrings
Calculation of entrainment survival: Discharge Survival/Intake Survival
Study noted that survival cannot be calculated with insufficient data or when intake survival is very low
Confidence intervals/ standard deviations: not presented
Significant differences: tested between the intake and discharge survival
Significantly lower survival in discharge: striped bass YSL and PYSL
white perch PYSL
herring PYSL and juveniles
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: none alive in either the intake or discharge samples
Larval survival: decreased markedly within 3 hours of collection
Size effects: survival by larval length was not studied
Raw data: were not provided to verify results
Temperature effects: not provided
Mechanical effects: not provided
Quality control: double check after initial sorting; monitoring of data entry
Peer review: not mentioned; study was conducted for the facility

Roseton Generating Station

Hudson River, NY

1976 Study

Ecological Analysts Inc., 1978e

Sampling: Dates: June 14th - July 30th
Samples collection frequency: 4 nights per week
Times of peak abundance: coincided with *Morone* spp. spawning season
Time: 1700 to 0300 EST
Number of replicates: actual numbers not give, an average of 12 per night stated
Intake and discharge sampling: pairing unknown
Elapsed collection time: 15 minutes
Method: pump/ larval table combination
Depth: mid-depth for both intake and discharge
Intake location: 1 m in front of trash rack
Discharge location: in seal well near end of discharge pipe
Water quality parameters measured: no
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: varied between 0 and 2
Number of pumps in operation: not given
Temperature: Intake temperature range: 18.7 - 27.5 °C
Discharge temperature ranged 24 - 37 °C
ΔT ranged from 1- 10 °C
Biocide use: not noted

Survival Estimation:
Number of sampling events: 27
Total number of samples collected: unknown
Total number of organisms collected: 3,491
Number of organisms entrained per year: not given
Fragmented organisms: not discussed
Equal number of organisms collected at intake / discharge: no, up to 5.7X more
Most abundant species: herrings, white perch and striped bass
Stunned larvae: were included in initial survival proportion
Dead and opaque organisms: not mentioned
Latent survival: observed in aerated glass jars for 96 hours
Data: combined by discharge temperature range: 34 - 30.5 and 30.6 to 37 °C
Controls: Survival in the intake samples; no other control.
Initial intake survival range: 74-100% for striped bass
53-94% for white perch
49-68% for herrings
Initial discharge survival range: 14 - 80% for striped bass
6 - 56% for white perch
5 - 29% for herrings
Calculation of Entrainment Survival: Discharge Survival/ Intake Survival
Data for many taxa or life stages collected were insufficient for analysis
Confidence intervals / standard deviations: were not presented
Significant differences were tested between the intake and discharge survival
Significantly lower survival in discharge: striped bass PYSL
white perch PYSL and juveniles
herring PYSL and juveniles
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: data not presented
Larval survival: decreased markedly within 3 hours of collection.
Size effects: survival by larval length was not studied
Raw data: were not provided to verify results
Temperature effects: significant decrease in survival at discharge temp > 30 °C
Mechanical effects: unknown
Quality control: double check after initial sorting; monitoring of data entry
Peer review: not mentioned, study was conducted for the facility

Roseton Generating Station

Hudson River, NY

1977 Study

Ecological Analysts Inc., 1978f

Sampling: Dates: March 3-17 and May 31st - July 15th
Samples collection frequency: unknown; usually 4 nights per week was stated
Times of peak abundance: coincided with spawning of targeted species
Time: 1700 to 0300 hours EST
Number of replicates: unknown; an average of 8 to 10 per night was stated
Intake and discharge sampling: unknown if samples were collected in pairs
Elapsed collection time: 15 minutes
Method: pump/larval table combination
ambient water flow in table to reduce thermal exposure during sorting
Depth: mid-depth
Intake location: in front of trash racks
Discharge location: from seal well 244 m from end of discharge pipe
Water quality parameters measured: no
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: varied between 2 and 4
Temperature: Intake temperature: 0.5 - 5.5 °C (March); 11-27 °C (June/July)
Discharge temperature: 7 - 17 °C (March); 24 - 36 °C (June/July)
ΔT range: unknown
Biocide use was not noted

Survival Estimation:
Number of sampling events: unknown
Total number of samples collected: unknown
Total number of organisms collected: 6,973
Number of organisms entrained per year: unknown
Fragmented organisms: if >50% present, organism was counted
Equal number collected at intake and discharge: up to 2.3X more in discharge
Most abundant species: atlantic tomcod, herrings, striped bass, white perch
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not mentioned
Latent survival: observed in aerated glass jars for 96 hours
Data: combined by discharge temperature range, <29.9, 30.0 - 32.9, >33 °C
Controls: Survival in the intake samples was considered to be the control
Initial intake survival range: 39% for Atlantic tomcod
0 to 50% for striped bass
0 to 33% for white perch
0 to 59% for herrings
Initial discharge survival range: 16% for Atlantic tomcod
0 to 83% for striped bass
0 to 50% for white perch
0 to 14% for herrings
Calculation of Entrainment Survival: Discharge Survival / Intake Survival
Confidence intervals / standard deviations: were not presented.
Significant differences were tested between the intake and discharge survival
Significantly lower survival in discharge: Atlantic tomcod YSL
striped bass PYSL
white perch PYSL
herring PYSL and juveniles
Survival calculated for species with fewer than 100 organisms collected: yes
number of some taxa and life stage were too low to estimate survival reliably
Egg survival: data not presented
Larval survival: decreased markedly within 3 hours of collection.
increased with larval length
Raw data: were not provided to verify results
Temperature effects: survival decreased at temperatures above 30 °C
very low survival at temperatures > 33 °C (0 to 3%)
Mechanical effects: survival may increase with number of pumps operating
Quality control: color coded labels, immediate checks of sorted sample, SOP's
Peer review: not mentioned, study was conducted for the facility

Roseton Generating Station

Hudson River, NY

1978 Study

Ecological Analysts Inc., 1980c

Sampling: Dates: March 13 - 23 and June 6 - July 13
Samples collection frequency: 3 - 4 nights per week
Times of peak abundance: coincided with spawning of targeted species
Time: 1700 to 0300 EDT
Number of replicates: 4 to 10 per night
Intake and discharge sampling: unknown if paired samples
Elapsed collection time: 15 minutes
Method: pump/ larval table combination with fine mesh
ambient water flow to table to minimize thermal exposure when sorting
Depth: mid-depth
Intake location: in front of trash rack
Discharge location: in seal well 244 m from end of discharge pipe
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: varied between 1 and 2
Number of pumps in operation: varied between 2 and 3
Temperature: Intake temperature: 0.2 - 5.5 °C (March), 19.8 - 24.0 °C (June/July)
Discharge temperature: 10 - 19 °C (March), 24 - 37 °C (June/July)
ΔT range was not given
Biocide use was not noted

Survival Estimation:
Number of sampling events: 30
Total number of samples collected: 256
Total number of organisms collected: 5,308
Number of organisms entrained per year: unknown
Fragmented organisms: counted if >50% of organism was present
22% of Atlantic tomcod could not be identified to life stage due to damage
Equal number of organisms collected at intake and discharge: varied
Most abundant species: herrings, white perch, striped bass, Atlantic tomcod
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not mentioned
Latent survival: observed in aerated glass jars for 96 hours
Data: combined by discharge temperature range <29.9, 30.0 - 32.9, >33 °C
also combined by larval length
Controls: Survival in the intake samples was considered to be the control
Initial intake survival range: 75-84% for Atlantic tomcod
8 - 100% for striped bass
0 - 93% for white perch
0 - 67% for herrings
Initial discharge survival range: 23-33% for Atlantic tomcod
0 - 50% for striped bass
0 - 100% for white perch
0 - 18% for herrings
Calculation of Entrainment Survival: Discharge survival/ Intake survival
Confidence intervals / standard deviations: were not presented
Significant differences were tested between the intake and discharge survival
Significantly lower survival in discharge: Atlantic tomcod YSL and PYSL
striped bass PYSL
white perch PYSL
herring PYSL
Survival calculated for species with fewer than 100 organisms collected: yes
samples sizes of some taxa and life stages were too small to analyze survival
Egg survival: data not presented
Larval survival: decreased markedly within 3 - 6 hours of collection
increased with larval length
Raw data: consolidated data by temp. and length was provided; not by sample
Temperature effects: significant decrease in survival at temperatures > 24 °C
very little survival at temperatures > 30 °C
Mechanical effects: lower tomcod survival in discharge w/o thermal effects
Quality control: color coded labels, checks of sorted samples, SOP’s
Peer review: not mentioned, study was conducted for the facility

Roseton Generating Station

Hudson River, NY

1980 Study

Ecological Analysts Inc., 1983

Sampling: Dates: May 26 - July 31
Samples collection frequency: usually 4 nights per week
Times of peak abundance: coincided spawning of striped bass and white perch
Time: 1600 to 0200 EDT
Number of replicates: varied between 1 and 10 per sampling date
Intake and discharge sampling: unknown if samples were paired
Elapsed collection time: 15 minutes
Method: pump/larval table or plankton sampling flume
ambient water injection system to minimize thermal exposure
Depth: unknown
Intake location: from the No. 1B circulating water pump forebay
Discharge location: from discharge seal well or submerged diffuser port
Water quality parameters measured: none
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: varied between 1 and 2
Number of pumps in operation: varied between 3 and 4
Temperature: Intake temperature: 17.0 - 29.0 °C
Discharge temperature: 21.5 - 34.5 °C
ΔT range not given
Biocide use was not noted

Survival Estimation:
Number of sampling events: 42
Total number of samples collected: 1431
Total number of organisms collected: 4,965
Number of organisms entrained per year: not given
Fragmented organisms: counted if >50% of organism was present
7% of all organisms would not be identified to a life stage due to damage
Equal no. of organisms collected at intake/ discharge: more samples at discharge
Most abundant species: herrings, striped bass, white perch
Stunned larvae: were included in initial survival proportion
Dead and opaque organisms: not mentioned
Latent survival: observed in aerated glass jars for 48 hours.
Data: combined by larval length
Controls: survival in the intake samples was considered to be the control
Initial intake survival range: 33 - 100% for striped bass
0 - 75% for white perch
30 - 53% for herrings
Initial discharge survival range: 23 - 100% for striped bass
0 - 88% for white perch
0 - 31% for herrings
Calculation of Entrainment Survival: Discharge survival / Intake survival
Confidence intervals / standard deviations: were not presented.
Significant differences were tested for latent survival only
Survival calculated for species with fewer than 100 organisms collected: yes
Egg survival: not studied
Larval survival: decreased markedly within 3 - 6 hours of collection
survival increased with larval length
survival lowest for YSL and highest for juveniles
survival using flume was very low
Raw data: only consolidated data were presented, not by sample
Temperature effects: data not given
Mechanical effects: number of pumps may not affect survival
Quality control: color coded labels, SOPs
Peer review: not mentioned, study was conducted for the facility

Salem Generating Station

Delaware Bay, NJ

1984 Demonstration Study

PSE&G, 1984

Sampling: Dates: 1977 - 1982
Samples collection frequency: varied, 1 to 4 times per month
Times of peak abundance: highest frequency in June and July
Time: unknown
Number of replicates: varied from 0 to 13 per sampling event
Intake and discharge sampling: usually paired with lag time
Elapsed collection time: 10 minutes
Method: larval table(1977- 1980) or low-velocity flume (1981-1982)
Depth: mid-depth for intake
Intake location: at intake bay 11A or 12B, inboard of traveling screen
Discharge location: discharge standpipe 12 or 22
Water quality parameters measured: unknown
DOC and POC measured: no
Intake and discharge velocity: unknown

Operating Conditions During Sampling:
Number of units in operation: unknown
Number of pumps in operation: unknown
Temperature: Intake temperature: unknown
Discharge temperature: unknown
ΔT range: unknown
Lab simulation studies used to test thermal mortality
Biocide use: three 30 minute periods of chlorination each day
estimated biocide use reduces survival by 6.25%

Survival Estimation:
Number of sampling events: 0 to 12 per year, 38 in all years combined
Total number of samples collected: varied per year, 640 in all years combined
Total number of organisms collected: 5,173 larvae and juvenile fish of 6 taxa
Number of organisms entrained per year: unknown
Fragmented organisms: not discussed
Equal no. of organisms collected at intake/ discharge: unknown
Most abundant species: spot and alewife
Stunned larvae: included in initial survival proportion
Dead and opaque organisms: not mentioned
Latent survival: tests varied with year, 12 to 96 hours in jars or aquaria
Data: combined data from all years, collected under all conditions
Controls: some fish were introduced into the larval table or low velocity flume directly; unclear if organisms passed through facility
Initial intake survival range: 90.9% for Spot
12.5% for Herrings
Initial discharge survival range: 74.1% for Spot
7.1% for Herrings
Calculation of Entrainment Survival: Discharge survival / Intake survival
Estimated survival rates from onsite and simulation studies and compared with results in the literature from other waterbodies to select "the most realistic estimates"
Confidence intervals / standard deviations: not presented
Significant differences: not tested
Survival calculated for species with fewer than 100 organisms collected: unknown
Egg survival: none collected
Larval survival: not separated from juvenile survival
Raw data: was not provided to verify results
Temperature effects: unknown
Mechanical effects: tested gear efficiency and related mortality only
Quality control: not mentioned
Peer review: not mentioned, study conducted for the facility

Chapter A8: Discounting Benefits

Chapter Contents

Introduction

Discounting refers to the economic conversion of future benefits and costs to their present values, accounting for the fact that individuals tend to value future outcomes less than comparable near-term outcomes. Annualization refers to the conversion of a series of annual costs or benefits of differing amounts to an equivalent annual series of constant costs or benefits. Discounting and annualization are important because these techniques allow the comparison of benefits and costs that occur in different time periods.

For the benefits analysis for the proposed section 316(b) regulation for Phase III facilities, EPA's discounting and annualization methodology included three steps. First, EPA developed a time profile of benefits to show when benefits occur. Second, the Agency calculated the total discounted value of the benefits as of the year 2007. Finally, EPA annualized the benefits of the regulation over a thirty year time span. The following sections explain these steps in detail.

A8-1 Timing of Benefits

In order to calculate the annualized value of the welfare gain from the proposed section 316(b) regulation for Phase III facilities, EPA developed a time profile of total benefits from all Phase III facilities that reflects when benefits from each facility will be realized. EPA first calculated the undiscounted commercial and recreational welfare gain from the expected annual regional reductions in impingement and entrainment (I&E) under the rule, based on the assumptions that all facilities in each region have achieved compliance with the rule and that benefits are realized immediately following compliance. Then, since there are regulatory and biological time lags between promulgation of the rule and the realization of benefits, EPA created a time profile of benefits that takes into account the fact that benefits do not begin immediately. Since this time profile requires information about facility-specific differences in magnitude and timing of benefits, but benefits were estimated only on a regional basis, EPA approximated benefits from each facility by multiplying total undiscounted regional benefits by the percentage of total regional flow that is attributable to each facility.

Regulatory-related time lags occur because although the proposed regulation will take effect at the beginning of 2007, facilities will not need to come into compliance with the rule until their current NPDES permits expire.[1] EPA used facility-specific permitting information to estimate the lag between promulgation of the rule and the compliance year for each facility. The terms of each facility's permit differ, but permits for all Phase III facilities are expected to expire between 2010 and 2014. Thus, EPA estimates that it will take from three to seven years after promulgation of the rule for Phase III facilities to install BTA to reduce I&E.

The biological time lags that affect the timing of benefits occur because most fish that will be spared from I&E will be in larval or juvenile stages. Since these fish may require several years to grow and mature before they can be harvested by commercial and recreational anglers, there will be a lag between installation of BTA and realization of commercial and recreational angling benefits. For example, a larval fish spared from entrainment (in effect, at age zero) may be caught by a recreational angler at age three, meaning that a three year time lag

[1] The final regulation for Phase III facilities is scheduled to be promulgated in June of 2006. However, to simplify the discounting and annualization calculations for the benefit cost analysis, EPA assumed that the regulation will take effect on January 1, 2007.

arises between the installation of BTA and the realization of the estimated recreational benefit. Likewise, if a one year old fish is spared from impingement and is then harvested by a commercial fisherman at age two, there is a one year lag between the installation of BTA and the subsequent commercial fishery benefit. In general, fish that tend to be harvested at young ages will have relatively short time lags between implementation of BTA and the subsequent timing of changes in catch. In contrast, long-lived fish that tend to be caught at relatively older ages will tend to have longer time lags (and, hence, they will have larger impacts from discounting and lower present values).

In order to model the biological lags between installation of BTA and realization of commercial and recreational benefits, EPA collected species-specific information on ages of fish at harvest to estimate the average time required for a fish spared from I&E to reach a harvestable age. The estimated time lags range from 0.5 years to six years, depending on the life history of each fish species affected. EPA used this information, along with information about the estimated age and species composition of I&E losses in each study region, to develop a benefits recognition schedule for facilities in each region. Following achievement of compliance, benefits from facilities in most regions are assumed to increase over a seven year period to a long-term, steady state average, equal to the approximated per-facility benefit value discussed above, according to a numerical profile of < 0.0, 0.1, 0.2, 0.8, 0.9, 0.95, 1.0 >. This profile indicates the fraction of the steady state benefit value that is realized in each of the first seven years following the achievement of compliance at a facility. After seven years, this fraction remains 1.0 for 23 additional years. After these combined 30 years the facility is assumed to cease compliance, which is consistent with the time period over which costs are evaluated. In the same way that the benefits profile builds up over time following compliance, the benefits profile declines at the end of the compliance period. Specifically, in the seven years following the end of compliance, the fraction of the steady state benefit value achieved follows the profile of < 1.0, 0.9, 0.8, 0.2, 0.1, 0.05, 0.0 >. Therefore, the analysis of benefits encompasses a 37-year period starting with the first year of compliance. There are 35 years when benefits do not equal zero for a facility; 25 years when benefits are 100%; 10 years when benefits are a percentage of the total. These profile values are approximations based on a review of the age-specific fishing mortality rates that were used in the I&E analysis and best professional judgment. Although EPA believes this approach is sufficient for this analysis, EPA could potentially refine these profile values through the use of a population model and will consider the feasibility of doing so.

For regions with the relatively high contribution of impingement to total I&E (Inland, Great Lakes, and the Gulf of Mexico regions), EPA used an adjusted benefits profile of < 0.1, 0.2, 0.8, 0.9, 0.95, 1.0 >. This adjusted profile reflects that impinged fish are usually larger and older than entrained fish and thus benefits will be realized sooner in these regions.

A8-2 Discounting and Annualization

Using the time profile of benefits discussed above, EPA discounted the total benefits generated in each year of the analysis to 2007, and then summed them to calculate the total discounted welfare gain from the proposed rule. EPA then calculated an equivalent constant (annualized) value that could be paid each year for 30 years, such that the total discounted value of the 30 year stream of constant payments would be equal to the total discounted welfare gain from the proposed rule. EPA performed these discounting and annualization calculations using two discount rates: a real rate of 3%, and a real rate of 7%. The 3% rate represents a reasonable estimate of the social rate of time preference. The 7% rate represents an alternative discount rate, recommended by the Office of Management and Budget (OMB), that reflects the estimated opportunity cost of capital.

Table A8-1 presents an illustrative summary of the time profile of undiscounted benefits for one of the proposed options, for each region and for the entire U.S. The table also presents the total discounted value and annualized value that are equivalent to this stream of undiscounted benefits.

Table A8-1: Time Profile of Mean Total Use Benefits for the "50 MGD for All Waterbodies" Option (thousands; 2003$)[a,b]

Year	California	North Atlantic	Mid-Atlantic	Gulf of Mexico	Great Lakes	Inland	National Total
2007	$0	$0	$0	$0	$0	$0	$0
2008	$0	$0	$0	$0	$0	$0	$0
2009	$0	$0	$0	$0	$0	$0	$0
2010	$0	$0	$0	$0	$0[e]	$7	$7
2011	$3	$0	$7	$0	$11	$33	$54
2012	$7	$5	$14	$76	$26	$96	$223
2013	$27	$10	$99	$152	$106	$231	$625
2014	$31	$42	$164	$608	$160	$275	$1,280
2015	$32	$50	$439	$684	$291	$329	$1,826
2016	$34	$72	$571	$722	$371	$349	$2,120
2017	$34	$78	$607	$760	$391	$354	$2,225
2018	$34	$79	$636	$760	$406	$358	$2,272
2019	$34	$81	$643	$760	$410	$358	$2,286
2020	$34	$81	$643	$760	$410	$358	$2,286
2021	$34	$81	$643	$760	$410	$358	$2,286
2022	$34	$81	$643	$760	$410	$358	$2,286
2023	$34	$81	$643	$760	$410	$358	$2,286
2024	$34	$81	$643	$760	$410	$358	$2,286
2025	$34	$81	$643	$760	$410	$358	$2,286
2026	$34	$81	$643	$760	$410	$358	$2,286
2027	$34	$81	$643	$760	$410	$358	$2,286
2028	$34	$81	$643	$760	$410	$358	$2,286
2029	$34	$81	$643	$760	$410	$358	$2,286
2030	$34	$81	$643	$760	$410	$358	$2,286
2031	$34	$81	$643	$760	$410	$358	$2,286
2032	$34	$81	$643	$760	$410	$358	$2,286
2033	$34	$81	$643	$760	$410	$358	$2,286
2034	$34	$81	$643	$760	$410	$358	$2,286
2035	$34	$81	$643	$760	$410	$358	$2,286
2036	$34	$81	$643	$760	$410	$358	$2,286
2037	$34	$81	$643	$760	$410	$358	$2,286
2038	$34	$81	$643	$760	$410	$358	$2,286
2039	$34	$81	$643	$760	$410	$358	$2,286
2040	$34	$81	$643	$760	$410	$351	$2,279
2041	$31	$81	$636	$760	$400	$324	$2,232
2042	$27	$76	$629	$684	$384	$262	$2,063
2043	$7	$71	$543	$608	$304	$127	$1,661
2044	$3	$39	$479	$152	$250	$83	$1,006
2045	$2	$31	$203	$76	$120	$28	$460
2046	$0	$9	$71	$38	$39	$8	$166
2047	$0	$3	$36	$0	$19	$4	$61
2048	$0	$2	$7	$0	$5	$0[e]	$14
Evaluated at 0%							
Total Present Value[c]	$1,024	$2,430	$19,287	$22,799	$12,306	$10,734	$68,581
Annualized Value[d]	$34	$81	$643	$760	$410	$358	$2,286
Evaluated at 3%							
Total Present Value[c]	$577	$1,298	$10,239	$12,463	$6,602	$5,998	$37,176
Annualized Value[d]	$29	$66	$522	$636	$337	$306	$1,897
Evaluated at 7%							

Table A8-1: Time Profile of Mean Total Use Benefits for the "50 MGD for All Waterbodies" Option (thousands; 2003$)[a,b]

Year	California	North Atlantic	Mid-Atlantic	Gulf of Mexico	Great Lakes	Inland	National Total
Total Present Value[c]	$302	$635	$4,972	$6,280	$3,252	$3,113	$18,556
Annualized Value[d]	$24	$51	$401	$506	$262	$251	$1,495

[a] The estimate of the total use value of I&E reductions includes recreational and commercial fishing benefits. EPA estimated non-use benefits only qualitatively.

[b] Note that all monetary values in this table are expressed in thousands 2003$, since EPA did not adjust the values for inflation.

[c] The total present value is equal to the sum of the values of the benefits realized in all years of the analysis, discounted to 2007.

[d] The annualized value represents the total present value of the benefits of the regulation, distributed over a thirty year period.

[e] Positive non-zero value less than $500.

Source: U.S. EPA analysis for this report.

Chapter A9: Threatened & Endangered Species Analysis Methods

Introduction

Threatened and endangered (T&E) and other special status species can be adversely affected in several ways by cooling water intake structures (CWISs). T&E species can suffer direct harm from impingement and entrainment (I&E), they can suffer indirect impacts if I&E at CWISs adversely affects another species upon which the T&E species relies within the aquatic ecosystem (e.g., as a food source), or they can suffer impacts if the CWIS disrupts their critical habitat.[1] The loss of individuals of listed species from CWISs is particularly important because, by definition, these species are already rare and at risk of irreversible decline because of other stressors.

This chapter provides information relevant to an analysis of listed species in the context of the section 316(b) regulation; defines species considered as threatened, endangered, or of special concern; gives a brief overview of the potential for I&E-related adverse impacts on T&E species; and describes methods available for considering the economic value of such impacts.

Chapter Contents

A9-1 Listed Species Background

The Federal government and individual States develop and maintain lists of species that are considered endangered, threatened, or of special concern. The federal trustees for endangered or threatened species are the Department of the Interior's U.S. Fish and Wildlife Service (U.S. FWS) and the Department of Commerce's National Marine Fisheries Service (NMFS). Both departments are also referred to herein as the Services. The U.S. FWS is responsible for terrestrial and freshwater species (including plants) and migratory birds, whereas the NMFS deals with marine species and anadromous fish (U.S. FWS, 1996a). At the

[1] To simplify the discussion, in this chapter EPA uses the terms "T&E species" and "special status species" interchangeably to mean all species that are specifically listed as threatened or endangered, plus any other species that has been given a special status designation at the state or federal level.

state level, the departments, agencies, or commissions with jurisdiction over T&E species include Fish and Game; Natural Resources; Fish and Wildlife Conservation; Fish, Wildlife and Parks; Game and Parks; Environmental Conservation; Conservation and Natural Resources; Parks and Wildlife; the States' Natural Heritage Programs, and several others.

A9-1.1 Listed Species Definitions

a. Threatened and endangered species

A species is listed as "endangered" when it is *likely to become extinct* within the foreseeable future throughout all or part of its range if no immediate action is taken to protect it. A species is listed as "threatened" if it is *likely to become endangered* within the foreseeable future throughout all or most of its range if no action is taken to protect it. Species are selected for listing based on petitions, surveys by the Services or other agencies, and other substantiated reports or field studies. The 1973 Endangered Species Act (ESA) outlines detailed procedures used by the Services to list a species, including listing criteria, public comment periods, hearings, notifications, time limits for final action, and other related issues (U.S. FWS, 1996a).

A species is considered to be endangered or threatened if one or more of the following listing criteria apply (U.S. FWS, 1996a):

- the species' habitat or range is currently undergoing or is jeopardized by destruction, modification, or curtailment;
- the species is overused for commercial, recreational, scientific, or educational purposes;
- the species' existence is vulnerable because of predation or disease;
- current regulatory mechanisms do not provide adequate protection; or
- the continued existence of a species is affected by other natural or man-made factors.

b. Species of concern

States and the Federal government have also included species of "special concern" on their lists. These species have been selected because they are (1) rare or endemic, (2) in the process of being listed, (3) considered for listing in the future, (4) found in isolated and fragmented habitats, or (5) considered a unique or irreplaceable state resource.

A9-1.2 Main Factors in Listing of Aquatic Species

Numerous physical and biological stressors have resulted in the listing of aquatic species. The major factors include habitat destruction or modification, displacement of populations by exotic species, dam building and impoundments, increased siltation and turbidity in the water column, sedimentation, various point and non-point sources of pollution, poaching, and accidental catching. Some stresses, such as increased contaminant loads or turbidity, can be alleviated by water quality programs such as the National Pollutant Discharge Elimination System (NPDES) or the current EPA efforts to develop Total Maximum Daily Loads (TMDLs). Other factors, such as dam building or habitat modifications for flood control purposes, are relatively permanent and therefore more difficult to mitigate. In addition to these major factors, negative effects of CWISs on some listed species have been documented.

Congress amended the ESA in 1982 and established a legal mechanism authorizing the Services to issue permits to non-federal entities — including individuals, private businesses, corporations, local governments, State governments, and tribal governments — who engage in the "incidental take" of Federally-protected wildlife species (plants are not explicitly covered by this program). Incidental take is defined as take that is "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity under local, State or Federal law." Examples of lawful activities that may result in the incidental take of T&E species include developing private or State-owned land containing habitats used by Federally-protected species, or the withdrawal of cooling water that may impinge or entrain Federally-protected aquatic species present in surface waters.

An integral part of the incidental take permit process is development of a Habitat Conservation Plan (HCP). An HCP provides a counterbalance to an incidental take by proposing measures to minimize or mitigate the impact and ensuring the long-term commitment of the non-federal entity to species conservation. HCPs often include conservation measures that benefit not only the target T&E species, but also proposed and candidate species, and other rare and sensitive species that are present within the plan area (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000). The ESA stipulates the major points that must be addressed in an HCP, including the following (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000):

- defining the potential impacts associated with the proposed taking of a Federally-listed species;
- describing the measures that the applicant will take to monitor, minimize, and mitigate these impacts, including funding sources;[2]
- analyzing alternative actions that could be taken by the applicant and reasons why those actions cannot be adopted; and
- describing additional measures that the Services may require as necessary or appropriate.

HCP permits can be issued by the Services' regional directors if:

- the taking will be incidental to an otherwise lawful activity;
- any impacts will be minimized or fully mitigated;
- the permittee provides adequate funding to fully implement the permit;
- the incidental taking will not reduce the chances of survival or recovery of the T&E species; and
- any other required measures are met.

The Services have published a detailed description of the incidental take permit process and the habitat conservation planning process (U.S. Fish and Wildlife Service and National Marine Fisheries Service, 2000). The Federal incidental take permit program has only limited application within the context of the section 316(b) regulation because many T&E species (fish in particular) are listed mainly by States, not by the Services, and hence fall outside of the jurisdiction of this program.

A9-2 Framework for Identifying Listed Species Potentially at Risk of I&E

Evaluating benefits to listed species from the proposed section 316(b) regulation requires data on the number of listed organisms impinged and entrained and an estimate of how much the I&E of listed species will be reduced as a result of the regulation. Estimating I&E for candidate and listed species presents significant challenges due to the following:

- most facilities operating CWISs do not monitor for I&E on a regular basis;
- T&E populations are generally restricted and fragmented so that their I&E may be sporadic and not easy to detect by conventional monitoring activities;
- entrained eggs and larvae are often impossible to identify to the species level, making it difficult to know the true number of losses of a species of concern.

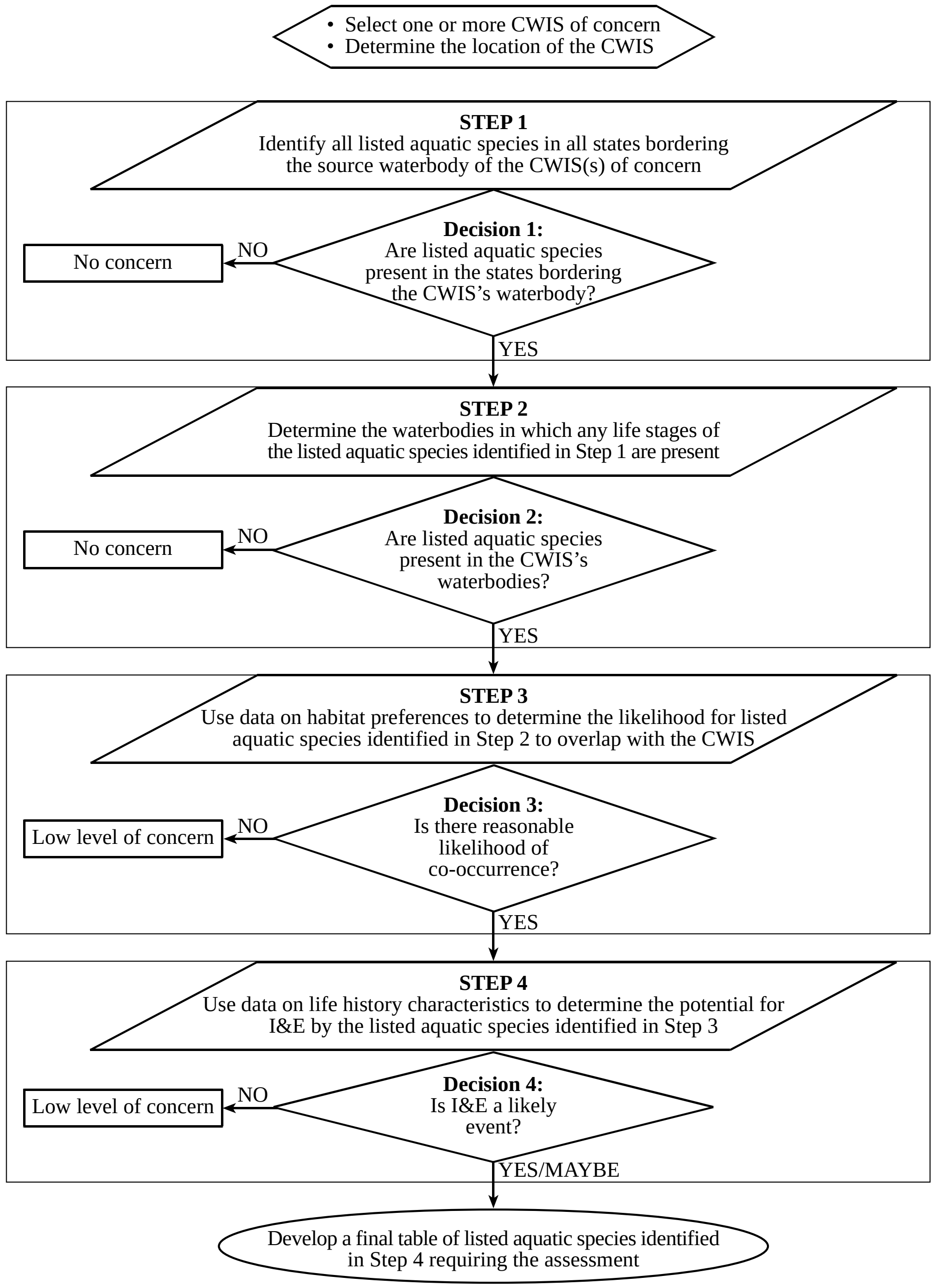
Some facilities have knowledge about the extent of their impact on T&E species. These facilities require incidental take permits and must develop HCPs (e.g., the Pittsburg and Contra Costa facilities in California, see Part B of this document). Where specific knowledge of I&E rates does not exist, risks to T&E species must be estimated from other information. The remainder of this section discusses EPA's methodology of estimating the numbers of listed species potentially at risk of I&E. The framework involves four main steps (see Figure A9-1).

[2] Mitigation can include preserving critical habitats, restoring degraded former habitat, creating new habitats, modifying land use practices to protect habitats, and establishing buffer areas around existing habitats.

- Step 1 identifies all State- or Federally-listed species for the States that border the CWIS source waterbody.
- Step 2 determines if a listed species from Step 1 is present in the vicinity of the CWIS. If a species distribution overlaps with the CWIS, the analysis proceeds to Step 3.
- Step 3 uses information on habitat preferences and site-specific intake structure characteristics to better define the degree of vulnerability of the listed species to the CWIS.
- Step 4, if necessary, further refines the potential for I&E based on the life history characteristics of the listed species.

The result of this four-step analysis is a table of listed species that are likely to experience I&E by a CWIS of concern based on their geographic distribution, habitat preferences, and life history characteristics.

Figure A9-1: Flowchart for Identifying T&E Aquatic Species with a Reasonable Potential for I&E by CWISs



Source: U.S. EPA analysis for this report.

A9-2.1 Step 1: Compile a Comprehensive Table of Potentially Affected Listed Species

The first step in determining the potential for I&E by a CWIS is to identify all State and Federally-listed aquatic species in the area of interest. Aquatic species may include fish; gastropods (such as snails, clams, or mussels); crustaceans (such as shrimp, crayfish, isopods, or amphipods); amphibians (such as salamanders, toads, or frogs);

reptiles (such as turtles, alligators, or water snakes); and mammals (such as seals or sea lions). The U.S. FWS maintains a web site (U.S. FWS, 2004; available at: http://endangered.fws.gov/index.html) on all Federally-listed species organized by State or taxonomic group. Because the Federal list represents only a small subset of the species listed by individual States, the analyst also needs to obtain State lists to develop a comprehensive table of aquatic species potentially affected by the CWISs of concern.[3] Individual State agencies, universities, or local organizations maintain web sites with data on State-listed species. A preliminary search in support of this chapter showed that various agencies have responsibilities for maintaining species lists in different States. The departments, agencies, or commissions with jurisdiction of T&E species include Fish and Game; Natural Resources; Fish and Wildlife Conservation; Fish, Wildlife and Parks; Game and Parks; Environmental Conservation; Conservation and Natural Resources; Parks and Wildlife; and several others. The States' Natural Heritage Programs can also be contacted to request listing information, species-specific data on geographic distributions, and other valuable data. Appendix A1 provides a recent compilation of aquatic T&E species by The Nature Conservancy (TNC) (see NatureServe, 2002, DCN 4-2261). A thorough search of these and other relevant sources should be performed to get the data required to identify target species.

If a CWIS of concern is located on a waterbody confined to one state, then only Federally-listed aquatic species found in that state and the aquatic species listed by the State itself need to be considered in the analysis. An example would be the Tampa Bay Estuary, which is entirely contained within the state of Florida. The search should expand if the CWIS is located on a waterbody that covers more than one state, which may be the case for large lakes, rivers, and estuaries. For example, the watersheds abutting the U.S. side of Lake Erie cover parts of New York, Pennsylvania, Ohio, and Michigan. The Delaware River Basin covers parts of Delaware, Pennsylvania, New Jersey, and New York. At a minimum, a table of potentially affected T&E species should include species listed by the State in which the CWIS is located, together with any Federally-listed aquatic species in all the states covered by the watershed. A more rigorous approach at this initial stage might be to include all State-listed aquatic species from every state covered by the waterbody of concern, even if the likelihood is small that a listed species moves beyond the boundaries of the CWIS's state.

The product of this initial step is a table of all the aquatic species listed by the U.S. FWS and the State(s) of interest. The information should be organized by species category — such as fish, amphibians, aquatic invertebrates, aquatic reptiles, and/or aquatic mammals. The information should also include:

- the common and scientific name of each listed species;
- the agency listing the species (State or U.S. FWS, or both); and
- the legal status of the species (threatened, endangered, or of special concern).

The analyst can assume that the CWIS does not have a direct impact on listed species only if no aquatic species are listed as threatened, endangered, or of special concern in the target state(s). The analyst must also determine if there is an indirect impact through the food chain. If not, then no further analysis is required for that CWIS.

A9-2.2 Step 2: Determine If Listed Species Are Present in the Same Waterbody as the CWIS

In the second step, the analyst determines if the listed species identified in Step 1 are present in the same waterbody as the CWIS of concern. This step represents a simple pass-fail decision: a species is retained if the distribution of one or more of its life stages coincides with the waterbody of interest; it is removed if it does not (see also Figure A9-1).

The analyst can obtain the information required for this step from several sources. Local agencies may have developed "species accounts" for certain Federally-listed species. Recovery plans may also be available for some of the Federally-listed species. These and other sources may provide information on species ranges, population levels, reproductive strategies, developmental characteristics, habitat requirements, reasons for current status,

[3] As discussed earlier, both T&E species and species of special concern should be included.

and/or management and protection needs. When compiling this information, the analyst should look not only at the distribution of adults but also of juveniles, particularly if the species is known to migrate between different locations over its life. This step is particularly important for anadromous fish species, but may also apply to other species that have seasonal or life cycle-dependent migrations (for example, adult frogs may live on land but spawn in rivers).

Most listed aquatic species are listed by individual States rather than on a Federal level. Data on the Federally-listed species are therefore unlikely to suffice for the analysis. States typically post their species list on the Internet. A few States have also developed short species accounts with information on distribution, life history characteristics, habitat requirements, and other useful details. Distribution or range data may consist of specific locations of sightings or catches (for example, particular rivermiles), general distributions within individual watersheds, or more generic and qualitative descriptions. Some States have also published hardcopy reports with species-specific information that may not be available on the Internet. Finally, the Natural Heritage Programs in numerous States have also developed species-specific data (see Appendix A1). All these materials should be obtained and reviewed during the data gathering process.

Distributional information for some of the T&E species may not be available. The analyst may need to consult secondary sources, such as species atlases (for example, see fish species distributions in the U.S.; or Smith, 1985, for fish distributions in New York State), field guides, published papers, or textbooks. Distributional data may be missing altogether for some of the more obscure species. The lack of such data should not by itself result in the removal of a T&E species at this point in the selection process. The analyst should instead look at habitat requirements (Step 3) or life history characteristics (Step 4) before the species is no longer considered of concern to the CWIS under consideration.

The majority of species will be eliminated at this stage because most of the listed aquatic species, with some notable exceptions, tend to have rather fragmented and limited distributions due to extensive habitat loss or narrow habitat requirements. Step 2 produces a table of listed species whose geographic distributions generally overlap with the location of the CWIS.

A9-2.3 Step 3: Compare Habitat Preferences of Listed Species to the CWIS Intake Location

Step 3 identifies listed species that could be affected by the CWIS of concern through a comparison of their habitat preferences and the location of the CWIS. The potential for I&E exists, and hence the listed species is retained, if the habitat preferences of one or more life stages match the location of the CWIS of concern. If the habitat preferences of no life stages of the listed species match the location of the CWIS, then the species can be removed from further consideration.

The analyst needs to obtain a general description of the location of the CWIS of concern in terms of (1) where the CWIS is found within the waterbody (e.g., nearshore versus offshore; deep versus shallow; etc.) and (2) the kinds of habitats associated with this general location. Such information may be available from site-specific field observations, permit applications by the facilities, natural resources maps, or other related sources.

a. Location

The presence of a listed species in the waterbody from which a CWIS withdraws water does not necessarily mean that the species will be impinged or entrained by the intake structure. Two additional variables need to be considered: the habitat preferences of the listed species and the characteristics of the CWIS (location, design, and capacity). The following example highlights the relationship between these two variables:

An endangered darter species is present in a river with a CWIS of concern. All life stages of this species are confined to swift-running, shallow (i.e., less than one foot deep) riffle zones, whereas the CWIS of concern is located many miles downstream in deep areas of the river that are unsuitable darter habitat. The likelihood of impact on the darter by the CWIS is minimal even though both are present within the same waterbody.

b. Other habitat information

Detailed information on the habitat requirements of the target species is also needed. This information should focus on any of the life stages, including eggs, larvae, juveniles, and adults, because habitat requirements often vary by life stage. For example, adults of a listed fish species may inhabit deeper waters of large lakes and produce pelagic eggs, but juveniles may be found only in nearshore nursery areas. It would be insufficient to consider only the habitat requirements of adults of this species, particularly if a CWIS of concern was located nearshore.

The U.S. FWS T&E species web page, the web pages of individual States or other organizations, or general reference materials can provide data on the habitat preferences of the listed species. Such information may be qualitative, anecdotal, or missing altogether for obscure T&E species. Not all States have developed accounts for their listed species. T&E species web sites of neighboring States may offer additional information if the target species has a regional distribution and is listed throughout its range. The information base can also be augmented by looking at a closely-related species. The substitute species must share the same general habitat preferences as the target species for the comparison to be valid. The analyst should consult appropriate reference materials to ensure a proper match.

c. Assess whether the overlap between habitat requirements and CWIS location exists

The information on habitat preferences for the listed species is compared to location-specific data on the CWIS of concern. The decision step is a simple pass-fail test: a species is retained if the habitat requirements of one or more of its life stages is likely to coincide with the CWIS of concern; otherwise it is removed. The logic supporting this decision is that I&E is unlikely if all the habitat requirements of the target T&E species do not overlap with the habitat in which the CWIS of concern is located.

The exact habitat cutoff point for eliminating a species outright cannot be defined up front; it will depend not only on the target T&E species but also on site-specific factors tied to the CWIS of concern. Several aquatic habitats, however, can be dismissed out of hand because they are not suitable to support CWISs. These habitats include springs, caves, temporary pools, very small ponds and lakes, and shallow headwater streams and creeks. Target T&E species that spend their entire life cycle in these habitats are unlikely to encounter CWISs and can be removed from further consideration. Habitats that have enough volume to support CWISs, namely large rivers and lakes, large estuaries, and inshore marine areas, are likely to require more analysis.

A9-2.4 Step 4: Use Life History Characteristics or Monitoring Data to Refine Estimate of I&E

From this point on, the assessment can go in two different directions (see Figure A9-1): (1) the target species is added to the final table because the data indicate potential for I&E, or because more data are needed to refine the assessment; or (2) the species is excluded from the list because there is a low level of concern.

The data may not be as clear-cut for smaller or less mobile species. The overlap between habitat requirements and the location of a CWIS of concern may not suffice to justify adding a target species to the final table without first considering life history information. The decision to proceed beyond Step 3 will vary on a case-by-case basis: it will depend on the target species, access to additional biological information, and the CWIS of concern. The analyst should focus on finding information that will support the decision to add or eliminate a target species. Additional data may not exist for some of the more obscure listed species. Given the protected status of T&E species, however, EPA recommends using a conservative approach to ensure that species are not accidentally omitted when in fact they should be added to the final table. The species should be retained if doubts persist after Step 3: it can still be removed during more site-specific assessments.

Listed clams in big Midwestern rivers are an example of species that may require further assessment in Step 4. Certain clam species would likely pass Step 2 because their distribution overlaps with the locations of CWISs of concern on major rivers. These clam species may also pass Step 3 if their presence coincided with the general location of one or more CWIS of concern. Yet, it is unclear if they should be added to the final table: a closer look at the clams’ life history is required to determine the potential for I&E.

The risk of I&E of adult clams is low because they are sedentary, benthic filter feeders or are firmly attached to the substrate. The risk may increase, however, during the reproductive season. During the reproductive season, males release their sperm into the water column. The sperm are carried downstream by the water current and are captured by feeding female clams. The sperm fertilize the female's eggs, which develop inside her body until they hatch. The larvae are released into the water column and must quickly find and attach themselves to a specific fish host to complete their development.[4] Larval clams die if they fail to find a host. After a period of days to weeks, the larval clams detach themselves from their hosts, drop to the bottom, and bury into the sediment or attach to a solid substrate where they remain for the rest of their lives. The only reasonable chance for clam I&E occurs when a fish host with larval life stages attached to it becomes impinged or entrained by a CWIS of concern. Adding a clam species to the final table would depend on whether or not the following occurs:

- The host fish is known to science.
- The host fish is present in the stretch of river containing the CWIS.
- The habitat characteristics of the host fish match the general location of the CWIS of concern. These decisions can be made only on a case-by-case and species-by-species basis.

The information on life history characteristics for the target T&E species should be carefully reviewed to determine the potential for I&E. Several variables may raise concerns, including migratory behavior, pelagic eggs or larvae, foraging activity, and so on. This information is evaluated in comparison to the location of the CWIS of concern. The decision point in this step is a simple pass-fail test: a species is retained if one or more of its life history characteristics enhances the potential for contact with the CWIS of concern; it is removed if all of its life characteristics are unlikely to result in vulnerability to the CWIS of concern.

A9-3 Identification of Species of Concern at Case Study Sites

The following sections illustrate the use of this procedure to identify vulnerable special status species. The example is for fish species of the Delaware Estuary.

A9-3.1 The Delaware Estuary Transition Zone

a. Step 1: Compile a comprehensive table of potentially affected listed species

Table A9-1 summarizes information compiled by EPA for fish species in the Delaware Estuary.

Table A9-1: Fish Species Listed as Endangered, Threatened, or of Special Concern (Federal plus PA, NJ, DE, and NY)

	Federally-Listed Species			State-Listed Species											
				Pennsylvania			New Jersey			Delaware			New York		
Common Name (*Latin Name*)	**E**	**T**	**O[a]**	**E**	**T**	**O[b]**	**E**	**T**	**O[b]**	**E**	**T**	**O[b]**	**E**	**T**	**O[b]**
Burbot (*Lota lota*)					X										
Chub, gravel (*Erimystax x-punctata*)				X										X	
Chub, silver (*Macrhybopsis storeiana*)													X		
Chub, streamline *(Erymystax dissimilis)*															X

[4] Larvae of freshwater clams typically require a very specific fish species to complete their development. Scientists do not always know which fish hosts are required by the T&E river clams.

Table A9-1: Fish Species Listed as Endangered, Threatened, or of Special Concern (Federal plus PA, NJ, DE, and NY)

	Federally-Listed Species			State-Listed Species											
				Pennsylvania			New Jersey			Delaware			New York		
Common Name (*Latin Name*)	**E**	**T**	**O**[a]	**E**	**T**	**O**[b]	**E**	**T**	**O**[b]	**E**	**T**	**O**[b]	**E**	**T**	**O**[b]
Chubsucker, lake *(Erimyzon sucetta)*														X	
Darter, bluebreast (*Etheostoma Camurum*)					X								X		
Darter, channel (*Percina copelandi*)					X										
Darter, eastern sand (*Ammocrypta pellucida*)					X									X	
Darter, gilt (*Percina evides*)					X								X		
Darter, longhead (*Percina macrocephala*)				X										X	
Darter, spotted (*Etheostoma maculatum*)				X										X	
Darter, swamp (*Etheostoma fusiforme*)														X	
Darter, tippecanoe (*Etheostoma tippecanoe*)				X											
Lamprey, mountain brook (*Ichthyomyzon greeleyi*)					X										X
Lamprey, northern brook (*Ichthyomyzon fossor*)				X											
Lamprey, Ohio (*Ichthyomyzon bdellium*)					X										
Madtom, mountain (*Noturus eleutherus*)					X										
Madtom, northern *(Notutus stigmotus)*					X										
Mooneye *(Hiodon tergisus)*														X	
Redhorse, black *(Moxostoma duquesnei)*															X
Sculpin, deepwater *(Myoxocephalus thompsoni)*													X		
Sculpin, spoonhead *(Cottus ricei)*													X		
Shiner, ironcolor *(Notropis chalybaeus)*															X
Shiner, pugnose *(Notropis anogenus)*													X		
Shiner, redfin *(Lythrurus umbratilis)*															X
Sturgeon, Atlantic (*Acipenser oxyrhynchus*)					X										
Sturgeon, lake (*Acipenser fulvescens*)				X										X	
Sturgeon, shortnose (*Acipenser brevirostrum*)	X			X			X			X			X		
Sucker, longnose (*Catostomus catostomus*)				X											
Sunfish, banded *(Enneacanthus obesus)*														X	
Sunfish, longear *(Lepomis megalotis)*														X	
Sunfish, mud *(Acantharchus pomotis)*														X	
Whitefish, round *(Prosopium cylindraceum)*													X		
Total	**1**	**0**	**0**	**8**	**10**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**8**	**11**	**5**

a. Other Federally-listed species may include species of special interest or concern, monitored species, candidate species, etc.
b. Other State-listed species may include rare species, species of special interest, species of concern, candidate species, etc.

Sources: New Jersey Division of Fish and Wildlife (2002); Pennsylvania Department of Conservation and Natural Resources (2002); State of New York, Department of Environmental Conservation (2001); U.S. FWS (1996a).

b. Step 2: Determine if listed species are present in the same waterbody as the CWIS

After identifying species of concern in the source waterbody, the next step is to determine if any of these species are present in the vicinity of the CWIS. This step involves consulting local biologists as well as literature sources such as species atlases, field guides, and scientific publications. Table A9-2 summarizes the results of EPA's analysis of the distribution of species of concern in the Delaware River Basin. Results indicate two there are two fish species potentially vulnerable to CWIS in the Delaware Estuary transition zone, Atlantic sturgeon and shortnose sturgeon (highlighted in bold in the table).

Table A9-2: Distribution of Listed Species Identified in Step 1

Species Name	Current Distribution	Found in Delaware River Basin?
Burbot	PA: Lake Erie and headwaters of Allegheny River	No
Chub, gravel	NY: medium and large-sized streams in the Allegheny Basin PA: Allegheny River and French Creek	NY: No PA: No
Chub, silver	NY: Lake Erie	No
Chub, streamline	NY: Allegheny River drainage	No
Chubsucker, lake	NY: the Lake Erie drainage basin and embayments along the southern shore of Lake Ontario	No
Darter, bluebreast	NY: upper reaches of the Allegheny River drainage basin PA: upper Allegheny River and two of its tributaries, namely Little Brokenstraw Creek and French Creek	NY: No PA: No
Darter, channel	PA: Lake Erie and large tributaries, and the upper part of the Allegheny River	No
Darter, eastern sand	NY: Lake Erie, the Metawee and Poultney Rivers near Lake Champlain, the Saint Regis and Salmon Rivers near Quebec, and the Grasse River PA: Lake Erie and Allegheny Basin	NY: No PA: No
Darter, gilt	NY: found only in the Allegheny River PA: upper Allegheny River	NY: No PA: No
Darter, longhead	NY: Allegheny River and a few of its large tributaries; French Creek PA: scattered sites in the Allegheny River and French Creek headwaters	NY: No PA: No
Darter, spotted	NY: French Creek PA: upper Allegheny River and French Creek	NY: No PA: No
Darter, swamp	NY: eastern two-thirds of Long Island	NY: No
Darter, tippecanoe	PA: upper Allegheny River and French Creek	PA: No
Lamprey, mountain brook	NY: French Creek and Allegheny River tributaries PA: moderate to large streams of the upper Allegheny River system	NY: No PA: No
Lamprey, northern brook	PA: Conneaut Creek in Crawford County in northwest PA	No
Lamprey, Ohio	PA: moderate to large streams of the upper Allegheny River system	No
Madtom, mountain	PA: French Creek in Mercer and Erie Counties in northwest PA	No
Madtom, northern	PA: French Creek	No
Mooneye	NY: Lake Champlain, Black Lake, Oswegatchie River, Lake Erie, Saint Lawrence River, and the mouth of Cattaraugus Creek	No
Redhorse, black	NY: Lake Ontario (likely extirpated) and Lake Erie drainage basins, and the Allegheny River	No
Sculpin, deepwater	NY: Lakes Erie and Ontario	No
Sculpin, spoonhead	NY: historically found in Lakes Erie and Ontario but believed to be extirpated	No
Shiner, ironcolor	NY: Basher Kill and Hackensack River	No
Shiner, pugnose	NY: Sodus Bay and Saint Lawrence River	No
Shiner, redfin	NY: drainages of Lakes Erie and Ontario in western NY	No
Sturgeon, Atlantic	PA: Delaware Estuary	**Yes**
Sturgeon, lake	NY: Saint Lawrence River, Niagara River, Oswegatchie River, Grasse River, Lakes Ontario & Erie, Lake Champlain, Cayuga Lake, Seneca & Cayuga canals PA: Lake Erie	NY: No PA: No

Table A9-2: Distribution of Listed Species Identified in Step 1

Species Name	Current Distribution	Found in Delaware River Basin?
Sturgeon, shortnose	DE: Tidal Delaware River NJ: Tidal Delaware River NY: lower portion of the Hudson River PA: Tidal Delaware River	**DE, NJ, PA: Yes** NY: No
Sucker, longnose	PA: Youghiogheny River headwater streams in southwest PA	No
Sunfish, landed	NY: Passaic River drainage and in eastern Long Island in the Peconic River drainage	No
Sunfish, longear	NY: Tonawanda Creek	No
Sunfish, mud	NY: Hackensack River	No
Whitefish, round	NY: scattered lakes throughout the state	No

Sources: New Jersey Division of Fish and Wildlife (2002); Pennsylvania Department of Conservation and Natural Resources (2002); Smith (1985); State of New York, Department of Environmental Conservation (2001).

c. Step 3: Compare habitat preferences of listed species to the CWIS intake location

Step 3 involves determining the habitat preferences and life history requirements of species identified in Step 2. In Step 2 EPA determined that two fish species of concern are potentially vulnerable to CWIS in the Delaware Estuary transition zone, Atlantic sturgeon and shortnose sturgeon. The habitat preferences and life histories of these species are summarized in Table A9-3.

Table A9-3: Habitat Preferences and Life Histories of Listed Species Identified in Step 2

Species Name	Current Distribution	Habitat Preferences	Potential of Overlap w/ CWIS?	Life History	Potential for I&E?	Life Stages Susceptible to I&E?
Sturgeon, Atlantic	Delaware Estuary	Estuarine and riverine bottom habitats of large river systems	Yes	Adults stay in the ocean but move into estuaries and large rivers to spawn in deep water (> 10m deep); eggs sink and stick to the bottom; juveniles make seasonal migrations between shallower areas (summer) and deeper areas (winter) of their birth rivers; juveniles move to the ocean at age 4-5 to mature	Yes	Larvae and juveniles
Sturgeon, shortnose	Tidal Delaware River (mostly in the upper and transitional estuary)	Estuarine and riverine bottom habitats of large river systems	Yes	Adults stay in nearshore marine habitats but move to estuaries and large rivers to spawn; eggs sink and stick to the bottom; juveniles make seasonal migrations between shallower areas (summer) and deeper areas (winter) of their birth rivers; juveniles move out to the ocean at age 4-5 to mature	Yes	Larvae and juveniles

Source: U.S. EPA analysis for this report.

d. Step 4: Use life history characteristics or monitoring data to refine estimate of I&E

In some cases I&E or waterbody monitoring data may be available to estimate CWIS impacts on T&E species. However, in many cases, it will be necessary to estimate relative risk based on waterbody monitoring of the species distribution relative to CWIS and life history and facility characteristics that influence a species vulnerability to I&E.

For the Delaware Estuary example discussed here, there are only limited data available for shortnose sturgeon (Masnik and Wilson, 1980) and Atlantic sturgeon (Shirey et al., 1997) from monitoring in the vicinity of transition zone CWISs. In the case of shortnose sturgeon, 1980 monitoring results indicate that the species is not vulnerable to transition zone CWISs. However, because the data are over 20 years old, further information is needed to confirm that the potential for I&E of shortnose sturgeon remains low. An analysis of life history information indicates that spawning takes place many miles upstream of transition zone CWISs, and therefore the risk of entrainment of eggs and larvae is minimal (Masnik and Wilson, 1980). Impingement is also unlikely because salinity and feeding conditions in the transition zone are unfavorable for impingeable-sized juveniles and adults (Masnik and Wilson, 1980).

In the case of Atlantic sturgeon, monitoring in the transition zone indicates that young Atlantic sturgeon occur in the vicinity of the Hope Creek and Salem facilities in the summer months. Data also suggest that Atlantic sturgeon move back downstream in fall, although use of the lower estuary (Delaware Bay) remains unknown (Shirey et al., 1997). This information suggests that Atlantic sturgeon are potentially at risk to transition zone CWISs and indicates the need for I&E monitoring to confirm the degree of harm.

A9-4 Benefit Categories Applicable for Impacts on T&E Species

Once a T&E species has been identified as vulnerable to a CWIS, special considerations are necessary to fully capture the human welfare gain from reducing I&E of the species. The benefits case study presented in Part B of this document illustrates some of the challenges in assigning economic value to T&E species and presents a valuation approach that may prove useful in other cases.

Estimating the economic benefits of helping to preserve T&E and other special status species, such as by reducing I&E impacts, is difficult due to a lack of knowledge of the ecological role of different T&E species and a relative paucity of economic studies focusing on the benefits of T&E preservation. Most of the wildlife economic literature focuses on recreational use benefits that may be irrelevant for valuation of T&E species because T&E species (e.g., the delta smelt in California) are not often targeted by recreational or commercial fishermen. The numbers of special status species that are recreationally or commercially fished (e.g., shortnose sturgeon in the Delaware Estuary) have been so depleted that any use estimates associated with angling participation or landings data for recent years (or decades) would not be indicative of the species' potential value for direct use if and when the population recovers. Nevertheless, there are some T&E species for which consumptive use-related benefits could be significant once the numbers of individuals are restored to levels that enable resumption of relevant uses.

Based on their potential uses, T&E species can be divided into three broad categories:

- *T&E species with high potential for consumptive uses.* The components of total value of such species are likely to include consumptive, non-consumptive, and indirect use values, as well as existence and option values. Pacific salmon, a highly prized game species, is a good example of such species. In addition to having a high consumptive use value, this species is likely to have a high non-consumptive use value. People who never go fishing may still watch salmon runs. The use value may actually dominate the total economic value of enhancing a T&E fish population for species like salmon. For example, Olsen et al. (1991) found that users contribute 65 percent to the total regional willingness-to-pay (WTP) value ($171 million in 1989$) for doubling the Columbia River salmon and steelhead runs. Non-users with zero probability of participation in the sport fishery contribute 25 percent. Non-users with some probability of future participation contribute the remaining ten percent.

- *T&E species that do not have consumptive uses, but are likely to have relatively large non-consumptive and indirect use values.* The total value of such species would include non-consumptive use and indirect values and existence values. Loggerhead sea turtles can represent such species. The non-consumptive use of loggerhead sea turtles may include photography or observation of nesting or swimming reptiles. For example, a study by Whitehead (1992) reports that the average subjective probability that North Carolina residents will visit the North Carolina coast for non-consumptive use recreation is 0.498. Policies that protect loggerhead sea turtles may therefore enhance individual welfare for a large group of participants in turtle viewing and photography.

- *T&E species whose total value is a pure non-use value*. Some prominent T&E species with minimal or no use values may have high non-use values. The bald eagle and the gray whale are examples of such species. Conversely, many T&E species with little or no use value are not well known or of significant public interest and therefore their non-use values may be difficult to elicit. Most obscure T&E species, which may have ecological, biological diversity, and other non-use values, are likely to fall into this category.

Non-use motives are often the principal source of benefits estimates for T&E species because many T&E species fall into the "obscure species" group. As described in greater detail in Chapter A3, motives often associated with non-use values held for T&E species include bequest (i.e., intergenerational equity) and existence (i.e., preservation and stewardship) values. These non-use values are not necessarily limited to T&E species, but I&E-related adverse impacts to these unique species would be locally or globally irreversible, leading to extinction being a relevant concern. Irreversible adverse impacts on unique resources are not a necessary condition for the presence of significant non-use values, but these attributes (e.g., uniqueness; irreversibility; and regional, national, or international significance) would generally be expected to generate relatively high non-use values (Carson et al., 1999; Harpman et al., 1993).

A9-5 Methods Available for Estimating the Economic Value Associated with I&E of T&E Species

Estimating the value of increased protection of T&E species from reducing I&E impacts requires the following steps:

- Estimating I&E impacts on T&E species; and
- Attaching an economic value to changes in T&E status from reducing I&E impacts on species of concern (e.g., increasing species population, preventing species extinction, etc.).

A9-5.1 Estimating I&E Impacts on T&E Species

Several cases of I&E of Federally-protected species by CWISs are documented, including the delta smelt in the Sacramento-San Joaquin River Delta, sea turtles in the Delaware Estuary and elsewhere (NMFS, 2001b), shortnose sturgeon eggs and larvae in the Hudson River (New York State Department of Environmental Conservation, 2000), and pallid sturgeon eggs and larvae in the Great Rivers Basin (Dames and Moore, 1977). Mortality rates vary by species and life stage: it is estimated to range from two to seven percent for impinged sea turtles (NMFS, 2001b), but mortality can be expected to be much higher for entrained eggs and larvae of the shortnose sturgeon and other special status fish species. The estimated yearly take of delta smelt by CWISs in the Sacramento-San Joaquin River Delta led to the development of a Habitat Conservation Plan as part of an incidental take permit application (Southern Energy Delta LLC, 2000).

A9-5.2 Economic Valuation Methods

Valuing impacts on special status species requires using nonmarket valuation methods to assign likely values to losses of these individuals. The fact that many of these species typically are not commercially or recreationally harvested (once they are listed) means no market value can be placed on their consumption. Benefits estimates are therefore often confined to non-use values for special status species. The total economic value of preserving species with potentially high use values (i.e., T&E salmon runs) should include both use and non-use values. Economic tools allowing estimates of both use and non-use values (e.g., stated preference methods) may be suitable for calculating the benefits of preserving T&E species. The relevant methods are briefly summarized below.

It is necessary to note that the benefits of preserving T&E species estimated to date reflect a human-centered view; benefit-cost analysis may not be appropriate when T&E species are involved because extinction is irreversible.

a. Stated preference methods

As described in Chapter A3, the only available way to directly estimate non-use values for special status species is through applying stated preference methods, such as the contingent valuation method (CVM). This method relies on statements of intended or hypothetical behavior elicited though surveys to value species. CVM has sometimes been criticized, especially in applications dating back a decade or more, because the analyst cannot verify whether the stated values are realistic and absent of various potential biases. CVM and other stated preference techniques (including conjoint analysis) have evolved and improved in recent years, however, and empirical evidence shows that the method can yield reliable (and perhaps even conservative) results where stated preference results are compared to those from revealed preference estimates (e.g., angling participation as observable behavior) (Carson et al., 1996).

The Agency has begun the preliminary development of a stated preference survey that would measure non-use benefits from the reductions in I&E attributable to the section 316(b) regulation for Phase III facilities. This stated preference study will be completed for the final regulation, but for the proposed regulation, no primary research was feasible within the budgeting, scheduling, and other constraints faced by the Agency.

b. Benefit transfer approach

Using a benefit transfer approach may be a viable option in some cases. By definition, benefit transfer involves extrapolating the benefits findings estimated from one analytic situation to another situation(s). The initial analytic situation is defined in terms of an environmental resource (e.g., T&E species), the policy variable(s) (e.g., changes in species status or population), and the benefitting populations being investigated. Only in ideal circumstances do the environmental resource and policy variables of the original study very closely match those of the analytic situation to which a policy or regulatory analyst may wish to extrapolate study results. Despite discrepancies, this approach may provide useful insights into benefits to society from reducing stress on T&E species.

The current approach to benefit transfers most often focuses on the meta-analysis of point estimates of the Hicksian or Marshalian surplus reported from original studies. If, for example, the number of candidate studies is small and the variation of characteristics among the studies is substantial, then meta-analysis is not feasible. This is likely to be the case when T&E species are involved, requiring a more careful consideration of analytic situations in the original and policy studies. If only one or a few studies are available, an analyst evaluates their transferability based on technical criteria developed by Desvousges (1992).

The analyst first identifies T&E species affected by I&E and the type of environmental change resulting from reducing I&E impacts on T&E species, and then from a pool of available studies selects the appropriate WTP values for protecting those species. EPA illustrated the value to society of protecting T&E species by conducting a review of the contingent valuation (CV) literature that estimates WTP to protect those species. This review focused on those studies valuing those aquatic species that may be at risk of I&E by CWISs. EPA also identified studies that provide WTP estimates for fish-eating species, i.e., the bald eagle, peregrine falcon, and the whooping crane. These species may also be at risk because they rely to some degree on aquatic organisms as a food source. EPA used select studies identified in a meta-analysis that Loomis and White (1996) conducted as a literature base. Loomis and White included all rare or endangered species in their analysis, but EPA limited its own literature review to those studies that valued threatened or endangered aquatic species, or birds that consume aquatic species. Table A9-4 lists the 14 relevant CV studies that EPA identified and provides corresponding WTP estimates and selected study characteristics. WTP estimates represent either one-time payments, annual payments, or an annual payment in a 5-year program. The table indicates which of these payment types each WTP estimate represents, along with the corresponding value, inflated to 2003$. EPA also converted lump-sum payments and 5-year program annual payments into annualized values in order to aid in the comparison of values from all studies.[5]

The identified valuation studies vary in terms of the species valued and the specific environmental change valued. Thirteen of these studies represent a total of 16 different species. In addition, one study (Walsh et al., 1985) estimates WTP for a group of 26 species. Most of these studies value prominent species well known by the public, such as salmon. The studies valued one of the following general types of environmental changes:

- avoidance of species loss/extinction;
- species recovery/gain;
- acceleration of the recovery process;
- improvement of an area of a species' habitat; and
- increases in species population.

In order to compare consistent measures of WTP, EPA chose to use values that represent either annual or annualized WTP, which represent conservative estimates of consumer surplus. The value of preserving or improving populations of T&E species reported in T&E valuation studies has a wide range. Mean annual (or annualized) household WTP estimates of obscure aquatic species range from $7.68 (2003$) for the striped shiner (Boyle and Bishop, 1987) to $8.50 for the silvery minnow (Berrens et al., 1996). It is not likely that use values associated with these species are significant.

WTP for prominent fish species range from the relatively low estimate of $2.34 (2003$; Stevens et al., 1991), to $8.92 (Stevens et al., 1991); both values are mean non-user WTP for Atlantic salmon, and are annualized. Total user values are much higher for Atlantic salmon, as this species is commonly targeted by recreational anglers.[6] WTP estimates for fish-eating species (i.e., whooping crane, bald eagle, and peregrine falcon), which all have high non-use values (i.e., existence value), range from $4.48 (Carson et al., 1994) to $63.46 (Bowker and Stoll, 1988). It is important to note that the above WTP ranges are derived from studies that used various valuation scenarios and valued different types of environmental changes, and therefore should be viewed as approximate values as opposed to finite ranges.

It may be possible to develop individual WTP ranges for a given species or species group based on the estimated changes in T&E status (e.g., species gain or recovery) from reducing I&E impacts and the applicable WTP values from existing studies.

Once individual WTP for protecting T&E species or increasing their population is developed, the next step is to estimate total benefits from reducing I&E of the special status species. The analyst should apply the estimated WTP value to the relevant population groups to estimate the total value of improving protection of T&E species. The affected population may include both potential users and non-users, depending on species type. The relevant population may also include area residents, regional population, or, in exceptional cases (e.g., bald eagle), the U.S. population. The total value of improved protection of T&E species (e.g., preventing extinction or doubling the population size) should be then adjusted to reflect the percentage of cumulative environmental stress attributable to I&E.

---

[5] For each study that presents annual payments in a 5-year program, EPA calculated the present value of those payments using a 3% discount rate, and annualized present day value over 25 years using the same discount factor. EPA considered lump-sum payments to represent present value, and thus merely annualized these payments using the same assumptions.

[6] See Chapter A5 of this report for detail on recreational fishing values for Atlantic salmon.

Table A9-4: WTP for Improving T&E Species Populations[a]

Species Type	Reference	Publi-cation Date	Survey Date	Species	Environ-mental Change	Size of Change	Value Type[b]	Mean WTP (2003$)	Annual or Annualized Mean WTP (2003$)[c]	CVM Method	Survey Region	Sample Size	Response Rate	Payment Vehicle
Aquatic	Berrens et al.	1996	1995	Silvery minnow	Maintain instream flow to protect species		5	$33.75	$8.50	DC	NM households	698	45%	Trust fund
	Boyle and Bishop	1987	1984	Striped shiner	Avoid loss	100%	A	$7.68	$7.68	DC	WI households	365	73%	Foundation
	Carson et al.	1994	1994	Kelp bass, white croaker, bald eagle, peregrine falcon	Speed recovery from 50 to 5 years		L	$80.39	$4.48	DC	CA households	2810	73%	One-time tax
	Cummings et al.	1994	1994	Squawfish	Avoid loss	100%	A	$10.70	$10.70	OE	NM	921	42%	Increase State taxes
	Duffield and Patterson	1992	1992	Arctic grayling	Improve 1 of 3 rivers		L	$22.08	$1.24	PC	US visitors	157	27%	Trust fund
				Cutthroat trout			L	$16.55	$0.92	PC	US visitors	170	77%	Trust fund
	Kotchen and Reiling	2000	1997	Shortnose sturgeon	Recovery to self-sustaining population		L	$30.48	$1.70	DC	Maine residents (random)	635	63%	One-time tax
	Loomis and Larson	1994	1991	Gray whale	Gain	50%	A	$21.80	$21.80	OE	CA households	890	54%	Protection fund
					Gain	100%	A	$24.45	$24.45	OE	CA households	890	54%	Protection fund
					Gain	50%	A	$33.69	$33.69	OE	CA visitors	1003	72%	Protection fund

Table A9-4: WTP for Improving T&E Species Populations[a]

Species Type	Reference	Publication Date	Survey Date	Species	Environmental Change	Size of Change	Value Type[b]	Mean WTP (2003$)	Annual or Annualized Mean WTP (2003$)[c]	CVM Method	Survey Region	Sample Size	Response Rate	Payment Vehicle
	Loomis and Larson (cont.)	1994	1991	Gray whale	Gain	100%	A	$40.06	$40.06	OE	CA visitors	1003	72%	Protection fund
	Olsen et al.	1991	1989	Pacific salmon and steelhead	Gain (existence value)	100%	A	$39.78	$39.78	OE	Pac. NW household	695	72%	Electric bill
					Gain (user value)	100%	A	$112.38	$112.38	OE	Pac. NW anglers	482	72%	Electric bill
	Stevens et al.	1991	1989	Atlantic salmon	Avoid loss	100%	5	$9.27	$2.34	DC	MA households	169	30%	Trust fund
				Atlantic salmon	Avoid loss	100%	5	$10.29	$2.59	OE	MA households	169	30%	Trust fund
		1994	1993	Atlantic salmon	Gain	50%	5	$24.70	$6.22	DCOE	College students	76	93%	Contribution
				Atlantic salmon	Gain	90%	5	$35.46	$8.92	DCOE	College students	76	93%	Contribution
	Walsh et al.	1985	1985	26 species in CO	Avoid loss	-100%	A	$73.74	$73.74	OE	CO households	198	99%	Taxes
	Whitehead	1992	1991	Sea turtle	Avoid loss	100%	L	$16.51	$0.92	DC	NC households	207	35%	Preservation fund
Fish-eating birds	Bowker and Stoll	1988	1983	Whooping crane	Avoid loss	100%	A	$40.45	$40.45	DC	TX and US visitors	316	36%	Foundation
				Whooping crane	Avoid loss	100%	A	$63.46	$63.46	DC	TX and US visitors	254	67%	Foundation
	Boyle and Bishop	1987	1984	Bald eagle	Avoid loss	100%	A	$19.57	$19.57	DC	WI households	365	73%	Foundation
	Carson et al.	1994	1994	Bald eagle Peregrine Falcon Kelp bass White croaker	Speed recovery from 50 to 5 years		L	$80.39	$4.48	DC	CA households	2810	73%	One-time tax

Table A9-4: WTP for Improving T&E Species Populations[a]

Species Type	Reference	Publi-cation Date	Survey Date	Species	Environ-mental Change	Size of Change	Value Type[b]	Mean WTP (2003$)	Annual or Annualized Mean WTP (2003$)[c]	CVM Method	Survey Region	Sample Size	Response Rate	Payment Vehicle
	Stevens et al.	1991	1989	Bald eagle	Avoid loss	100%	A	$41.88	$41.88	DCOE	NE households	339	37%	Trust fund
				Bald eagle	Avoid loss	100%	A	$29.50	$29.50	DCOE	NE households	339	37%	Trust fund
	Swanson	1993	1991	Bald eagle	Increase in populations	300%	L	$323.71	$18.04	DC	WA visitors	747	57%	Membership fund
				Bald eagle	Increase in populations	300%	L	$226.74	$12.64	OE	WA visitors	747	57%	Membership fund

a. Exhibit adapted from Loomis and White (1996) and includes only those studies that valued aquatic species or fish-eating birds.
b. Indicates type/ length of WTP payment reported in study: 5 = annual payment in 5-year program; LS = lump-sum, or one-time; payment, A = annual payment.
c. Lump-sum values are annualized over 25 years using a 3% discount rate; values that are annual payments in 5-year programs were converted into present value before annualizing over 25 years at a 3% discount rate; annual payments are presented as in the original study, inflated to 2003$ using the Consumer Price Index (CPI). Values that already represent annual values are unadjusted.

Sources: Loomis and White, 1996; CPI: U.S. Bureau of Labor Statistics, 2004.

c. Cost of T&E species restoration

EPA explored an approach based on the premise that under specific circumstances it is possible to infer how much value society places on a program or activity by observing how much society is willing to forego (in out-of-pocket expenses and opportunity costs) to implement the program. For example, the costs borne by society to implement programs that preserve and restore special status species can, under select conditions, be interpreted as a measure of how much society values the outcomes it anticipates receiving. This approach is analogous to the broadly accepted revealed preference method of inferring values for private goods and services based on observed individual behavior.

In the case of observed individual behavior, when a person willingly bears a cost (pays a price) to receive a good or service, then it is deduced that the person's value for that acquired good or service must be at least as great as the price paid. That is, based on the presumption that individual behavior reflects the economic rationality of seeking to maximize utility (well-being), the person's observed WTP must exceed the price paid, otherwise they would not have purchased that unit of the commodity. The approach described in this section uses the same premise, but applies it to societal choices rather than to a single individual's choices.

A critical issue with the approach is determining when it is likely that a specific public sector activity (or other form of collective action) does indeed reflect a "societal choice." EPA recognizes clearly that not every policy enacted by a public sector entity can rightfully be interpreted as an indication of social choice. Hence, the costs imposed in such instances may not in any way reveal social values. For example, some regulatory actions may have social costs that outweigh the social benefits, but may be implemented anyway because of legal requirements or other considerations. In such a case, asserting that the costs imposed reflect a lower bound estimate of the "value" of the action would not be accurate (the values may be less than the imposed costs). Alternatively, there are some regulatory programs for which the benefits greatly exceed costs, and in such instances using costs as a reflection of value would greatly understate social benefits.

There are some public policy actions that can be suitably interpreted as expressions of societal preferences and values. In these instances, the incurred costs may be viewed as an indication of social values. The criteria to help identify when such situations arise include whether the actions taken are voluntary, or whether the actions reflect an open and broadly inclusive policy-making process that enables and encourages active participation by a broad spectrum of stakeholders. This is especially relevant where (1) plans and actions are developed in an inclusive, consensus-building manner; (2) implementation steps are pursued in an adaptive management framework that enables continuous feedback and refinement; or (3) the actions are ultimately supported by some positive indication of broad community support, such as voter approval of a referendum. In such instances, the policy choices made are the product of a broad-based, collective decision-making process, and such programs should be viewed as an expression of societal preferences. When programs or activities stem from such open collective processes, the actions (and costs incurred) reflect the revealed preference of society.

EPA's method values T&E species in a two step process. First, estimates of costs incurred and anticipated from voluntary or other suitable collective actions taken to maintain and or increase the populations of T&E species (e.g., restoration of critical spawning or nursery habitat) are combined with estimates of the value of any foregone opportunities (i.e., opportunity costs, where direct costs are not involved) from additional actions required to achieve the T&E population objectives (e.g., maintaining instream flows for a species instead of providing water for agricultural diversions). This resulting total social cost provides a cumulative estimate of society's valuation of the preservation and enhancement of the T&E species affected by the actions. Categories of actions that would be addressed in this step could include private and public expenditures on habitat restoration/population enhancement programs, funds that have been allocated for such actions through legislative appropriations or public referenda (even if not yet expended), or resources allocated through a formal project evaluation and selection process designed to allocate limited resources such as those used by numerous State and Federal resource management agencies.

Second, the numbers of the T&E organisms that are expected to benefit from the identified actions, as measured by the increased production or avoided losses of individuals, are estimated to place the valuation estimates in context. If dollar per organism results are required for a valuation analysis, as is the case in this rulemaking, the estimates from the first step can be divided by the increased production (avoided loss) estimate from the second step to provide such results.

The economic foundations for using this approach to value T&E species are firmly established through the widespread recognition and acceptance of revealed preference data as a source of nonmarket information that is acceptable for the valuation of resources. In EPA's approach, valuation estimates rely on the costs of actions or the value of foregone opportunities that are *voluntarily* undertaken or that have been approved through extensive public input and review (and developed in a consensus-oriented approach). With these sources of data, the method avoids the well-established problems associated with using "costs" as a measure of "value" — a problem that can arise when the cost is realized involuntarily (e.g., avoided cost-based measures of value). Specifically, because of the available evidence of the public's acceptance and willingness to incur the opportunity costs associated with the actions that are selected for evaluation, the fundamental criteria for defining the value of any resource are satisfied.

One issue that arises with the use of the method is that it is not clear that the resulting values can be distinctly categorized as direct use or non-use values because the underlying actions benefitting the T&E species could reflect an expressed mix of non-use values (e.g., preservation and existence) and discounted future use values (i.e., the actions are seen as an "investment" that could return the species to levels at which direct use would be permitted). As result, it is believed that results provide an approximation of the total use value for the T&E species in question.

A9-6 Issues in Estimating and Valuing Environmental Impacts from I&E on T&E Species

Several technical and conceptual issues are associated with valuing I&E impacts on T&E species:

- issues associated with estimating the size of the population of special status fish;
- issues associated with estimating I&E contribution to the cumulative impact from all stressors; and
- issues associated with implementing an economic valuation approach.

A9-6.1 Issues in Estimating the Size of the Population of Special Status Fish

Difficulties in estimating the number of individuals or size of the population of special status fish present in a given location are often very difficult for numerous reasons, including the following:

- The act of monitoring a T&E species is problematic in and of itself because monitoring generally results in some harm to the species, so researchers and Federal agencies are reluctant to do it;
- Monitoring programs typically focus only on harvested species;
- The number of individuals may be so low that they rarely or never show up in monitoring programs for other species; and
- A lack of complete knowledge of the life cycles of special status fish species contributes to an inability to accurately estimate population sizes for some species.

Deriving population estimates from existing monitoring programs often means extrapolating sampling catches to the population as a whole. The variance in estimates is likely to be very high. Several assumptions must be met when extrapolating sample catches to population estimates:

- Fish are completely recruited and vulnerable to the gear (i.e., are large enough to be retained by the mesh and do not preferentially occupy habitats not sampled) or selectivity of the gear by size is known.

- Sampling fixed locations for species approximates random sampling, which approximates a stratified random sampling scheme.

- Species are uniformly distributed through the water column.
- Volume filtered by trawls can be accurately estimated.
- Volumes of water can be estimated for each embayment in the habitat range for the species.

A9-6.2 Issues Associated with Estimating I&E Contribution to the Cumulative Impact from All Stressors

There are several issues associated with estimating the relative contribution of I&E to the total impact of all stressors on T&E species:

- Even if I&E data is available from sample facilities, the size of populations of T&E species is hard to measure. Thus, it may be difficult to determine how much of an impact I&E has on population levels. For very rare species, even relatively low levels of I&E may be important.
- There are often a number of stressors that harm or limit populations of special status fish. Even if significant numbers of fish are lost to I&E, other factors may still have a greater role in determining populations levels. For example, if lack of spawning areas is limiting population growth of a species, then reducing I&E of that species may not increase the population.

A9-6.3 Issues Associated with Implementing an Economic Valuation Approach

a. Issues associated with benefit transfer approach

The following issues may arise when using a benefit transfer approach:

- Some studies estimated WTP for multiple species. Values established by Carson et al. (1994), Olsen et al. (1991), and Walsh et al. (1985) are for groups of T&E species, and therefore transferring values from these studies to particular species may not be feasible.
- The type of environmental change valued in the study may not match the environmental changes resulting from reducing I&E impacts. As noted above, previous T&E valuation studies addressed one of the following qualitative changes in T&E status:
    - avoidance of species loss/extinction,
    - species recovery/gain,
    - acceleration of the recovery process,
    - improvement of an area of a species' habitat, and
    - increases in species population.
- The *size of the environmental change* that the hypothetical scenario defines is also vital for developing WTP estimates. Several studies describe programs that avoid the loss of a species. This outcome may be considered a 100% improvement with respect to the alternative, extinction, but the restoration of a species or the increase in population may be specified at any level (e.g., 50 percent, 300 percent). Swanson (1993) estimated a 300% *increase* in bald eagle populations and Boyle and Bishop (1987) estimated WTP to avoid the possibility of bald eagle *extinction* in Wisconsin (cited in Loomis and White, 1996). Although avoiding extinction may be considered a 100% improvement, this environmental change is not comparable to the 300% increase in existing populations. Preventing regional extinction is quite different than realizing a nominal increase in species population (in which the alternative is not necessarily species loss).
- Although a considerable amount of CV literature has valued T&E species, such research is largely limited to species with high consumptive use or non-use values. They either have high recreational or commercial value, or are popularly valued as significant species for various reasons (e.g., national symbol, aesthetics). Many T&E species that are likely to be affected by I&E (either Federal or State-listed) are obscure, and WTP for their preservation has not been estimated.

b. Issues associated with cost of restoration approach

The following issues may arise when using a cost of restoration approach:

- "Restoration" programs need not be relied on exclusively to infer societal WTP to preserve special status species. In many instances, other programs or restrictions are used in lieu of (or in conjunction with) restoration programs. In these cases, the costs associated with the restoration components also reveal a WTP.

- Costs directed at a special status species must be isolated from program elements intended to address other species or problems. In a multifaceted restoration or use restriction program, the percentage of costs used mainly to target restoration of special status species as opposed to other ecosystem benefits needs to be estimated.
- Estimates of the change in species abundance associated with the program must be developed, since the size of the change in species abundance is necessary to determine societal WTP per individual. Often targets are set to abundance levels that existed before a significant decline in populations. However, a habitat restoration program may target restoration of special status species, but might not target a specific population size.

Appendix A1

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	01080205
AFCAA01040	Freshwater Fishes	*Acipenser Oxyrinchus*	Atlantic Sturgeon	G3	(LT,C)	01080205
AFCAA01040	Freshwater Fishes	*Acipenser Oxyrinchus*	Atlantic Sturgeon	G3	(LT,C)	01100003
AFCAA01040	Freshwater Fishes	*Acipenser Oxyrinchus*	Atlantic Sturgeon	G3	(LT,C)	01100004
AFCAA01040	Freshwater Fishes	*Acipenser Oxyrinchus*	Atlantic Sturgeon	G3	(LT,C)	01100005
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	01100007
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	02040105
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	02040201
AFCQC02680	Freshwater Fishes	*Etheostoma Sellare*	Maryland Darter	GH	LE	02050306
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	02050306
AFCAA01040	Freshwater Fishes	*Acipenser Oxyrinchus*	Atlantic Sturgeon	G3	(LT,C)	02050306
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	02060001
AFCAA01040	Freshwater Fishes	*Acipenser Oxyrinchus*	Atlantic Sturgeon	G3	(LT,C)	02060001
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	02060002
AFCQC02680	Freshwater Fishes	*Etheostoma Sellare*	Maryland Darter	GH	LE	02060003
AFCQC04240	Freshwater Fishes	*Percina Rex*	Roanoke Logperch	G1G2	LE	03010101
AFCQC04240	Freshwater Fishes	*Percina Rex*	Roanoke Logperch	G1G2	LE	03010103
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	03010107
AFCQC04240	Freshwater Fishes	*Percina Rex*	Roanoke Logperch	G1G2	LE	03010201

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	03010203
AFCQC04240	Freshwater Fishes	*Percina Rex*	Roanoke Logperch	G1G2	LE	03010204
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	03010205
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	03020105
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	03020204
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	03030001
AFCJB28660	Freshwater Fishes	*Notropis Mekistocholas*	Cape Fear Shiner	G1	LE	03030002
AFCJB28660	Freshwater Fishes	*Notropis Mekistocholas*	Cape Fear Shiner	G1	LE	03030003
AFCJB28660	Freshwater Fishes	*Notropis Mekistocholas*	Cape Fear Shiner	G1	LE	03030004
AFCPB09010	Freshwater Fishes	*Microphis Brachyurus*	Opossum Pipefish	G4G5	(PS:C)	03030005
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	03030005
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	03040201
AFCND02020	Freshwater Fishes	*Menidia Extensa*	Waccamaw Silverside	G1	LT	03040206
AFCPB09010	Freshwater Fishes	*Microphis Brachyurus*	Opossum Pipefish	G4G5	(PS:C)	03080103
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	03080103
AFCAA01042	Freshwater Fishes	*Acipenser Oxyrinchus Oxyrinchus*	Atlantic Sturgeon	G3T3	C	03080103
AFCPB09010	Freshwater Fishes	*Microphis Brachyurus*	Opossum Pipefish	G4G5	(PS:C)	03080201
AFCNG01020	Marine Fishes	*Rivulus Marmoratus*	Mangrove Rivulus	G3	(PS:C)	03080202
AFCAA01042	Freshwater Fishes	*Acipenser Oxyrinchus Oxyrinchus*	Atlantic Sturgeon	G3T3	C	03080202
AFCPB09010	Freshwater Fishes	*Microphis Brachyurus*	Opossum Pipefish	G4G5	(PS:C)	03080203
AFCNG01020	Marine Fishes	*Rivulus Marmoratus*	Mangrove Rivulus	G3	(PS:C)	03080203

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCPB09010	Freshwater Fishes	*Microphis Brachyurus*	Opossum Pipefish	G4G5	(PS:C)	03090202
AFCNG01020	Marine Fishes	*Rivulus Marmoratus*	Mangrove Rivulus	G3	(PS:C)	03090202
AFCND02030	Marine Fishes	*Menidia Conchorum*	Key Silverside	G3Q	C	03090203
AFCNG01020	Marine Fishes	*Rivulus Marmoratus*	Mangrove Rivulus	G3	(PS:C)	03090203
AFCNG01020	Marine Fishes	*Rivulus Marmoratus*	Mangrove Rivulus	G3	(PS:C)	03090204
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03100101
AFCPB09010	Freshwater Fishes	*Microphis Brachyurus*	Opossum Pipefish	G4G5	(PS:C)	03100206
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03100207
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03110101
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03110205
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03120003
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03130011
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03140101
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03140102
AFCQC02520	Freshwater Fishes	*Etheostoma Okaloosae*	Okaloosa Darter	G1	LE	03140102
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03140103
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03140104
AFCNB04090	Marine Fishes	*Fundulus Jenkinsi*	Saltmarsh Topminnow	G2	C	03140105
AFCNB04090	Marine Fishes	*Fundulus Jenkinsi*	Saltmarsh Topminnow	G2	C	03140107
AFCNB04090	Marine Fishes	*Fundulus Jenkinsi*	Saltmarsh Topminnow	G2	C	03140305
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03140305

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCAA02030	Freshwater Fishes	*Scaphirhynchus Suttkusi*	Alabama Sturgeon	G1	LE	03160103
AFCQC04360	Freshwater Fishes	*Percina Aurora*	Pearl Darter	G1	C	03170001
AFCQC04360	Freshwater Fishes	*Percina Aurora*	Pearl Darter	G1	C	03170004
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03170004
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03170006
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03170007
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03170008
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03170009
AFCNB04090	Marine Fishes	*Fundulus Jenkinsi*	Saltmarsh Topminnow	G2	C	03170009
AFCFA01020	Freshwater Fishes	*Alosa Alabamae*	Alabama Shad	G3	C	03180001
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03180002
AFCQC04360	Freshwater Fishes	*Percina Aurora*	Pearl Darter	G1	C	03180002
AFCFA01020	Freshwater Fishes	*Alosa Alabamae*	Alabama Shad	G3	C	03180002
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03180003
AFCFA01020	Freshwater Fishes	*Alosa Alabamae*	Alabama Shad	G3	C	03180003
AFCFA01020	Freshwater Fishes	*Alosa Alabamae*	Alabama Shad	G3	C	03180004
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03180004
AFCQC04360	Freshwater Fishes	*Percina Aurora*	Pearl Darter	G1	C	03180004
AFCQC04360	Freshwater Fishes	*Percina Aurora*	Pearl Darter	G1	C	03180005
AFCFA01020	Freshwater Fishes	*Alosa Alabamae*	Alabama Shad	G3	C	03180005
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	03180005

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB31010	Freshwater Fishes	*Phoxinus Cumberlandensis*	Blackside Dace	G2	LT	05130101
AFCJB31010	Freshwater Fishes	*Phoxinus Cumberlandensis*	Blackside Dace	G2	LT	05130101
AFCJB31010	Freshwater Fishes	*Phoxinus Cumberlandensis*	Blackside Dace	G2	LT	05130102
AFCJB31010	Freshwater Fishes	*Phoxinus Cumberlandensis*	Blackside Dace	G2	LT	05130103
AFCJB28A90	Freshwater Fishes	*Notropis Albizonatus*	Palezone Shiner	G2	LE	05130104
AFCQC02X30	Freshwater Fishes	*Etheostoma Percnurum*	Duskytail Darter	G1	LE	05130104
AFCFA01020	Freshwater Fishes	*Alosa Alabamae*	Alabama Shad	G3	C	05140101
AFCKA02060	Freshwater Fishes	*Noturus Flavipinnis*	Yellowfin Madtom	G1	(LT,XN)	06010101
AFCJB50010	Freshwater Fishes	*Erimystax Cahni*	Slender Chub	G1	LT	06010101
AFCJB15080	Freshwater Fishes	*Hybopsis Monacha*	Spotfin Chub	G2	LT	06010101
AFCJB15080	Freshwater Fishes	*Hybopsis Monacha*	Spotfin Chub	G2	LT	06010102
AFCJB15080	Freshwater Fishes	*Hybopsis Monacha*	Spotfin Chub	G2	LT	06010105
AFCJB15080	Freshwater Fishes	*Hybopsis Monacha*	Spotfin Chub	G2	LT	06010202
AFCJB15080	Freshwater Fishes	*Hybopsis Monacha*	Spotfin Chub	G2	LT	06010203
AFCJB50010	Freshwater Fishes	*Erimystax Cahni*	Slender Chub	G1	LT	06010205
AFCQC02X30	Freshwater Fishes	*Etheostoma Percnurum*	Duskytail Darter	G1	LE	06010205
AFCKA02060	Freshwater Fishes	*Noturus Flavipinnis*	Yellowfin Madtom	G1	(LT,XN)	06010205
AFCJB50010	Freshwater Fishes	*Erimystax Cahni*	Slender Chub	G1	LT	06010206
AFCFA01020	Freshwater Fishes	*Alosa Alabamae*	Alabama Shad	G3	C	06040006
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08010100
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	08010100

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08010100
AFCFA01020	Freshwater Fishes	*Alosa Alabamae*	Alabama Shad	G3	C	08010100
AFCQC02B00	Freshwater Fishes	*Etheostoma Chienense*	Relict Darter	G1	LE	08010201
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08020100
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08020203
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08030100
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08030207
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08060100
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	08060100
AFCQC02630	Freshwater Fishes	*Etheostoma Rubrum*	Bayou Darter	G1	LT	08060203
AFCQC02630	Freshwater Fishes	*Etheostoma Rubrum*	Bayou Darter	G1	LT	08060302
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08070100
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	08070205
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08080101
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08090100
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	08090201
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	08090202
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	08090203
AFCAA01041	Freshwater Fishes	*Acipenser Oxyrinchus Desotoi*	Gulf Sturgeon	G3T2	LT	08090203
AFCHA07011	Freshwater Fishes	*Thymallus Arcticus Pop 2*	Arctic Grayling - Upper Missouri River Fluvial	G5T2Q	C	10020007
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10060005

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCHA07011	Freshwater Fishes	*Thymallus Arcticus Pop 2*	Arctic Grayling - Upper Missouri River Fluvial	G5T2Q	C	10070001
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10080007
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10080010
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10090202
AFCJB3705B	Freshwater Fishes	*Rhinichthys Osculus Thermalis*	Kendall Warm Springs Dace	G5T1	LE	10090202
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10090207
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10100004
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10100004
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10110101
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10110101
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10110201
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10110202
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10110203
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10110204
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10110205
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10110205
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10120109
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10120110
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10120111
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10120112
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10130102

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10130102
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10130102
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10130105
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10130202
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10140101
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10140101
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10140103
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10140201
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10140202
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10140203
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10140204
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10150007
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10160004
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10160006
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10160011
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10160011
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10170101
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10170101
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10170101
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10170101
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10170102

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10170103
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10170202
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10170203
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10180002
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10200101
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10200202
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10200202
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10200203
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10210006
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10210009
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10220002
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10220003
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10230001
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10230001
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10230001
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10230006
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10230006
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10230006
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10230006
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10240001
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10240001

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10240001
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10240005
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10240005
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10240005
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10240011
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10240011
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10240011
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10250004
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10250016
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10250017
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10260001
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10260008
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10260008
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10270101
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10270102
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10270102
AFCJB53030	Freshwater Fishes	*Macrhybopsis Meeki*	Sicklefin Chub	G3	C	10270104
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10270104
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10270104
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10270202
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10270205

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10270206
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	10290101
AFCLA01010	Freshwater Fishes	*Amblyopsis Rosae*	Ozark Cavefish	G2G3	LT	11010001
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11030004
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11030009
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11030010
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11030010
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11030013
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11030013
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11030014
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11030015
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11030015
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11030016
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11030016
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	11030017
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11040006
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11040006
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11040007
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11040007
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11040008
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11040008

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11060002
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11060002
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11060003
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11060003
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11060005
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	11070201
AFCKA02200	Freshwater Fishes	*Noturus Placidus*	Neosho Madtom	G2	LT	11070201
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	11070202
AFCKA02200	Freshwater Fishes	*Noturus Placidus*	Neosho Madtom	G2	LT	11070203
AFCJB28960	Freshwater Fishes	*Notropis Topeka*	Topeka Shiner	G2	LE	11070203
AFCKA02200	Freshwater Fishes	*Noturus Placidus*	Neosho Madtom	G2	LT	11070204
AFCKA02200	Freshwater Fishes	*Noturus Placidus*	Neosho Madtom	G2	LT	11070205
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11070207
AFCKA02200	Freshwater Fishes	*Noturus Placidus*	Neosho Madtom	G2	LT	11070207
AFCLA01010	Freshwater Fishes	*Amblyopsis Rosae*	Ozark Cavefish	G2G3	LT	11070208
AFCLA01010	Freshwater Fishes	*Amblyopsis Rosae*	Ozark Cavefish	G2G3	LT	11070209
AFCLA01010	Freshwater Fishes	*Amblyopsis Rosae*	Ozark Cavefish	G2G3	LT	11110103
AFCQC02170	Freshwater Fishes	*Etheostoma Cragini*	Arkansas Darter	G3	C	11110103
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11110202
AFCQC04210	Freshwater Fishes	*Percina Pantherina*	Leopard Darter	G1	LT	11140108
AFCQC04210	Freshwater Fishes	*Percina Pantherina*	Leopard Darter	G1	LT	11140109

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB16070	Freshwater Fishes	*Hybognathus Amarus*	Rio Grande Silvery Minnow	G1G2	LE	13020201
AFCJB16070	Freshwater Fishes	*Hybognathus Amarus*	Rio Grande Silvery Minnow	G1G2	LE	13020203
AFCJB13110	Freshwater Fishes	*Gila Nigrescens*	Chihuahua Chub	G1	LT	13030202
AFCHA02101	Freshwater Fishes	*Oncorhynchus Gilae Gilae*	Gila Trout	G3T1	LE	13030202
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	13060003
AFCJB28891	Freshwater Fishes	*Notropis Simus Pecosensis*	Pecos Bluntnose Shiner	G2T2	LT	13060003
AFCNC02070	Freshwater Fishes	*Gambusia Nobilis*	Pecos Gambusia	G2	LE	13060003
AFCNC02070	Freshwater Fishes	*Gambusia Nobilis*	Pecos Gambusia	G2	LE	13060005
AFCNC02070	Freshwater Fishes	*Gambusia Nobilis*	Pecos Gambusia	G2	LE	13060007
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	13060007
AFCJB28891	Freshwater Fishes	*Notropis Simus Pecosensis*	Pecos Bluntnose Shiner	G2T2	LT	13060007
AFCNC02070	Freshwater Fishes	*Gambusia Nobilis*	Pecos Gambusia	G2	LE	13060008
AFCJB28891	Freshwater Fishes	*Notropis Simus Pecosensis*	Pecos Bluntnose Shiner	G2T2	LT	13060011
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	13060011
AFCNC02070	Freshwater Fishes	*Gambusia Nobilis*	Pecos Gambusia	G2	LE	13060011
AFCJB13080	Freshwater Fishes	*Gila Cypha*	Humpback Chub	G1	LE	14040106
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	14040106
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	14040107
AFCJB13080	Freshwater Fishes	*Gila Cypha*	Humpback Chub	G1	LE	14070006
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	14070006
AFCJB35020	Freshwater Fishes	*Ptychocheilus Lucius*	Colorado Pikeminnow	G1	(LE,XN)	14080101

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB13080	Freshwater Fishes	*Gila Cypha*	Humpback Chub	G1	LE	15010001
AFCJB13080	Freshwater Fishes	*Gila Cypha*	Humpback Chub	G1	LE	15010002
AFCJB13080	Freshwater Fishes	*Gila Cypha*	Humpback Chub	G1	LE	15010003
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	15010005
AFCJB33010	Freshwater Fishes	*Plagopterus Argentissimus*	Woundfin	G1	(LE,XN)	15010010
AFCJB13170	Freshwater Fishes	*Gila Seminuda*	Virgin River Chub	G1	(PS:LE)	15010010
AFCJB20040	Freshwater Fishes	*Lepidomeda Vittata*	Little Colorado Spinedace	G1G2	LT	15020001
AFCJB20040	Freshwater Fishes	*Lepidomeda Vittata*	Little Colorado Spinedace	G1G2	LT	15020002
AFCJB20040	Freshwater Fishes	*Lepidomeda Vittata*	Little Colorado Spinedace	G1G2	LT	15020005
AFCJB20040	Freshwater Fishes	*Lepidomeda Vittata*	Little Colorado Spinedace	G1G2	LT	15020008
AFCJB20040	Freshwater Fishes	*Lepidomeda Vittata*	Little Colorado Spinedace	G1G2	LT	15020010
AFCJB13080	Freshwater Fishes	*Gila Cypha*	Humpback Chub	G1	LE	15020016
AFCJB13100	Freshwater Fishes	*Gila Elegans*	Bonytail	G1	LE	15030101
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	15030101
AFCJB13100	Freshwater Fishes	*Gila Elegans*	Bonytail	G1	LE	15030104
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	15030104
AFCJB35020	Freshwater Fishes	*Ptychocheilus Lucius*	Colorado Pikeminnow	G1	(LE,XN)	15030107
AFCNB02061	Freshwater Fishes	*Cyprinodon Macularius Macularius*	Desert Pupfish	G1T1	(LE)	15030203
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	15030204
AFCJB13100	Freshwater Fishes	*Gila Elegans*	Bonytail	G1	LE	15030204
AFCHA02101	Freshwater Fishes	*Oncorhynchus Gilae Gilae*	Gila Trout	G3T1	LE	15040001

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB37140	Freshwater Fishes	*Rhinichthys Cobitis*	Loach Minnow	G2	LT	15040001
AFCJB22010	Freshwater Fishes	*Meda Fulgida*	Spikedace	G2	LT	15040001
AFCJB37140	Freshwater Fishes	*Rhinichthys Cobitis*	Loach Minnow	G2	LT	15040002
AFCHA02101	Freshwater Fishes	*Oncorhynchus Gilae Gilae*	Gila Trout	G3T1	LE	15040002
AFCJB22010	Freshwater Fishes	*Meda Fulgida*	Spikedace	G2	LT	15040002
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15040004
AFCJB37140	Freshwater Fishes	*Rhinichthys Cobitis*	Loach Minnow	G2	LT	15040004
AFCHA02101	Freshwater Fishes	*Oncorhynchus Gilae Gilae*	Gila Trout	G3T1	LE	15040004
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	15040004
AFCJB22010	Freshwater Fishes	*Meda Fulgida*	Spikedace	G2	LT	15040005
AFCNB02061	Freshwater Fishes	*Cyprinodon Macularius Macularius*	Desert Pupfish	G1T1	(LE)	15040005
AFCJB37140	Freshwater Fishes	*Rhinichthys Cobitis*	Loach Minnow	G2	LT	15040005
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15040005
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	15040005
AFCNB02061	Freshwater Fishes	*Cyprinodon Macularius Macularius*	Desert Pupfish	G1T1	(LE)	15040006
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15040007
AFCNB02061	Freshwater Fishes	*Cyprinodon Macularius Macularius*	Desert Pupfish	G1T1	(LE)	15050100
AFCJB22010	Freshwater Fishes	*Meda Fulgida*	Spikedace	G2	LT	15050100
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15050202
AFCJB22010	Freshwater Fishes	*Meda Fulgida*	Spikedace	G2	LT	15050203
AFCJB37140	Freshwater Fishes	*Rhinichthys Cobitis*	Loach Minnow	G2	LT	15050203

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15050203
AFCNB02061	Freshwater Fishes	*Cyprinodon Macularius Macularius*	Desert Pupfish	G1T1	(LE)	15050301
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15050301
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15050302
AFCJB37140	Freshwater Fishes	*Rhinichthys Cobitis*	Loach Minnow	G2	LT	15060101
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	15060103
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15060105
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15060106
AFCNB02061	Freshwater Fishes	*Cyprinodon Macularius Macularius*	Desert Pupfish	G1T1	(LE)	15060106
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15060201
AFCJB22010	Freshwater Fishes	*Meda Fulgida*	Spikedace	G2	LT	15060202
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	15060202
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15060202
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	15060203
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15060203
AFCNB02061	Freshwater Fishes	*Cyprinodon Macularius Macularius*	Desert Pupfish	G1T1	(LE)	15070102
AFCJB13160	Freshwater Fishes	*Gila Intermedia*	Gila Chub	G2	C	15070102
AFCNB02061	Freshwater Fishes	*Cyprinodon Macularius Macularius*	Desert Pupfish	G1T1	(LE)	15070103
AFCJB13100	Freshwater Fishes	*Gila Elegans*	Bonytail	G1	LE	15070103
AFCNB02062	Freshwater Fishes	*Cyprinodon Macularius Eremus*	Quitobaquito Desert Pupfish	G1T1	(LE)	15080102
AFCJB13090	Freshwater Fishes	*Gila Ditaenia*	Sonora Chub	G2	LT	15080201

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB13140	Freshwater Fishes	*Gila Purpurea*	Yaqui Chub	G1	LE	15080301
AFCJB13140	Freshwater Fishes	*Gila Purpurea*	Yaqui Chub	G1	LE	15080302
AFCJB49080	Freshwater Fishes	*Cyprinella Formosa*	Beautiful Shiner	G2	LT	15080302
AFCHA02089	Freshwater Fishes	*Oncorhynchus Clarki Seleniris*	Paiute Cutthroat Trout	G4T1T2	LT	16060010
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010101
AFCAA01051	Freshwater Fishes	*Acipenser Transmontanus Pop 1*	White Sturgeon - Kootenai River	G4T1Q	LE	17010104
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010104
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010105
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010213
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010214
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010215
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010216
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010301
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010303
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010304
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010304
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010304
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010304
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010304
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010304
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010304

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17010304
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17040212
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17040217
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17050101
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17050102
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17050103
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17050111
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17050112
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17050113
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17050120
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17050121
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17050122
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17050124
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17050201
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17050201
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon or King Salmon	G5	(PS)	17060101
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17060101
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060101
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060101
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060103
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060103

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCHA02042	Freshwater Fishes	*Oncorhynchus Nerka Pop 1*	Sockeye Salmon - Snake River	G5T1Q	LE	17060103
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060103
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17060103
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060108
AFCHA02042	Freshwater Fishes	*Oncorhynchus Nerka Pop 1*	Sockeye Salmon - Snake River	G5T1Q	LE	17060201
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060201
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17060201
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060201
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060201
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060202
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060202
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060202
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060203
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060203
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060203
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17060203
AFCHA02042	Freshwater Fishes	*Oncorhynchus Nerka Pop 1*	Sockeye Salmon - Snake River	G5T1Q	LE	17060203
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060204
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060204
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060204
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060205

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060205
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060205
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060206
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060206
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060206
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060207
AFCHA02042	Freshwater Fishes	*Oncorhynchus Nerka Pop 1*	Sockeye Salmon - Snake River	G5T1Q	LE	17060207
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060207
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060207
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17060207
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060208
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060208
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060208
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060209
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060209
AFCAA01050	Freshwater Fishes	*Acipenser Transmontanus*	White Sturgeon	G4	(PS)	17060209
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060209
AFCHA02042	Freshwater Fishes	*Oncorhynchus Nerka Pop 1*	Sockeye Salmon - Snake River	G5T1Q	LE	17060209
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060210
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060210
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060210

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060301
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060301
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060301
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060302
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060302
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060302
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060303
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060303
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060303
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060304
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060304
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060304
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060305
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060305
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060305
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060306
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060306
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060306
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060307
AFCHA05020	Freshwater Fishes	*Salvelinus Confluentus*	Bull Trout	G3	(PS)	17060308
AFCHA02050	Freshwater Fishes	*Oncorhynchus Tshawytscha*	Chinook Salmon Or King Salmon	G5	(PS)	17060308

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCHA0209M	Freshwater Fishes	*Oncorhynchus Mykiss Pop 13*	Steelhead - Snake River Basin	G5T2T3Q	LT	17060308
AFCJB1303M	Freshwater Fishes	*Gila Bicolor Vaccaceps*	Cowhead Lake Tui Chub	G4T1	PE	17120007
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18010101
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18010102
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18010108
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18010111
AFCJC03010	Freshwater Fishes	*Chasmistes Brevirostris*	Shortnose Sucker	G1	LE	18010204
AFCJC12010	Freshwater Fishes	*Deltistes Luxatus*	Lost River Sucker	G1	LE	18010204
AFCJC12010	Freshwater Fishes	*Deltistes Luxatus*	Lost River Sucker	G1	LE	18010206
AFCJC03010	Freshwater Fishes	*Chasmistes Brevirostris*	Shortnose Sucker	G1	LE	18010206
AFCJC02140	Freshwater Fishes	*Catostomus Microps*	Modoc Sucker	G1	LE	18020002
AFCHA0205B	Freshwater Fishes	*Oncorhynchus Tshawytscha Pop 7*	Chinook Salmon - Sacramento River Winter Run	G5T1Q	LE	18020101
AFCHA0205B	Freshwater Fishes	*Oncorhynchus Tshawytscha Pop 7*	Chinook Salmon - Sacramento River Winter Run	G5T1Q	LE	18020102
AFCHA0205B	Freshwater Fishes	*Oncorhynchus Tshawytscha Pop 7*	Chinook Salmon - Sacramento River Winter Run	G5T1Q	LE	18020103
AFCJB34020	Freshwater Fishes	*Pogonichthys Macrolepidotus*	Splittail	G2	LT	18020104
AFCJB34020	Freshwater Fishes	*Pogonichthys Macrolepidotus*	Splittail	G2	LT	18020106
AFCJB34020	Freshwater Fishes	*Pogonichthys Macrolepidotus*	Splittail	G2	LT	18020109
AFCHA0205B	Freshwater Fishes	*Oncorhynchus Tshawytscha Pop 7*	Chinook Salmon - Sacramento River Winter Run	G5T1Q	LE	18020112
AFCHA0209B	Freshwater Fishes	*Oncorhynchus Mykiss Whitei*	Little Kern Golden Trout	G5T2Q	LT	18030001

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCHA0209B	Freshwater Fishes	*Oncorhynchus Mykiss Whitei*	Little Kern Golden Trout	G5T2Q	LT	18030006
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18050005
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18050006
AFCHA0209J	Freshwater Fishes	*Oncorhynchus Mykiss Pop 10*	Steelhead - Southern California	G5T1T2Q	LE	18050006
AFCHA0209J	Freshwater Fishes	*Oncorhynchus Mykiss Pop 10*	Steelhead - Southern California	G5T1T2Q	LE	18060001
AFCHA0209J	Freshwater Fishes	*Oncorhynchus Mykiss Pop 10*	Steelhead - Southern California	G5T1T2Q	LE	18060001
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18060001
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18060001
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18060006
AFCHA0209J	Freshwater Fishes	*Oncorhynchus Mykiss Pop 10*	Steelhead - Southern California	G5T1T2Q	LE	18060006
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18060008
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18060009
AFCPA03011	Freshwater Fishes	*Gasterosteus Aculeatus Williamsoni*	Unarmored Threespine Stickleback	G5T1	LE	18060010
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18060011
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18060013
AFCPA03011	Freshwater Fishes	*Gasterosteus Aculeatus Williamsoni*	Unarmored Threespine Stickleback	G5T1	LE	18060013
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18070101
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18070102
AFCJC02190	Freshwater Fishes	*Catostomus Santaanae*	Santa Ana Sucker	G1	LT	18070102
AFCJC02190	Freshwater Fishes	*Catostomus Santaanae*	Santa Ana Sucker	G1	LT	18070203
AFCQN04010	Freshwater Fishes	*Eucyclogobius Newberryi*	Tidewater Goby	G3	LE,PDL	18070301

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCNB02090	Freshwater Fishes	*Cyprinodon Radiosus*	Owens River Pupfish	G1	LE	18090102
AFCJB1303J	Freshwater Fishes	*Gila Bicolor Snyderi*	Owens Tui Chub	G4T1	LE	18090102
AFCHA02089	Freshwater Fishes	*Oncorhynchus Clarki Seleniris*	Paiute Cutthroat Trout	G4T1T2	LT	18090102
AFCNB02090	Freshwater Fishes	*Cyprinodon Radiosus*	Owens River Pupfish	G1	LE	18090103
AFCJB1303J	Freshwater Fishes	*Gila Bicolor Snyderi*	Owens Tui Chub	G4T1	LE	18090103
AFCJB1303H	Freshwater Fishes	*Gila Bicolor Mohavensis*	Mohave Tui Chub	G4T1	LE	18090207
AFCJB1303H	Freshwater Fishes	*Gila Bicolor Mohavensis*	Mohave Tui Chub	G4T1	LE	18090208
AFCPA03011	Freshwater Fishes	*Gasterosteus Aculeatus Williamsoni*	Unarmored Threespine Stickleback	G5T1	LE	18100200
AFCNB02060	Freshwater Fishes	*Cyprinodon Macularius*	Desert Pupfish	G1	LE	18100200
AFCJC11010	Freshwater Fishes	*Xyrauchen Texanus*	Razorback Sucker	G1	LE	18100200
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	07110000
AFCAA02010	Freshwater Fishes	*Scaphirhynchus Albus*	Pallid Sturgeon	G1G2	LE	10000000
AFCJB53020	Freshwater Fishes	*Macrhybopsis Gelida*	Sturgeon Chub	G2	C	10000000
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11040001
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11040006
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11040008
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11050001
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11050002
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11050003
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11060004
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11060006

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11070105
AFCKA02200	Freshwater Fishes	*Noturus Placidus*	Neosho Madtom	G2	LT	11070206
AFCLA01010	Freshwater Fishes	*Amblyopsis Rosae*	Ozark Cavefish	G2G3	LT	11070206
AFCLA01010	Freshwater Fishes	*Amblyopsis Rosae*	Ozark Cavefish	G2G3	LT	11070207
AFCLA01010	Freshwater Fishes	*Amblyopsis Rosae*	Ozark Cavefish	G2G3	LT	11070209
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11090201
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11090202
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11090203
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11090204
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11100101
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11100102
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11100103
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11100104
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11100201
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11100203
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11100301
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11100302
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11100303
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11110101
AFCKA02200	Freshwater Fishes	*Noturus Placidus*	Neosho Madtom	G2	LT	11110103
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11110104

Table A1-1: Listing Status and Hydrologic Unit Code (HUC) for Threatened and Endangered Species in 30 States Compiled by The Nature Conservancy

ABI Identifier	Informal Taxon	Scientific Name	Common Name	Global Status	Federal Status	HUC Code
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11130210
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11130304
AFCJB28490	Freshwater Fishes	*Notropis Girardi*	Arkansas River Shiner	G2	LT	11140107
AFCQC04210	Freshwater Fishes	*Percina Pantherina*	Leopard Darter	G1	LT	11140107
AFCQC04210	Freshwater Fishes	*Percina Pantherina*	Leopard Darter	G1	LT	11140108
AFCAA01010	Freshwater Fishes	*Acipenser Brevirostrum*	Shortnose Sturgeon	G3	LE	02040202
AFCAA01040	Freshwater Fishes	*Acipenser Oxyrinchus*	Atlantic Sturgeon	G3	(LT,C)	02040201

Source: NatureServe, 2002.

Table A1-2: Definitions of Abbreviations for Global Status

Abbreviation	Global Status
GX	Presumed Extinct (species) — Believed to be extinct throughout its range. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
GH	Possibly Extinct (species) — Known from only historical occurrences, but may nevertheless still be extant; further searching needed.
G1	Critically Imperiled — Critically imperiled globally because of extreme rarity or because of some factor(s)making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (<1,000) or acres (<2,000) or linear miles (<10).
G2	Imperiled — Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).
G3	Vulnerable — Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
G4	Apparently Secure — Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.
G5	Secure — Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals.
G#G#	Range Rank — A numeric range rank (e.g., G2G3) is used to indicate uncertainty about the exact status of a taxon. Ranges cannot skip more than one rank (e.g., GU should be used rather than G1G4).
GU	Unrankable — Currently unrankable due to lack of information or due to substantially conflicting information about status or trends. NOTE: Whenever possible, the most likely rank is assigned and the question mark qualifier is added (e.g., G2?) to express uncertainty, or a range rank (e.g., G2G3) is used to delineate the limits (range) of uncertainty.
G?	Unranked — Global rank not yet assessed.
HYB	Hybrid — (species elements only) Element not ranked because it represents an interspecific hybrid and not a species. (Note, however, that hybrid-derived species are ranked as species, not as hybrids.)
?	Inexact Numeric Rank — Denotes inexact numeric rank.
Q	Questionable taxonomy that may reduce conservation priority. Distinctiveness of this entity as a taxon at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority (numerically higher) conservation status rank.
C	Captive or Cultivated Only — Taxon at present is extant only in captivity or cultivation, or as a reintroduced population not yet established.
T_	Infraspecific Taxon (trinomial) — The status of infraspecific taxa (subspecies or varieties) are indicated by a “T-rank” following the species’ global rank. Rules for assigning T ranks follow the same principles outlined above. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1. A T subrank cannot imply the subspecies or variety is more abundant than the species (e.g., a G1T2 subrank should not occur). A vertebrate animal population (e.g., listed under the U.S. Endangered Species Act or assigned candidate status) may be tracked as an infraspecific taxon and given a T rank; in such cases a Q is used after the T rank to denote the taxon’s informal taxonomic status.

Table A1-3: Definitions of Abbreviations for Federal Status Listing

Abbreviation	Federal Status
LE	Listed endangered.
LT	Listed threatened.
PE	Proposed endangered.
PT	Proposed threatened.
C	Candidate.
PDL	Proposed for delisting.
E(S/A) or T(S/A)	Listed endangered or threatened because of similarity of appearance.
XE	Essential experimental population.
XN	Experimental nonessential population.
Combination values	The taxon has one status currently, but a more recent proposal has been made to change that status with no final action yet published. For example, LE-PDL indicates that the species is currently listed as endangered, but has been proposed for delisting.
Values in parentheses	The taxon itself is not named in the Federal Register as having federal status; however, it does have federal status as a result of its taxonomic relationship to a named entity. For example, if a species is federally listed with endangered status, then by default, all of its recognized subspecies also have endangered status. The subspecies in this example would have the value "(LE)" under U.S. Federal Status. Likewise, if all of a species' infraspecific taxa (worldwide) have the same federal status, then that status appears in the record for the "full" species as well. In this case, if the taxon at the species level is not mentioned in the Federal Register, the status appears in parentheses in that record.
Combination values in parentheses	The taxon itself is not named in the Federal Register as having official federal status; however, all of its infraspecific taxa (worldwide) do have official status. The statuses shown in parentheses indicate the statuses that apply to infraspecific taxa or populations within this taxon.
(PS)	Indicates "partial status" – status in only a portion of the species' range. Typically indicated in a "full" species record where an infraspecific taxon or population has federal status, but the entire species does not.
Null value	Usually indicates that the taxon does not have any federal status. However, because of potential lag time between publication in the Federal Register and entry in the NHCD, some taxa may have a status that does not yet appear.

Part B: California

Chapter B1: Background

Introduction

Chapter Contents

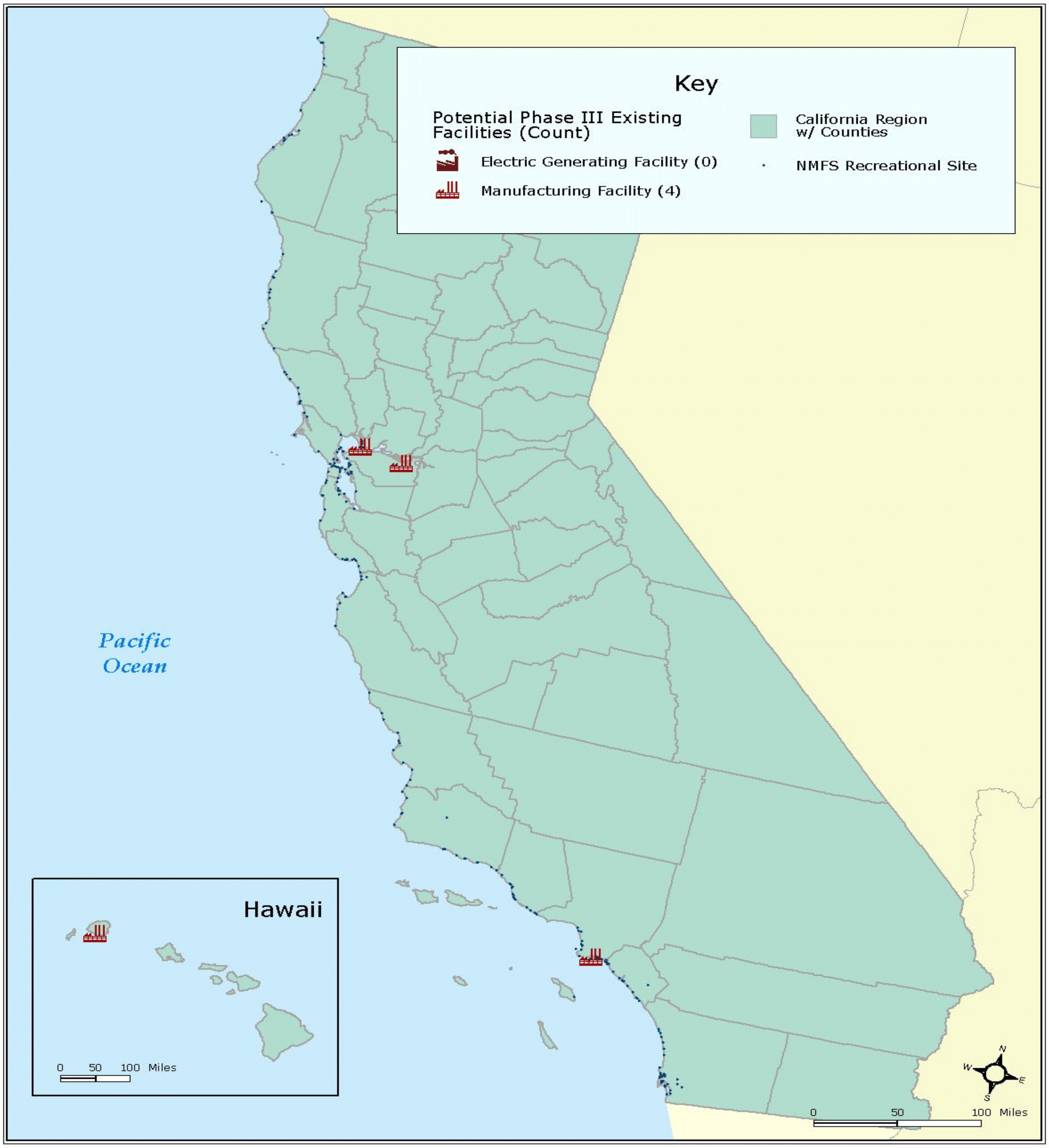
This chapter presents an overview of the potential Phase III existing facilities in the California study region and summarizes their key cooling water and compliance characteristics. For further discussion of the technical and compliance characteristics of potential Phase III existing facilities, refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* and the *Technical Development Document for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a,b).

B1-1 Facility Characteristics

The California Regional Study includes four sample facilities that are potentially subject to the proposed standards for Phase III existing facilities. All four facilities are manufacturing facilities. Industry-wide, these four sample facilities represent eight manufacturing facilities.[1] Figure B1-1 presents a map of these facilities.

[1] EPA applied sample weights to the survey respondents to account for non-sampled facilities and facilities that did not respond to the survey. For more information on EPA's 2000 Section 316(b) Industry Survey, please refer to the Information Collection Request (U.S. EPA, 2000).

Figure B1-1: Potential Existing Phase III Facilities in the California Regional Study



Source: U.S. EPA analysis for this report.

Table B1-1 summarizes key technical and compliance characteristics for all potentially regulated Phase III existing facilities in the California study region and for the three proposed regulatory options considered by EPA for this proposal (the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD for Certain Waterbodies" option). Facilities with a design intake flow below the three applicability thresholds would be subject to permitting based on best professional judgment and are excluded from EPA's analyses.[2] Therefore, a different number of facilities is affected under each option.

Table B1-1 shows that eight Phase III existing facilities in the California study region would potentially be subject to the national requirements. Under the "50 MGD for All Waterbodies" option, the most inclusive of the three proposed options, only one facility would be subject to the national requirements for Phase III existing facilities. Under the less inclusive "200 MGD for All Waterbodies" option and "100 MGD for Certain Waterbodies" option (which includes all facilities in the California study region), no facilities would be subject to the national requirements. No facility in the California study region has a recirculating system in the baseline. Data on design intake flow for the California study facilities have been withheld due to data confidentiality reasons.

Table B1-1: Technical and Compliance Characteristics of Phase III Existing Facilities (Sample-Weighted)

	All Potentially Regulated Facilities	Proposed Options		
		50 MGD All	200 MGD All	100 MGD CWB
Total Number of Facilities (Sample-Weighted)	**8**	**1**	**-**	**-**
Number of Facilities with Recirculating System in Baseline	-	-	-	-
Design Intake Flow (MGD)	**w[a]**	**w[a]**	**w[a]**	**w[a]**
Number of Facilities by Compliance Response				
New larger intake structure with fine mesh and fish H&R	1	1	-	-
Passive fine mesh screens	3	-	-	-
None	4	-	-	-
Compliance Cost at 3%[b]	$2.23	$0.85	$0.00	$0.00
Compliance Cost at 7%[b]	$2.24	$0.97	$0.00	$0.00

[a] Data withheld because of confidentiality reasons.
[b] Annualized pre-tax compliance cost (2003$, millions)

Source: U.S. EPA, 2000; U.S. EPA analysis for this report.

[2] Also excluded are facilities that are estimated to be baseline closures. For additional information on EPA's baseline closure analyses, please refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a).

Chapter B2: Evaluation of Impingement and Entrainment in California

Chapter Contents

Background: California Marine Fisheries

California marine fisheries are managed by the Pacific Fishery Management Council (PFMC), which governs commercial and recreational fisheries in Federal waters from 3 to 200 nautical miles off the coasts of Washington, Oregon, and California (PFMC, 2003a). The National Marine Fisheries Service (NMFS) Northwest Fisheries Science Center provides scientific and technical support for management, conservation, and fisheries development for Northern California. The NMFS Southwest Fisheries Science Center provides support for Southern California.

There are 83 species of groundfish included under PFMC's Groundfish Fishery Management Plan, including nearly 50 species of rockfish (*Sebastes* spp.) (Table 3 in NMFS, 2002a). The midwater trawl fishery for Pacific whiting (*Merluccius productus*) dominates the commercial fishery, accounting for 78% of Pacific Coast landings (NMFS, 1999a). Important deepwater trawl fisheries also exist for sablefish, Dover sole, and thornyheads. During the 1990s a major fishery developed for nearshore species, including rockfishes, cabezon, and sheephead (Leet et al., 2001). Rockfishes are important for both commercial and recreational fisheries (NMFS, 1999a). In 1994, a limited entry program was implemented for the groundfish fishery because of concerns about overfishing (NMFS, 1999a). Most major Pacific Coast groundfishes are now fully harvested, and catches have recently been controlled by quotas and trip limits (PFMC, 2003c).

Pacific Coast pelagic species managed by the PFMC include Pacific mackerel (*Scomber japonicus*), jack mackerel (*Trachurus symmetricus*), Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), and California market squid (*Loligo opalescens*) (NMFS, 2002a). These species typically fluctuate widely in abundance, and currently most stocks are low relative to historical levels (NMFS, 1999a). Pacific mackerel and Pacific sardine are not overfished, but the stock size of the other species governed by the Coastal Pelagic FMP is unknown (Table 3 in NMFS, 2002a). Because of increases in abundance in recent years, Pacific mackerel now accounts for over half of recent landings of Pacific Coast pelagic species (NMFS, 1999a). At times, Pacific sardine has been the most abundant fish species in the California current. When the population is large, it is abundant from the tip of Baja California to southeastern Alaska (PFMC, 2003b).

Five species of anadromous Pacific salmon support coastal and freshwater commercial and recreational fisheries along the Pacific Coast, including chinook (*Oncorhynchus tshawytscha)*, coho (*O. kisutch*), sockeye (*O. nerka*), pink (*O. gorbuscha*), and chum (*O. keta*) salmon (NMFS, 1999a). The Sacramento River is a major producer of chinook salmon in California. Since 1991, NMFS has listed 20 Evolutionary Significant Units (ESUs)[1] of Pacific Coast salmon and steelhead trout (*O. mykiss*) under the Federal Endangered Species Act (ESA) (NMFS, 1999b).

[1] An Evolutionarily Significant Unit (ESU) is a term introduced by NMFS in 1991 to refer to the Endangered Species Act (ESA) interpretation of "distinct population segment." A stock must satisfy two criteria to be considered an ESU: (1) "it must be substantially reproductively isolated from other conspecific population units," and (2) "it must represent an important component in the evolutionary legacy of the species."

In NMFS's Northern California region, listed species include steelhead, coho salmon, and chinook salmon of the central California Coast and steelhead and chinook salmon of California's Central Valley.

Ocean fisheries for chinook and coho salmon are managed by the PFMC under the Pacific Coast Salmon FMP. In Puget Sound and the Columbia River, chinook and coho fisheries are managed by the States and Tribal fishery agencies. Declines in chinook and coho salmon along the coast have led to reductions and closures of ocean fisheries in recent years (NMFS, 1999a).

The Pacific Salmon FMP contains no fishery management objectives for sockeye, chum, even-year pink, and steelhead stocks because fishery impacts are considered inconsequential (Table 3 in NMFS, 2002a). Pink, chum, and sockeye salmon are managed jointly by the Pacific Salmon Commission, Washington State, and Tribal agencies (NMFS, 1999a).

Pacific Coast shellfish resources are important both commercially and recreationally (NMFS, 1999a). Shrimps, crabs, abalones, and clams command high prices and contribute substantially to the value of Pacific Coast fisheries, even though landings are small.

B2-1 I&E Species/Species Groups Evaluated

Table B2-1 provides a list of species/species groups in California that are impinged and entrained at cooling water intake structures in scope of the proposed section 316(b) rule for Phase III facilities. The life history data used in EPA's analysis and associated data sources are provided in Appendix B1.

Table B2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in California

Species/Species Group	Recreational	Commercial	Forage	Special Status[a]
American shad		X		
Anchovies		X		
Blennies			X	
Cabezon	X	X		
California halibut	X	X		
California scorpionfish	X	X		
Chinook salmon			X	X (FT, ST, FE, SE, FCT)
Commercial sea basses		X		
Commercial shrimp		X		
Delta smelt			X	X (FT, ST)
Drums and croakers	X	X		
Dungeness crab		X		
Flounders	X	X		
Forage shrimp			X	
Gobies			X	
Herrings			X	
Longfin smelt			X	X (SOC)
Northern anchovy		X		
Other (commercial)		X		
Other (commercial crabs)		X		

Table B2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in California

Species/Species Group	Recreational	Commercial	Forage	Special Status[a]
Other (forage)			X	
Other (recreational)	X			
Other (recreational and commercial)	X	X		
Pacific herring			X	
Recreational sea basses	X			
Rockfishes	X	X		
Sacramento splittail			X	X (FT)
Salmon	X			
Sculpins	X	X		
Silversides			X	
Smelts	X	X		
Steelhead			X	X (FT)
Striped bass	X			
Surfperches	X	X		

[a] FT = Federally listed as threatened.
ST = State listed as threatened.
FE = Federally listed as endangered.
SE = State listed as endangered.
FCT = Federal candidate for listing as threatened.
SOC = Species of concern.

B2-2 I&E Data Evaluated

Table B2-2 lists the facility impingement and entrainment (I&E) data evaluated by EPA to estimate I&E losses at Phase III facilities in California. None of the Phase III facilities in California have conducted I&E studies, so it was necessary to estimate I&E rates at these facilities by extrapolation from Phase II facilities. See Chapter A1 of Part A for a discussion of extrapolation methods.

Table B2-2: Phase II Facility I&E Data Evaluated for California Analysis

Facility	Years of Data
Contra Costa	1978-1992
Diablo Canyon Nuclear	1985-1998
El Segundo	1990-2001
Encina	1979
Harbor	1979
Haynes	1979-2001
Humboldt Bay	1980
Hunter’s Point	1978

Table B2-2: Phase II Facility I&E Data Evaluated for California Analysis

Facility	Years of Data
Huntington Beach	1979-2001
Mandalay	2001
Morro Bay	2000
Moss Landing	1979-1999
Ormond Beach	1979-2001
Pittsburg	1978-1992
Potrero	1978-2001
AES Redondo Beach	1979-2001
San Onofre Nuclear	1979-2001
Scattergood	1990-2002

B2-3 EPA's Estimate of Current I&E at Phase III Facilities in California Expressed as Age-1 Equivalents and Foregone Yield

Table B2-3 provides EPA's estimates of the annual age-1 equivalents and foregone fishery yield resulting from the impingement of aquatic species at Phase III facilities in California. Table B2-4 displays this information for entrainment. Note that in these tables, "total yield" includes direct losses of harvested species and the yield of harvested species that is lost due to losses of forage species. As discussed in Chapter A1 of Part A of the section 316(b) Phase III Regional Benefits Assessment, the conversion of forage to yield contributes only a very small fraction to total yield.

Table B2-3: Estimated Current Annual Impingement at Phase III Facilities in California Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
American shad	<1	<1
Anchovies	10,700	17
Blennies	<1	na
Cabezon	4	6
California halibut	<1	2
California scorpionfish	<1	<1
Chinook salmon	<1	na
Commercial sea bass	<1	<1
Commercial shrimp	139	<1
Delta smelt	5	na
Drums and croakers	9	<1
Dungeness crab	47	22
Flounders	425	41

Table B2-3: Estimated Current Annual Impingement at Phase III Facilities in California Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Forage shrimp	5	na
Gobies	164	na
Herrings	2,000	na
Longfin smelt	58	na
Other (commercial)	<1	<1
Other (commercial crabs)	230	<1
Other (forage)	616	na
Other (recreational)	<1	<1
Other (recreational and commercial)	5	1
Recreational sea basses	<1	<1
Rockfishes	441	106
Sacramento splittail	8	na
Salmon	<1	<1
Sculpins	730	29
Silversides	3,120	na
Smelts	313	8
Steelhead	<1	na
Striped bass	382	333
Surfperches	1,650	107
Trophic transfer[a]	na	28

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table B2-4: Estimated Current Annual Entrainment at Phase III Facilities in California Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
American shad	<1	<1
Anchovies	496	<1
Blennies	21,400	na
Cabezon	4,950	8,410
California halibut	5,780	21,700
Chinook salmon	<1	na
Commercial shrimp	17,700	<1
Delta smelt	1	na
Drums and croakers	885	52

Table B2-4: Estimated Current Annual Entrainment at Phase III Facilities in California Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Dungeness crab	709	327
Flounders	66	6
Forage shrimp	79,900	na
Gobies	12,500	na
Herrings	19,000	na
Longfin smelt	<1	na
Northern anchovy	7	<1
Other (commercial)	426	84
Other (commercial crabs)	318,000	64
Other (forage)	524,000	na
Other (recreational)	58	12
Pacific herring	2,860	na
Recreational sea basses	559	138
Rockfishes	260,000	62,700
Sacramento splittail	<1	na
Sculpins	16,300	647
Silversides	22	na
Smelts	11	<1
Striped bass	1,010	883
Trophic transfer[a]	na	91

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

B2-4 Reductions in I&E at Phase III Facilities in the California Region Under Three Alternative Options

Table B2-5 presents estimated reductions in I&E under the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD for Certain Waterbodies" option. Reductions under all other options are presented in Appendix B2.

Table B2-5: Estimated Reductions in I&E Under Three Alternative Options

Option	Age-One Equivalents (#s)	Foregone Fishery Yield (lbs)
50 MGD All Option	383,000	28,000
200 MGD All Option	0	0
100 MGD Option	0	0

B2-5 Assumptions Used in Calculating Recreational and Commercial Losses

The lost yield estimates presented in Tables B2-3 and B2-4 are expressed as total pounds and include losses to both commercial and recreational catch. To estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table B2-6 presents the percentage impacts assumed for each species/species group.

Table B2-6: Percentage of Total Impacts Occurring to the Commercial and Recreational Fisheries as a Result of Impingement and Entrainment at Phase III Facilities

Species/Species Group	Percent Impact to Recreational Fishery[a,b]	Percent Impact to Commercial Fishery[a,b]
American shad	0.0%	100.0%
Anchovies	0.0%	100.0%
Cabezon	45.9%	54.1%
California halibut	85.6%	14.4%
California scorpionfish	83.7%	16.3%
Commercial sea basses	0.0%	100.0%
Commercial shrimp	0.0%	100.0%
Drums and croakers	69.1%	30.9%
Dungeness crab	0.0%	100.0%
Flounders	1.0%	99.0%
Northern anchovy	0.0%	100.0%
Other (commercial)	0.0%	100.0%
Other (commercial crab)	0.0%	100.0%
Other (recreational)	100.0%	0.0%
Other (commercial and recreational)	54.0%	46.0%
Recreational sea basses	100.0%	0.0%
Rockfishes	23.6%	76.4%
Salmon	100.0%	0.0%
Sculpins	85.0%	15.0%
Smelts	6.2%	93.8%
Striped bass	100.0%	0.0%
Surfperches	93.0%	7.0%
Trophic transfer[c]	50.0%	50.0%

[a] Based on landings from 1993 to 2001.
[b] Calculated using recreational landings data from NMFS (2003b, http://www.st.nmfs.gov/recreational/queries/catch/snapshot.html) and commercial landings data from NMFS (2003a, http://www.st.nmfs.gov/commercial/landings/annual_landings.html).
[c] Assumed equally likely to be caught by recreational or commercial fishermen. Commercial value calculated as overall average for region based on data from NMFS (2003a).

See Chapter B3 for results of the commercial fishing benefits analysis and Chapter B4 for recreational fishing results. As discussed in Chapter A8, benefits were discounted to account for 1) the time to achieve compliance once the rule goes into effect in 2007, and 2) the time it takes for fish spared from I&E to reach a harvestable age.

Chapter B3: Commercial Fishing Valuation

Introduction

This chapter presents the results of the commercial fishing benefits analysis for the California region. Section B3-1 details the estimated losses under current, or baseline, conditions. Section B3-2 presents expected benefits under three alternative options. Chapter A4 details the methods used in this analysis. All results are for Northern California and Southern California combined.

Chapter Contents

B3-1 Baseline Losses

Table B3-1 provides EPA's estimate of the value of gross revenues lost in commercial fisheries resulting from the impingement of aquatic species at facilities in the California region. Table B3-2 displays this information for entrainment. Total annualized revenue losses are approximately $52,400 (undiscounted).

Table B3-1: Annualized Commercial Fishing Gross Revenues Lost due to Impingement at Facilities in the California Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
Cabezon	3	$3.78	$13
Dungeness crab	22	$1.71	$37
Flounders	40	$0.39	$16
Rockfishes	81	$0.53	$43
Sculpins	4	$2.61	$11
Smelts	7	$0.27	$2
Surfperches	8	$1.64	$12
Trophic transfer[b]	14	$0.28	$4

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table B3-2: Annualized Commercial Fishing Gross Revenues Lost due to Entrainment at Facilities in the California Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
Cabezon	4,550	$3.78	$17,200
California halibut	3,140	$2.72	$8,540
Drums and croakers	16	$1.03	$17
Dungeness crab	327	$1.71	$561
Flounders	6	$0.39	$2
Other (species are only commercially fished, not recreationally)	84	$0.05	$4
Other crabs (commercial)	64	$1.18	$76
Rockfishes	47,900	$0.53	$25,600
Sculpins	97	$2.61	$253
Trophic transfer[b]	45	$0.28	$13

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

B3-2 Expected Benefits Under Three Alternative Options

As described in Chapter A4, EPA estimates that 0 to 40% of the gross revenue losses represent surplus losses to producers, assuming no change in prices or fishing costs. The 0% estimate, of course, results in loss estimates of $0. The 40% estimates, as presented in Tables B3-3, B3-4, and B3-5, total approximately $21,000 (undiscounted).

The expected reductions in impingement and entrainment (I&E) attributable to changes at facilities required by the "50 MGD for All Waterbodies" option (50 MGD option) are 39% for impingement and 29% for entrainment, for the "200 MGD for All Waterbodies" option (200 MGD option) are 0% for impingement and 0% for entrainment, and for the "100 MGD for Certain Waterbodies" option (100 MGD option) are also 0% for impingement and 0% for entrainment. Total annualized benefits are estimated by applying these estimated reductions to the annual producer surplus loss. As presented in Tables B3-3, B3-4, and B3-5, this results in total annualized benefits of up to approximately $5,300 for the 50 MGD option, and $0 for both the 200 MGD option and the 100 MGD option, assuming a 3% discount rate.

Table B3-3: Annualized Commercial Fishing Benefits Attributable to the 50 MGD Option at Facilities in the California Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$141	$52,300	$52,400
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$56	$20,900	$21,000
Expected reduction due to rule	39%	29%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$6,100
3% discount rate			$5,300
7% discount rate			$4,400

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table B3-4: Annualized Commercial Fishing Benefits Attributable to the 200 MGD Option at Facilities in the California Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$141	$52,300	$52,400
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$56	$20,900	$21,000
Expected reduction due to rule	0%	0%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$0
3% discount rate			$0
7% discount rate			$0

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table B3-5: Annualized Commercial Fishing Benefits Attributable to the 100 MGD Option at Facilities in the California Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$141	$52,300	$52,400
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$56	$20,900	$21,000
Expected reduction due to rule	0%	0%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$0
3% discount rate			$0
7% discount rate			$0

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Chapter B4: Recreational Use Benefits

Introduction

This chapter presents the results of the recreational fishing benefits analysis for the California region. The chapter presents EPA's estimates of baseline (i.e., current) annual recreational fishery losses from impingement and entrainment (I&E) at potentially regulated facilities in the California region and annual reduction in these losses under the three proposed regulatory options for Phase III existing facilities:[1]

- the "50 MGD for All Waterbodies" option,
- the "200 MGD for All Waterbodies" option, and
- the "100 MGD for Certain Waterbodies" option.

The chapter then presents the estimated welfare gain to California anglers from eliminating baseline recreational fishing losses from I&E and the expected benefits under the three proposed options.

EPA estimated the recreational benefits of reducing and eliminating I&E losses using a benefit transfer methodology based on a meta-analysis of the marginal value of catching different species of fish. This meta-analysis is discussed in detail in Chapter A5, "Recreational Fishing Benefits Methodology." To validate these results, this chapter also presents the results of a random utility model (RUM) analysis for the California region. A detailed discussion of the RUM analysis for the California region can be found in Chapter B4 of the final Phase II Regional Studies report (U.S. EPA, 2004).

EPA considered a wide range of policy options in developing this regulation. Results of the recreational fishing benefits analysis for five other options evaluated by EPA are presented in Appendix B4.

Chapter Contents

[1] See the introduction to this report for a description of the three proposed options.

B4-1 Benefit Transfer Approach Based on Meta-Analysis

EPA estimated the recreational welfare gain from the reduction in annual I&E losses expected under the policy options, and the welfare gain from eliminating I&E at potentially regulated facilities, using a benefit transfer approach. As discussed in Chapter A5, the Agency used the meta-analysis regression equation to estimate the marginal recreational value per additional fish caught by anglers, for different species in different regions. Since I&E at potentially regulated facilities affects a variety of species, EPA assigned each species with I&E losses to one of the general species groups used in the meta-analysis. The Agency then calculated the economic value of reducing or eliminating baseline I&E losses, for each species group, by multiplying the value per fish for that species group by the number of fish in the group that are lost in the baseline or saved under the policy options.[2]

In general, the fit between the species with I&E losses and the species groups in the meta-analysis was good. However, EPA's estimates of baseline I&E losses and reductions in I&E under the policy options included losses of 'unidentified' species. The 'unidentified' group includes fish lost indirectly through trophic transfer, as well as species for which no species information was available.[3] Rather than using the meta-analysis regression to try to predict the value per fish for an "unidentified" species, EPA assumed that per-fish values for these species can be approximated by the weighted average value per fish for all species affected by I&E in the California region.[4]

B4-1.1 Estimated Reductions in Recreational Fishery Losses under the Proposed Regulation

Table B4-1 presents EPA's estimates of baseline (i.e., current) annual recreational I&E losses at potentially regulated facilities, and annual reductions in these losses under each of the proposed options, in the California region. The table shows that total baseline losses to recreational fisheries are 18.4 thousand fish per year. In comparison, the "50 MGD for All Waterbodies" option prevents losses of 5.4 thousand fish per year. The "200 MGD for All Waterbodies" option and the "100 MGD for Certain Waterbodies" options do not prevent any losses in the California region. Of all the affected species, rockfish and sculpin have the highest losses in the baseline and the highest prevented losses under the 50 MGD option.

---

[2] The estimates of I&E presented in this chapter include only the fraction of impinged and entrained recreational fish that would otherwise be caught by anglers. The total amount of I&E of recreational fish is actually much higher.

[3] In addition to recreational fish that are lost because they are impinged or entrained, some recreational fish are lost because the forage fish that they feed on are impinged or entrained, and thus removed from the food chain. These trophic transfer losses of recreational species are included in EPA's estimates of total I&E losses. However, since it is difficult to predict which recreational species would be affected by losses of forage fish, these losses are classified as 'unidentified' recreational species. Also included in the 'unidentified' group are losses of fish that were reported by facilities without information about their exact species.

[4] EPA used the estimated level of baseline recreational losses for each species group as a weighting factor.

Table B4-1: Baseline Recreational Fishing Losses from I&E at Potentially Regulated Phase III Facilities and Reductions in Recreational Losses under the Proposed Regulatory Options in the California Region

Species[a]	Baseline Annual Recreational Fishing Losses (# of fish)	Annual Reductions in Recreational Fishing Losses (# of fish)		
		50 MGD All	200 MGD All[b]	100 MGD CWB[b]
Striped bass	140	44	0	0
Total (small game)	**140**	**44**	**0**	**0**
California halibut	953	277	0	0
Flounders	1	0	0	0
Total (flatfish)	**954**	**278**	**0**	**0**
Cabezon	600	175	0	0
Croakers	105	31	0	0
Rockfish	11,692	3,404	0	0
Sculpin	4,332	1,279	0	0
Sea bass	101	29	0	0
Smelts	1	0	0	0
Surfperch	432	168	0	0
Total (other saltwater)	**17,264**	**5,086**	**0**	**0**
Total (unidentified)	**78**	**24**	**0**	**0**
Total (all species)	***18,436***	***5,432***	***0***	***0***

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The 'other saltwater' group includes bottomfish and other miscellaneous species. The 'unidentified' group includes fish lost indirectly through trophic transfer.

[b] No facilities located in the California region have design intake flows greater than 100 MGD. Thus, no facilities would have technology requirements under the "200 MGD for All Waterbodies" or "100 MGD for Certain Waterbodies" options.

Source: U.S. EPA analysis for this report.

B4-1.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table B4-2 shows the results of EPA's analysis of the welfare gain to recreational anglers from eliminating baseline recreational fishery losses at potentially regulated facilities in the California region. The table presents baseline annual recreational I&E losses, the estimated value per fish, and the monetized annual welfare gain from eliminating recreational losses, for each species group. Total baseline recreational fishing losses for the North Atlantic region are 18.4 thousand fish per year. The undiscounted annual welfare gain to California anglers from eliminating these losses is $95.2 thousand (2003$), with lower and upper bounds of $40.5 thousand and $224.4 thousand. Evaluated at 3% and 7%, the mean annualized welfare gain from eliminating these losses is $89.6 thousand and $83.1 thousand, respectively. The majority of monetized recreational losses from I&E under baseline conditions are attributable to losses of species in the 'other saltwater' group, such as rockfish and sculpin.

Table B4-2: Recreational Fishing Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the California Region (2003$)

Species Group	Baseline Annual Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Benefits from Eliminating Recreational Fishing Losses (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	140	$6.08	$12.57	$26.06	$0.9	$1.8	$3.6
Flatfish	954	$6.65	$15.61	$36.54	$6.3	$14.9	$34.9
Other saltwater	17.3	$1.92	$4.52	$10.71	$33.2	$78.1	$185.0
Unidentified	0.1	$2.20	$5.16	$12.17	$0.2	$0.4	$0.9
Total (undiscounted)	**18.4**				**$40.5**	**$95.2**	**$224.4**
Total (evaluated at 3%)[c]	**18.4**				**$38.2**	**$89.6**	**$211.3**
Total (evaluated at 7%)[c]	**18.4**				**$35.4**	**$83.1**	**$195.9**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying baseline losses by the estimated value per fish.
[d] Annualized values represent the total welfare gain over the time frame of the analysis from eliminating recreational losses, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

B4-1.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table B4-3 shows the results of EPA's analysis of the recreational benefits of the "50 MGD for All Waterbodies" option for the California region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 5.4 thousand fish per year, resulting in an undiscounted welfare gain to recreational anglers of $28.0 thousand (2003$), with lower and upper bounds of $11.9 thousand and $66.1 thousand. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $24.2 thousand and $20.0 thousand, respectively. The majority of benefits result from reduced losses of species in the 'other saltwater' group, such as rockfish and sculpin.

Table B4-3: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the California Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	0.0[e]	$6.08	$12.57	$26.06	$0.3	$0.6	$1.2
Flatfish	0.3	$6.65	$15.61	$36.54	$1.8	$4.3	$10.1
Other saltwater	5.1	$1.92	$4.52	$10.71	$9.8	$23.0	$54.5
Unidentified	0.0[e]	$2.20	$5.16	$12.17	$0.1	$0.1	$0.3
Total (undiscounted)	**5.4**				**$11.9**	**$28.0**	**$66.1**
Total (evaluated at 3%)[c]	**5.4**				**$10.3**	**$24.2**	**$57.0**
Total (evaluated at 7%)[c]	**5.4**				**$8.5**	**$20.0**	**$47.1**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] Denotes a positive value less than 50 fish.

Source: U.S. EPA analysis for this report.

B4-1.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

No facilities located in the California region have design intake flows greater than 200 MGD, so no facilities would have technology requirements under the "200 MGD for All Waterbodies" option. Thus, no recreational benefits are expected under this option in the California region.

B4-1.5 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

No facilities located in the California region have design intake flows greater than 100 MGD, so no facilities would have technology requirements under the "100 MGD for Certain Waterbodies" option. Thus, no recreational benefits are expected under this option in the California region.

B4-2 RUM Approach

To validate the results of the benefit transfer approach, EPA applied the RUM model presented in Chapter F4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004) to the baseline losses and reductions in losses at potentially regulated Phase III existing facilities. This section presents the results of the recreational fishing benefits analysis for the California region based on the Phase II RUM approach.

B4-2.1 RUM Methodology: California Region

EPA's methodology for evaluating the change in welfare resulting from a change in recreational losses from I&E consists of four basic steps: (1) calculating the change in historical catch rates under a given policy scenario, (2) estimating the per-trip welfare gain to anglers based on the Phase II RUM model, (3) estimating the number of fishing trips taken by anglers, and (4) combining fishing participation data with the estimated per-trip welfare gain to calculate the total annual welfare gain. These steps are briefly described in the following sections. For a more detailed discussion of the RUM methodology, see Chapters A11 and F4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004).

B4-2.1.1 Estimating Changes in the Quality of Fishing Sites

The first step in EPA's analysis was to combine estimates of recreational I&E losses at potentially regulated facilities with state-level recreational fishery landings data to estimate the percentage change in historical catch rates under each policy option. Because most species considered in this analysis (e.g., rockfish, sculpin) are found throughout California waters, EPA divided the state into two subregions (Northern California and Southern California) and made the assumption that changes in I&E will result in uniform changes in catch rates across all marine fishing sites in each subregion. Thus, EPA used five-year National Marine Fisheries Service (NMFS) recreational landings data (1996 through 2000) for state waters to calculate the average statewide landings per year for all species groups, in Northern and Southern California.[5] EPA then divided baseline recreational I&E losses by total recreational landings for each subregion to calculate the percentage change in historical catch rates from completely eliminating recreational fishing losses from I&E. Similarly, the Agency also estimated the percentage changes to historic catch rates that would result under each policy option.

B4-2.1.2 Estimating Per-Trip Benefits from Reducing I&E

EPA's second step was to use the recreational behavior model described in Chapter F4 of the Phase II Regional Studies document to estimate an angler's per-trip welfare gain from changes in the historical catch rates in the California region. The Agency estimated welfare gains to recreational anglers under four scenarios: eliminating baseline recreational fishing losses from I&E at potentially regulated facilities, and reducing recreational fishing losses from I&E by implementing the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, or the "100 MGD for Certain Waterbodies" option. EPA assumed that the welfare gain per fishing trip is independent of the number of days fished per trip and therefore equivalent for both single- and multiple-day trips. Thus, a multiple-day trip is valued the same as a single-day trip.[6] EPA estimated separate per-day welfare gains for different categories of anglers, based on their target species and fishing mode.[7]

B4-2.1.3 Estimating Angler Participation

The third step in EPA's analysis was to estimate baseline and post-regulatory fishing participation, measured by the total number of fishing trips taken by Northern and Southern California anglers.[8] Because the policy options for Phase III facilities are expected to result in relatively small improvements in fishing quality, EPA assumed that increases in recreational fishing participation under the policy options will be negligible. Thus, to estimate both baseline and post-regulatory participation, EPA used the total number of fishing trips taken by Northern and Southern California anglers in 2002. The total number of trips to the California fishing sites was calculated from data provided by NMFS. To estimate the proportion of recreational fishing trips taken by no-target anglers and

---

[5] State waters include sounds, inlets, tidal portions of rivers, bay, estuaries, and other areas of salt or brackish water, plus ocean waters to three nautical miles from shore (NMFS, 2003a).

[6] See section B4-4.1 of Chapter B4 of the 316(b) Phase II document for limitations and uncertainties associated with this assumption.

[7] EPA used the per-day values for private/rental boat anglers to estimate welfare gains for charter boat anglers.

[8] See Chapter B4 of the section 316(b) Phase II Case Study document for a detailed description of the angler participation estimates in California.

by anglers targeting each species of concern, EPA used the Marine Recreational Fisheries Statistics Survey (MRFSS) sample. The Agency then applied those percentages to the total number of fishing trips taken by California anglers to calculate the number of anglers.

B4-2.1.4 Estimating Total Benefits from Eliminating or Reducing I&E

The final step in EPA's analysis was to calculate the total benefits of the policy options. To calculate total benefits for each subcategory of anglers targeting a particular species with a particular fishing mode, EPA multiplied the per-trip welfare gain for an angler with that particular species/fishing mode combination by the total number of fishing trips taken by all anglers with that species/fishing mode combination. EPA then summed benefits for all subcategories of anglers in Northern and Southern California to calculate the total undiscounted welfare change in the California region. Finally, as discussed in Chapter A8, EPA discounted and annualized the benefits estimates, using both 3% and 7% discount rates.

B4-2.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table B4-4 presents the baseline level of recreational landings and the estimated change in catch rates that would result from eliminating recreational fishing losses from I&E at potentially regulated facilities in Southern and Northern California. In Northern California, catch rates for the 'other fish' species group would increase the most from eliminating I&E (0.69%). In Southern California, the estimated changes in catch rates are very small (less than 0.13%) for all species groups.

Table B4-4: Estimated Changes in Historical Catch Rates from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the California Region

	Northern California			Southern California		
Species Group	Annual Recreational Landings (thousands of fish)[a]	Baseline Annual Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Eliminating I&E	Annual Recreational Landings (thousands of fish)[a]	Baseline Annual Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Eliminating I&E
Bottomfish	3,248.4	12.0	0.37%	2,089.3	0.2	0.01%
Flounders	238.4	0.0[c]	0.00%[d]	730.8	1.0	0.13%
Striped bass[e]	220.3	0.1	0.06%	n/a	n/a	n/a
Sea bass[f]	n/a	n/a	n/a	3,298.5	0.1	0.00%[d]
Other fish	691.4	4.7	0.69%	1,461.8	0.2	0.01%
No target	6,091.5[g]	16.9	0.28%	11,598.1[g]	1.5	0.01%

[a] Annual recreational landings are calculated as a five-year average (1996-2000) for state waters.
[b] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[c] Denotes a positive value less than 50 fish.
[d] Denotes a positive value less than 0.005%.
[e] Striped bass are not commonly caught by recreational anglers in the Southern California region.
[f] Sea bass are not commonly caught by recreational anglers in the Northern California region.
[g] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table B4-5 presents the per-trip welfare gain for boat and shore anglers targeting different species, the number of fishing trips taken by anglers targeting those species, and the total annual welfare gain from eliminating baseline

I&E at potentially regulated facilities, for Northern and Southern California. The table shows that the annual undiscounted benefits of eliminating baseline losses in Northern California, $33.4 thousand (2003$), are greater than the annual benefits of eliminating baseline losses in Southern California, $16.6 thousand, primarily because the per-trip welfare gain from eliminating baseline I&E is much larger in Northern California than in Southern California. The table shows that the largest share of benefits in the California region are attributable to anglers targeting bottomfish in the northern part of the state. The next largest share of the welfare gain is attributable to anglers targeting flounders (primarily halibut) in Southern California. The total undiscounted value of eliminating baseline recreational losses in California is $50.0 thousand, and the annualized value of those losses is $47.1 thousand and $43.7 thousand, evaluated at 3% and 7%, respectively.

Table B4-5: Recreational Fishing Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the California Region (2003$)

Species Group	Per-Trip Welfare Gain		Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
	Boat Anglers	Shore Anglers		
Northern California				
Flounders	$0.00[c]	$0.00[c]	126.5	$0.1
Striped bass	$0.01	$0.01	259.6	$1.6
Bottomfish	$0.08	$0.02	474.3	$23.7
Other fish	$0.00[c]	$0.11	45.4	$3.5
No target	$0.00[c]	$0.01	652.7	$4.4
Total, All Species[a]	***n/a***	***n/a***	***2,071.9***	***$33.4***
Southern California				
Flounders	$0.04	$0.01	459.4	$15.6
Sea bass	$0.00[c]	$0.00[c]	359.5	$0.0[d]
Bottomfish	$0.00[c]	$0.00[c]	310.9	$0.3
Other fish	$0.00[c]	$0.00[c]	27.8	$0.0[d]
No target	$0.00[c]	$0.00[c]	1,773.2	$0.6
Total, All Species[a]	***n/a***	***n/a***	***3,722.9***	***$16.6***
Total, California Region (undiscounted)			**5,794.9**	**$50.0**
Total, California Region (evaluated at 3%)			**5,794.9**	**$47.1**
Total, California Region (evaluated at 7%)			**5,794.9**	**$43.7**

[a] The number of fishing trips for all species is not equal to the sum of those listed because the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.
[d] Denotes a positive value less than $50.

Source: U.S. EPA analysis for this report.

B4-2.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table B4-6 presents the estimated change in historical catch rates that would result from reductions in I&E under the "50 MGD for All Waterbodies" option. In Northern California, catch rates for the 'other fish' species group would increase the most under this option, by 0.20%. In Southern California, the estimated changes in catch rates are very small (less than 0.04%) for all species groups.

Table B4-6: Estimated Changes in Historical Catch Rates from Reducing I&E under the "50 MGD for All Waterbodies" Option in the California Region

	Northern California			Southern California		
Species Group	Annual Recreational Landings (thousands of fish)[a]	Annual Reduction in Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Reducing I&E	Annual Recreational Landings (thousands of fish)[a]	Annual Reduction in Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Reducing I&E
Bottomfish	3,248.4	3.5	0.11%	2,089.3	0.1	0.00%[d]
Flounders	238.4	0.0[c]	0.00%[d]	7.3	0.3	0.04%
Striped bass[e]	220.3	0.0[c]	0.02%	n/a	n/a	n/a
Sea bass[f]	n/a	n/a	n/a	3,298.5	0.0[c]	0.00%[d]
Other fish	691.4	1.4	0.20%	1,461.8	0.1	0.00%[d]
No target	6,092.5[g]	5.0	0.08%	11,598.1[g]	0.4	0.00%[d]

[a] Annual recreational landings are calculated as a five-year average (1996-2000) for state waters.
[b] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[c] Denotes a positive value less than 50 fish.
[d] Denotes a positive value less than 0.005%.
[e] Striped bass are not commonly caught by recreational anglers in the Southern California region.
[f] Sea bass are not commonly caught by recreational anglers in the Northern California region.
[g] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table B4-7 presents the recreational benefits of the "50 MGD for All Waterbodies" option for Northern and Southern California, by species and fishing mode. The table shows that the annual undiscounted benefits of this option are $9.9 thousand (2003$) in Northern California and $4.9 thousand in Southern California. Benefits are larger in Northern California primarily because the per-trip welfare gain under this option is much larger in Northern California than in Southern California. The table shows that the largest share of benefits in the California region are attributable to anglers targeting bottomfish in the northern part of the state. The next largest share of the welfare gain is attributable to anglers targeting flounders (primarily halibut) in Southern California. Total undiscounted benefits in California are $14.7 thousand, and the annualized value of those benefits is $12.7 thousand and $10.5 thousand, evaluated at 3% and 7%, respectively.

Table B4-7: Recreational Fishing Benefits under the "50 MGD for All Waterbodies" Option in the California Region (2003$)

Species Group	Per-Trip Welfare Gain		Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
	Boat Anglers	Shore Anglers		
Northern California				
Flounders	$0.00[c]	$0.00[c]	126.5	$0.0[d]
Striped bass	$0.00[c]	$0.00[c]	259.6	$0.5
Bottomfish	$0.02	$0.00[c]	474.3	$7.0
Other fish	$0.00[c]	$0.03	45.4	$1.0
No target	$0.00[c]	$0.00[c]	652.7	$1.3
Total, All Species[a]	***n/a***	***n/a***	***2,071.9***	***$9.9***
Southern California				
Flounders	$0.01	$0.00[c]	459.4	$4.5
Sea bass	$0.00[c]	$0.00[c]	359.5	$0.0[d]
Bottomfish	$0.00[c]	$0.00[c]	310.9	$0.1
Other fish	$0.00[c]	$0.00[c]	27.8	$0.0[d]
No target	$0.00[c]	$0.00[c]	1,773.2	$0.2
Total, All Species[a]	***n/a***	***n/a***	***3,722.9***	***$4.9***
Total, California Region (undiscounted)			**5,794.9**	**$14.7**
Total, California Region (evaluated at 3%)			**5,794.9**	**$12.7**
Total, California Region (evaluated at 7%)			**5,794.9**	**$10.5**

[a] The number of fishing trips for all species is not equal to the sum of those listed because the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.
[d] Denotes a positive value less than $50.

Source: U.S. EPA analysis for this report.

B4-2.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

No facilities located in the California region have design intake flows greater than 200 MGD, so no facilities would have technology requirements under the "200 MGD for All Waterbodies" option. Thus, no recreational benefits are expected under this option in this region.

B4-2.5 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

No facilities located in the California region have design intake flows greater than 100 MGD, so no facilities would have technology requirements under the "100 MGD for Certain Waterbodies" option. Thus, no recreational benefits are expected under this option in this region.

B4-3 Validation of Benefit Transfer Results Based on RUM Results

Table B4-8 compares the undiscounted results of the benefit transfer based on the meta-analysis with the results of the RUM analysis. In general, the RUM-based results fall within the lower end of the range of values estimated based on the meta-model. Nonetheless, the magnitudes of the two sets of estimates are similar, corroborating the use of meta-analysis in estimating the value of incremental recreational fishing improvements from the proposed options for the section 316(b) regulation for Phase III existing facilities.

Table B4-8: Recreational Fishing Benefits in the California Region Calculated from Meta-Analysis Approach and RUM Approach

Policy Option	Estimated Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands, 2003$)			
		Based on Meta-Analysis			Based on RUM
		Low	Mean	High	
Eliminating baseline recreational fishing losses from I&E	18.4	$40.5	$95.2	$224.4	$50.0
50 MGD All	5.4	$11.9	$28.0	$66.1	$14.7
200 MGD All[a]	0.0	$0.0	$0.0	$0.0	$0.0
100 MGD CWB[a]	0.0	$0.0	$0.0	$0.0	$0.0

[a] No facilities located in the California region have design intake flows greater than 100 MGD. Thus, no facilities would have technology requirements under the “200 MGD for All Waterbodies” or the “100 MGD for Certain Waterbodies” options.

Source: U.S. EPA analysis for this report.

B4-4 Limitations and Uncertainty

B4-4.1 Limitations and Uncertainty: Meta-Analysis

The results of the benefit transfer based on the meta-analysis results represent EPA’s best estimate of the recreational benefits of the proposed options. Nonetheless, there are a number of limitations and uncertainties inherent in these estimates. General limitations pertaining to the development of the meta-analysis model, the use of the model to estimate per-fish values, and the validity of the benefit transfer are discussed in section A5-3.3e and section A5-5.3 of the recreational methodology chapter (A5). In addition to these general concerns about the analysis, there are one or two limitations and uncertainties that are specific to the California region.

The main limitation of applying the meta-analysis to the California region is that California is a large state with varied recreational fishing resources. The species that are targeted in the northern and southern parts of the state are somewhat different, and assigning a single value to each species based on an average for California may introduce some error into the resulting benefit estimates.

B4-4.2 Limitations and Uncertainty: RUM Approach

The results of the benefit transfer based on the RUM analysis results confirm that EPA's estimates of the recreational benefits of the proposed options are reasonable. However, there are a number of limitations and uncertainties inherent in these estimates. Some general limitations pertaining to the RUM model are discussed in Chapter A11 of the Regional Benefits Assessment for Phase II facilities. Some additional region-specific limitations are discussed in Chapter B4 of the Phase II document.

Although the estimated total welfare gain to the California recreational anglers based on the regional RUM model is likely to be accurate, the estimated average per-trip welfare gain presented in Tables B4-5 and B4-7 must be used and understood in the context of the regional model developed by EPA for the Phase II analysis. The regional RUM model assumes uniform changes in catch rates at all sites across the region. Given that there are only eight potentially regulated facilities in the California region, and given that the total intake flow associated with these facilities is relatively small, catch rate improvements are more likely to occur locally rather than regionally. These local improvements in catch rates and the associated average per-trip welfare gain are likely to be greater than those presented in Tables B4-4 through B4-7. However, the number of anglers benefitting from these improvements would be smaller, so the resulting aggregate benefits are likely to be similar.

Chapter B5: Threatened and Endangered Species Analysis

Introduction

This chapter presents EPA's estimates of baseline (i.e., current) annual losses of special status species from impingement and entrainment (I&E) at potentially regulated facilities in the California region and annual reduction in these losses under the three proposed regulatory options for Phase III existing facilities:[1,2]

- the "50 MGD for All Waterbodies" option,
- the "200 MGD for All Waterbodies" option, and
- the "100 MGD for Certain Waterbodies" option.

The analysis focuses on four special status species affected by I&E: delta smelt, longfin smelt, Sacramento splittail, and chinook salmon. This chapter also presents the benefit transfer approach explored by EPA to estimate public willingness-to-pay (WTP) for protection of special status fish species from I&E in California.

Chapter Contents

B5-1 Estimated Reductions in Losses of Special Status Species in the California Region under the Proposed Section 316 (b) Regulation for Phase III Facilities

Table B5-1 presents EPA's estimates of baseline (i.e., current) annual I&E losses of special status species at potentially regulated Phase III facilities and annual reductions in these losses under each of the proposed options in the California region. The table shows that total baseline losses of special status species are 73 fish per year, 79.5% of which are longfin smelt. In comparison, the "50 MGD for All Waterbodies" option prevents losses of 28 fish per year. The "200 MGD for All Waterbodies" option and the "100 MGD for Certain Waterbodies" options do not prevent any losses of special status species in the California region because no facilities located in the California region have design intake flows greater than 100 MGD.

[1] See the introduction to this report for a description of the three proposed options.

[2] "Special status species" is a term used to refer to species that have been listed as "threatened and endangered" (T&E) or that have been given a special status designation at the State or federal level.

Table B5-1: I&E Losses of Special Status Species in the California Region

Special Status Fish Species	Baseline Losses of Special Status Species		Annual Reductions in Losses of Special Status Species		
	Age-1 Equivalents	% of Total I&E Loss of Special Status Species	50 MGD All	200 MGD All[a]	100 MGD CWB[a]
Delta smelt	6	8.2%	2	0	0
Longfin smelt	58	79.5%	23	0	0
Sacramento splittail	8	11.0%	3	0	0
Chinook salmon (all runs)	1	1.3%	0	0	0
Total	**73**	**100.0%**	**28**	**0**	**0**

[a] No facilities located in the California region have design intake flows greater than 100 MGD. Thus, no facilities would have technology requirements under the "200 MGD for All Waterbodies" or "100 MGD for Certain Waterbodies" options.

Source: U.S. EPA analysis for this report.

B5-2 An Exploration of Benefit Transfer to Estimate Non-use Benefits of Reduced Impingement and Entrainment of Special Status Species in the California Region

Case-specific estimates of non-use values for the protection of special status species can only be derived by primary research using stated preference techniques (e.g., the contingent valuation method). However, the cost, administrative burden, and time required to develop primary research estimates is beyond the schedule and resources available to EPA for the section 316(b) rulemaking. As an alternative, EPA explored a benefit transfer approach that relies on information from existing studies. Boyle and Bergstrom (1992) define benefit transfer as "the transfer of existing estimates of nonmarket values to a new study which is different from the study for which the values were originally estimated."

There are three commonly-used types of benefit transfer studies: point estimate, benefit function, and meta-analysis techniques (U.S. EPA, 2000). The point estimate approach involves taking the mean value (or range of values) from the study case and applying it directly to the policy case (U.S. EPA, 2000). This approach may be used to transfer estimates of values for preserving certain endangered species in one region to another region or to another species. A conceptually preferred benefit transfer approach is to use the benefit function transfer approach, which is more refined but also more complex than the point estimate approach. If the study case provides a WTP function, valuation estimates can be updated by substituting applicable values of key variables, such as baseline risk and population characteristics (e.g., mean or median income, racial or age distribution) from the policy case into the benefit function (U.S. EPA, 2000). The meta-analysis technique involves two steps: (1) regressing WTP values from a large number of studies on variables representing study methodology, population, and species characteristics, and (2) estimating WTP for the policy case by evaluating the regression equation using input values that describe the policy case. In many cases, this technique can provide superior results to either the point estimate or the benefit function transfer techniques. However, because the academic literature contains few studies valuing endangered aquatic species, EPA did not consider implementing the meta-analysis technique for the T&E analysis for the 316(b) rule.

Ideally, the point estimate approach would be implemented using transfer studies that value special status species that are identical to the species affected in the California region. EPA, however, was unable to identify any such studies. Thus, the Agency selected benefit transfer studies that valued aquatic species that have attributes similar to those of the affected species. One of the most important attributes to consider is whether the affected species have any use values. Table B5-2 presents the types of values associated with special status species lost to I&E in the California region. The table shows that the majority I&E losses of special status species (98.7%) are associated with forage species that do not have direct use values.

Table B5-2: Type of Value Associated with Special Status Species Lost to I&E in the California Region

Special Status Fish Species	Type of Value
Delta smelt	Non-use
Longfin smelt	Non-use
Sacramento splittail	Non-use
Chinook salmon (all runs)	Use and non-use

Source: U.S. EPA analysis for this report.

Only one of the four special status species, chinook salmon, has high direct use values. The remaining three species — delta smelt, longfin smelt, and Sacramento splittail — have primarily non-use values. There are no known recreational or consumptive uses for the delta smelt. Longfin smelt is occasionally targeted by anglers, and it has been sold seasonally at fish markets, but neither use appears to be widespread. Before it was listed as a threatened species, Sacramento splittail was used as bait by striped bass anglers, but not to a large extent (Federal Register, 1999). Given that I&E losses of chinook salmon represent only 1.3 percent of total I&E losses of special status species in California, EPA focused on identifying economic studies valuing preservation of obscure forage species that could be used in a benefit transfer analysis of the three species with primarily non-use values.

The Agency identified two studies that value special status species with characteristics that closely match characteristics of the species affected by I&E in California. Boyle and Bishop (1987) found that citizens of Wisconsin are willing to pay $7.68 (2003$) per household per year to preserve the striped shiner, a small minnow native to the Milwaukee River that is listed as endangered by the State of Wisconsin (although not federally listed as a threatened or endangered species).[3] A different study by Berrens et al. (1996) found that preservation of the endangered silvery minnow in New Mexico would be worth an average of $8.50 (2003$) per household per year.[4]

EPA considered using benefit function transfer in combination with the results of these two studies to estimate WTP to prevent I&E losses of special status species in the California region. However, neither the Boyle and Bishop (1987) nor the Berrens et al. (1996) study contained sufficient relevant information to apply this technique. Boyle and Bishop did not estimate a function that could be transferred to other regions. They obtained WTP values by asking citizens if they would accept or reject fixed membership fees to join a foundation that would conduct the necessary activities to preserve the species in question. However, since the study reported estimated results but not a regression function, it cannot be used to support the benefit function transfer approach. The Berrens et al. study also does not lend itself to benefit function transfer.

[3] The original WTP amount, $4.00 (1984$), was converted to 2003$ using the consumer price index (CPI) (U.S. Bureau of Labor Statistics, 2004).

[4] Berrens et al. (1996) estimated that New Mexico residents would be willing to pay $28 (1995$) per household each year for five years. To make this payment stream comparable with the annual payment estimated by Boyle and Bishop (1987), EPA converted the five annual payments to an equivalent annual payment over a 25 year time frame. EPA chose the 25 year period as a reasonable proxy for the longer-term indefinite period implied by the other studies because typical median-aged household heads probably would not envision paying appreciable taxes or contributions after 25 or 30 years (i.e., past age 70). After re-annualizing over the longer time frame using a 3% discount rate, and then converting from 1995$ to 2003$ using the CPI, EPA estimated that New Mexico residents would be willing to pay $8.50 (2003$) per household per year to preserve the endangered silvery minnow.

EPA also considered using a point estimate benefit transfer approach to derive a range of WTP values from these two studies. By applying a range of per-household WTP values for protecting the striped shiner and silvery minnow to the 2000 population of California, it would be possible to estimate the social benefits of preventing extinction of the delta smelt and other federally listed special status fish species in California. However, because I&E is only one of several factors that affect populations of delta smelt, longfin smelt, Sacramento splittail, and chinook salmon, the social benefit achieved by preventing I&E losses is lower than the benefit of reducing the risk of species extinction to zero. One reasonable assumption would be to assume that the fraction of per-household WTP for species preservation programs that is attributable to preventing I&E losses is directly proportional to the percent of the current populations of special status species lost to baseline I&E. Since less than 1% of the estimated current populations of special status species in the California region are lost to I&E each year, the per-household WTP for I&E reductions would be less than 1% of per-household WTP to prevent extinction.

EPA notes that although the Agency explored this approach, benefits based on this method were not included in the Phase III benefits estimates due to data uncertainties and limitations. However, EPA also notes the encouraging point that the valuation results are highly consistent across the relevant T&E studies available in the literature. As more studies become available, it may be possible to obtain insights into the effects of different variables (e.g., population and resource characteristics) and to develop welfare estimates that may be adjusted for the attributes of the policy or region under consideration. Researchers and policy makers have placed increasing focus on using meta-analysis and similar empirical approaches to improve the performance of benefit transfer in policy analysis.

Appendix B1: Life History Parameter Values Used to Evaluate I&E in the California Region

The tables in this appendix present the life history parameter values used by EPA to calculate age-1 equivalents and fishery yields from impingement and entrainment (I&E) data for the California region. Because of differences in the number of life stages represented in the loss data, there are cases where more than one life stage sequence was needed for a given species or species group. Alternative parameter sets were developed for this purpose and are indicated with a number following the species or species group name (i.e., Anchovies 1, Anchovies 2).

Table B1-1: American Shad Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.496	0	0	0.000000716
Larvae	3.01	0	0	0.000000728
Juvenile	7.40	0	0	0.000746
Age 1+	0.300	0	0	0.309
Age 2+	0.300	0	0	1.17
Age 3+	0.300	0	0	2.32
Age 4+	0.540	0.21	0.45	3.51
Age 5+	1.02	0.21	0.90	4.56
Age 6+	1.50	0.21	1.0	5.47
Age 7+	1.50	0.21	1.0	6.20
Age 8+	1.50	0.21	1.0	6.77

Sources: USFWS, 1978; Able and Fahay, 1998; and PSE&G, 1999.

Table B1-2: Anchovies Life History Parameters 1[a]				
Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.669	0	0	0.00000138
Larvae	7.99	0	0	0.00000151
Juvenile	2.12	0	0	0.0132
Age 1+	0.700	0.03	0.50	0.0408
Age 2+	0.700	0.03	1.00	0.0529
Age 3+	0.700	0.03	1.00	0.0609
Age 4+	0.700	0.03	1.00	0.0684
Age 5+	0.700	0.03	1.00	0.0763
Age 6+	0.700	0.03	1.00	0.0789

[a] Includes northern anchovy, deepbody anchovy, slough anchovy and other anchovies not identified to species.

Sources: Ecological Analysts Inc., 1981b; Wang, 1986; PFMC, 1998; Virginia Tech, 1998; Tenera Environmental Services, 2000a; and Froese and Pauly, 2002.

Table B1-3: Anchovies Life History Parameters 2[a]				
Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.669	0	0	0.00000138
Larvae 3 mm	0.172	0	0	0.00000151
Larvae 4 mm	0.172	0	0	0.00000173
Larvae 5 mm	0.172	0	0	0.00000334
Larvae 6 mm	0.172	0	0	0.00000572
Larvae 7 mm	0.172	0	0	0.00000901
Larvae 8 mm	0.172	0	0	0.0000134
Larvae 9 mm	0.172	0	0	0.0000189
Larvae 10 mm	0.172	0	0	0.0000258
Larvae 11 mm	0.172	0	0	0.0000342
Larvae 12 mm	0.172	0	0	0.0000442
Larvae 13 mm	0.172	0	0	0.0000559
Larvae 14 mm	0.172	0	0	0.0000696
Larvae 15 mm	0.172	0	0	0.0000853
Larvae 16 mm	0.172	0	0	0.000103
Larvae 17 mm	0.172	0	0	0.000123
Larvae 18 mm	0.172	0	0	0.000146
Larvae 19 mm	0.172	0	0	0.000171
Larvae 20 mm	0.172	0	0	0.000199
Larvae 21 mm	0.172	0	0	0.000230
Larvae 22 mm	0.172	0	0	0.000264

Table B1-3: Anchovies Life History Parameters 2[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Larvae 23 mm	0.172	0	0	0.000301
Larvae 24 mm	0.172	0	0	0.000341
Larvae 25 mm	0.172	0	0	0.000385
Larvae 26 mm	0.172	0	0	0.000432
Larvae 27 mm	0.172	0	0	0.000483
Larvae 28 mm	0.172	0	0	0.000538
Larvae 29 mm	0.172	0	0	0.000597
Larvae 30 mm	0.172	0	0	0.000659
Larvae 31 mm	0.172	0	0	0.000726
Larvae 32 mm	0.172	0	0	0.000798
Larvae 33 mm	0.172	0	0	0.000873
Larvae 34 mm	0.172	0	0	0.000954
Larvae 35 mm	0.172	0	0	0.00104
Larvae 36 mm	0.172	0	0	0.00113
Larvae 37 mm	0.172	0	0	0.00122
Larvae 38 mm	0.172	0	0	0.00132
Larvae 39 mm	0.172	0	0	0.00143
Larvae 40 mm	0.172	0	0	0.00154
Larvae 41 mm	1.249	0	0	0.00166
Larvae 59 mm	0.208	0	0	0.00485
Juvenile	2.12	0	0	0.0132
Age 1+	0.700	0.03	0.50	0.0408
Age 2+	0.700	0.03	1.0	0.0529
Age 3+	0.700	0.03	1.0	0.0609
Age 4+	0.700	0.03	1.0	0.0684
Age 5+	0.700	0.03	1.0	0.0763
Age 6+	0.700	0.03	1.0	0.0789

[a] Includes northern anchovy.

Sources: Ecological Analysts Inc., 1980b, 1981b; Wang, 1986; PFMC, 1998; Tenera Environmental Services, 2000a; and Froese and Pauly, 2002.

Table B1-4: Anchovies Life History Parameters 3[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.669	0	0	0.00000138
Larvae 6 mm	0.104	0	0	0.00000572
Larvae 7 mm	0.207	0	0	0.00000901
Larvae 9 mm	0.104	0	0	0.0000189
Larvae 10 mm	0.104	0	0	0.0000258

Table B1-4: Anchovies Life History Parameters 3[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Larvae 11 mm	0.104	0	0	0.0000342
Larvae 12 mm	0.104	0	0	0.0000442
Larvae 13 mm	0.104	0	0	0.0000559
Larvae 14 mm	0.104	0	0	0.0000696
Larvae 15 mm	0.207	0	0	0.0000853
Larvae 17 mm	0.207	0	0	0.000123
Larvae 19 mm	0.104	0	0	0.000171
Larvae 20 mm	0.104	0	0	0.000199
Larvae 21 mm	0.207	0	0	0.000230
Larvae 23 mm	0.311	0	0	0.000301
Larvae 26 mm	0.207	0	0	0.000432
Larvae 28 mm	0.104	0	0	0.000538
Larvae 29 mm	0.104	0	0	0.000597
Larvae 30 mm	0.104	0	0	0.000659
Larvae 31 mm	0.104	0	0	0.000726
Larvae 32 mm	0.622	0	0	0.000798
Larvae 38 mm	1.97	0	0	0.00132
Larvae 57 mm	0.519	0	0	0.00438
Larvae 62 mm	0.207	0	0	0.00561
Larvae 64 mm	0.104	0	0	0.00616
Larvae 65 mm	0.104	0	0	0.00645
Larvae 66 mm	0.104	0	0	0.00675
Larvae 67 mm	0.311	0	0	0.00706
Larvae 70 mm	0.519	0	0	0.00803
Larvae 75 mm	0.622	0	0	0.00984
Larvae 81 mm	0.104	0	0	0.0123
Larvae 82 mm	0.104	0	0	0.0128
Juvenile	2.12	0	0	0.0132
Age 1+	0.700	0.03	0.50	0.0408
Age 2+	0.700	0.03	1.0	0.0529
Age 3+	0.700	0.03	1.0	0.0609
Age 4+	0.700	0.03	1.0	0.0684
Age 5+	0.700	0.03	1.0	0.0763
Age 6+	0.700	0.03	1.0	0.0789

[a] Includes northern anchovy.

Sources: Ecological Analysts Inc., 1980b, 1981b, 1982a; Wang, 1986; PFMC, 1998; Tenera Environmental Services, 2000a; and Froese and Pauly, 2002.

Table B1-5: Blennies Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.105	0	0	0.00000176
Larvae	3.98	0	0	0.00000193
Juvenile	0.916	0	0	0.000501
Age 1+	1.34	0	0	0.00314
Age 2+	1.34	0	0	0.00745
Age 3+	1.34	0	0	0.0101
Age 4+	1.34	0	0	0.0113
Age 5+	1.34	0	0	0.0119
Age 6+	1.34	0	0	0.0122
Age 7+	1.34	0	0	0.0123
Age 8+	1.34	0	0	0.0123
Age 9+	1.34	0	0	0.0124

[a] Includes bay blenny, combtooth blenny, mussel blenny, orangethroat pikeblenny, rockpool blenny, tube blenny, and other blennies not identified to species.

Sources: Froese and Binohlan, 2000; Tenera Environmental Services, 2000b; and Froese and Pauly, 2003.

Table B1-6: Cabezon Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000430
Larvae	3.79	0	0	0.000605
Juvenile	0.916	0	0	0.00825
Age 1+	0.288	0	0	0.169
Age 2+	0.144	0.14	0.50	1.06
Age 3+	0.144	0.14	1.0	3.26
Age 4+	0.144	0.14	1.0	4.72
Age 5+	0.144	0.14	1.0	5.30
Age 6+	0.144	0.14	1.0	6.13
Age 7+	0.144	0.14	1.0	6.78
Age 8+	0.144	0.14	1.0	7.37
Age 9+	0.144	0.14	1.0	8.76
Age 10+	0.144	0.14	1.0	9.23
Age 11+	0.144	0.14	1.0	10.5
Age 12+	0.144	0.14	1.0	12.0
Age 13+	0.144	0.14	1.0	13.7

Sources: O'Connell, 1953; Tenera Environmental Services, 1988; Cailliet, 2000; Leet et al., 2001; and personal communication with Y. DeReynier (NMFS, November 19, 2002).

Table B1-7: California Halibut Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.223	0	0	0.000000548
Larvae	2.86	0	0	0.00000444
Juvenile	0.555	0	0	0.0170
Age 1+	0.160	0	0	0.130
Age 2+	0.160	0	0	0.739
Age 3+	0.160	0	0	1.94
Age 4+	0.160	0	0	3.87
Age 5+	0.160	0	0	6.21
Age 6+	0.160	0.16	1.0	8.89
Age 7+	0.160	0.16	1.0	12.2
Age 8+	0.160	0.16	1.0	15.3
Age 9+	0.160	0.16	1.0	18.9
Age 10+	0.160	0.16	1.0	21.3
Age 11+	0.160	0.16	1.0	23.8
Age 12+	0.160	0.16	1.0	26.6
Age 13+	0.160	0.16	1.0	28.6
Age 14+	0.160	0.16	1.0	30.7
Age 15+	0.160	0.16	1.0	33.0
Age 16+	0.160	0.16	1.0	35.3
Age 17+	0.160	0.16	1.0	37.7
Age 18+	0.160	0.16	1.0	40.2
Age 19+	0.160	0.16	1.0	42.9
Age 20+	0.160	0.16	1.0	45.7
Age 21+	0.160	0.16	1.0	48.5
Age 22+	0.160	0.16	1.0	51.5
Age 23+	0.160	0.16	1.0	54.7
Age 24+	0.160	0.16	1.0	57.9
Age 25+	0.160	0.16	1.0	61.3
Age 26+	0.160	0.16	1.0	64.8
Age 27+	0.160	0.16	1.0	68.4
Age 28+	0.160	0.16	1.0	72.2
Age 29+	0.160	0.16	1.0	76.1
Age 30+	0.160	0.16	1.0	80.1

Sources: Kucas and Hassler, 1986; Cailliet, 2000; Tenera Environmental Services, 2000a; Leet et al., 2001; Froese and Pauly, 2002; and personal communication with Y. DeReynier (NMFS, November 19, 2002).

Table B1-8: California Scorpionfish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000200
Larvae	1.00	0	0	0.00000219
Juvenile	1.00	0	0	0.000712
Age 1+	0.130	0	0	0.281
Age 2+	0.130	0.13	0.50	0.445
Age 3+	0.130	0.13	1.0	0.662
Age 4+	0.130	0.13	1.0	0.940
Age 5+	0.130	0.13	1.0	1.42
Age 6+	0.130	0.13	1.0	1.80
Age 7+	0.130	0.13	1.0	2.19
Age 8+	0.130	0.13	1.0	2.58
Age 9+	0.130	0.13	1.0	2.95
Age 10+	0.130	0.13	1.0	3.31
Age 11+	0.130	0.13	1.0	3.65
Age 12+	0.130	0.13	1.0	3.96
Age 13+	0.130	0.13	1.0	4.25
Age 14+	0.130	0.13	1.0	4.51
Age 15+	0.130	0.13	1.0	4.75
Age 16+	0.130	0.13	1.0	4.97
Age 17+	0.130	0.13	1.0	5.17
Age 18+	0.130	0.13	1.0	5.35
Age 19+	0.130	0.13	1.0	5.51
Age 20+	0.130	0.13	1.0	5.65
Age 21+	0.130	0.13	1.0	6.18

[a] Includes California scorpionfish and spotted scorpionfish.

Sources: Cailliet, 2000; Froese and Binohlan, 2000; and Leet et al., 2001.

Table B1-9: Chinook Salmon Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000317
Larvae	5.04	0	0	0.000349
Juvenile	0.916	0	0	0.199
Age 1+	0.160	0	0	0.397
Age 2+	0.160	0	0	4.50
Age 3+	0.160	0	0	12.2
Age 4+	0.160	0	0	23.8
Age 5+	0.160	0	0	33.8

Sources: Beauchamp et al., 1983; Allen and Hassler, 1986; Wang, 1986; and Froese and Pauly, 2001.

Table B1-10: Commercial Sea Basses/Recreational Sea Basses Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.00000101
Larvae	1.00	0	0	0.0000216
Juvenile	0.190	0	0	0.000138
Age 1+	0.190	0	0	0.0313
Age 2+	0.190	0	0	0.0625
Age 3+	0.190	0	0	0.125
Age 4+	0.190	0	0	0.312
Age 5+	0.190	0.26	0.50	0.531
Age 6+	0.190	0.26	1.0	0.813
Age 7+	0.287	0.26	1.0	1.13
Age 8+	0.287	0.26	1.0	1.50
Age 9+	0.287	0.26	1.0	1.88
Age 10+	0.287	0.26	1.0	2.19
Age 11+	0.287	0.26	1.0	2.30
Age 12+	0.287	0.26	1.0	2.41
Age 13+	0.287	0.26	1.0	2.67
Age 14+	0.287	0.26	1.0	2.93
Age 15+	0.287	0.26	1.0	3.19
Age 16+	0.287	0.26	1.0	3.44
Age 17+	0.287	0.26	1.0	3.69
Age 18+	0.287	0.26	1.0	3.94
Age 19+	0.287	0.26	1.0	4.19

Table B1-10: Commercial Sea Basses/Recreational Sea Basses Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Age 20+	0.287	0.26	1.0	4.42
Age 21+	0.287	0.26	1.0	4.66
Age 22+	0.287	0.26	1.0	4.88
Age 23+	0.287	0.26	1.0	5.10
Age 24+	0.287	0.26	1.0	5.31
Age 25+	0.287	0.26	1.0	5.51
Age 26+	0.287	0.26	1.0	5.71
Age 27+	0.287	0.26	1.0	5.90
Age 28+	0.287	0.26	1.0	6.08
Age 29+	0.287	0.26	1.0	6.25
Age 30+	0.287	0.26	1.0	6.42
Age 31+	0.287	0.26	1.0	6.58
Age 32+	0.287	0.26	1.0	6.73
Age 33+	0.287	0.26	1.0	6.88

[a] Commercial sea bass species includes giant sea bass; recreational sea bass species includes barred sand bass, paralabrax species, broomtail grouper, kelp bass, spotted bass, and spotted sand bass.

Sources: Cailliet, 2000; California Department of Fish and Game, 2002; Froese and Binohlan, 2000; Leet et al., 2001; and Froese and Pauly, 2002.

Table B1-11: Commercial Shrimp Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.693	0	0	0.000000249
Larvae	3.00	0	0	0.000000736
Juvenile	2.16	0.14	1.0	0.0000865
Age 1+	2.16	0.14	1.0	0.000452
Age 2+	2.16	0.14	1.0	0.00236

[a] Includes Alaskan bay shrimp, bay shrimp, black tailed bay shrimp, blackspotted shrimp, Franscican bay shrimp, ghost shrimp, smooth bay shrimp, spot shrimp, and spotted bay shrimp.

Sources: Bielsa et al., 1983; Siegfried, 1989; Virginia Tech, 1998; Leet et al., 2001; and Tenera Environmental Services, 2001.

Table B1-12: Delta Smelt Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.90	0	0	0.00000115
Larvae	4.89	0	0	0.00000120
Juvenile	0.916	0	0	0.0000462
Age 1+	1.28	0	0	0.00418

Sources: Wang, 1986; Buckley, 1989; Moyle et al., 1992; Froese and Pauly, 2001, 2003; and Brown and Kimmerer, 2002.

Table B1-13: Drums/Croakers Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.500	0	0	0.000000722
Larvae	4.61	0	0	0.00000464
Juvenile	3.38	0	0	0.000212
Age 1+	0.420	0	0	0.120
Age 2+	0.420	0	0	0.156
Age 3+	0.210	0.21	0.50	0.195
Age 4+	0.210	0.21	1.0	0.239
Age 5+	0.210	0.21	1.0	0.287
Age 6+	0.210	0.21	1.0	0.340
Age 7+	0.210	0.21	1.0	0.398
Age 8+	0.210	0.21	1.0	0.458
Age 9+	0.210	0.21	1.0	0.519
Age 10+	0.210	0.21	1.0	0.584
Age 11+	0.210	0.21	1.0	0.648
Age 12+	0.210	0.21	1.0	0.723

[a] Includes black croaker, California corbina, queenfish, spotfin croaker, white croaker, white seabass, yellowfin croaker, and other drums or croakers not identified to species.

Sources: Isaacson, 1964; Tenera Environmental Services, 1988, 2000b, 2001; and Cailliet, 2000.

Table B1-14: Dungeness Crab Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.223	0	0	0.000000153
Zoea/Larvae[a]	1.20	0	0	0.000134
Megalopae	1.20	0	0	0.590
Age 1+	0.500	0	0	1.10
Age 2+	0.500	0.50	0.50	1.37
Age 3+	0.500	0.50	1.0	2.48
Age 4+	1.71	0.50	1.0	4.04
Age 5+	1.71	0.50	1.0	4.41
Age 6+	1.71	0.50	1.0	4.79
Age 7+	1.71	0.50	1.0	5.20
Age 8+	1.71	0.50	1.0	5.63
Age 9+	1.71	0.50	1.0	6.08
Age 10+	1.71	0.50	1.0	6.56

[a] Life stages reported as larvae and zoea were assigned the same life history parameters.

Sources: Carroll, 1982; Wild and Tasto, 1983; Pauley et al., 1989; Virginia Tech, 1998; Tenera Environmental Services, 2000a; University of Washington, 2000; and Leet et al., 2001.

Table B1-15: Flounders Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.223	0	0	0.000000303
Larvae	6.28	0	0	0.00121
Juvenile	1.14	0	0	0.00882
Age 1+	0.363	0.24	0.50	0.0672
Age 2+	0.649	0.43	1.0	0.226
Age 3+	0.752	0.50	1.0	0.553
Age 4+	0.752	0.50	1.0	1.13

[a] Includes bigmouth sole, CO turbot, California halibut, curlfin sole, diamond turbot, dover sole, english sole, fantail sole, hornyhead turbot, longfin sanddab, pacific sanddab, petrale sole, rock sole, sand sole, slender sole, speckled sanddab, spotted turbot, starry flounder, and other flounders not identified to species.

Sources: Cailliet, 2000; ENSR and Marine Research Inc., 2000; Tenera Environmental Services, 2000a, 2001; Leet et al., 2001; and personal communication with Y. DeReynier (NMFS, November 19, 2002).

Table B1-16: Forage Shrimp Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.693	0	0	0.000000249
Larvae	3.00	0	0	0.000000736
Juvenile	2.30	0	0	0.0000865
Age 1+	2.30	0	0	0.000131
Age 2+	2.30	0	0	0.00236

[a] Includes anemone shrimp, blue mud shrimp, broken back shrimp, brown shrimp, California green shrimp, dock shrimp, mysids, opossum shrimp, oriental shrimp, pistol shrimp, sidestriped shrimp, skeleton shrimp, stout bodied shrimp, striped shrimp, tidepool shrimp, twistclaw pistol shrimp, and other shrimp not identified to species.

Sources: Siegfried, 1989; Virginia Tech, 1998; and Tenera Environmental Services, 2001.

Table B1-17: Gobies Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0	0	0	0.0000115
Larvae	5.77	0	0	0.0000190
Juvenile	0.871	0	0	0.000169
Age 1+	1.10	0	0	0.00194
Age 2+	1.10	0	0	0.00414
Age 3+	1.10	0	0	0.00763
Age 4+	1.10	0	0	0.0310
Age 5+	1.10	0	0	0.0810

[a] Includes arrow goby, bay goby, blackeye goby, blind goby, chameleon goby, cheekspot goby, longjaw mudsucker shadow goby, yellowfin goby, and other gobies not identified to species.

Sources: Wang, 1986; Froese and Pauly, 2000, 2002; Tenera Environmental Services, 2000a; and NMFS, 2003a.

Table B1-18: Herrings Life History Parameters 1[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000164
Larvae	4.61	0	0	0.00000180
Juvenile	0.693	0	0	0.00161
Age 1+	0.473	0	0	0.0408
Age 2+	0.474	0	0	0.128
Age 3+	0.474	0	0	0.167
Age 4+	0.474	0	0	0.211
Age 5+	0.474	0	0	0.258
Age 6+	0.474	0	0	0.288
Age 7+	0.474	0	0	0.330
Age 8+	0.474	0	0	0.345
Age 9+	0.474	0	0	0.353
Age 10+	0.474	0	0	0.364
Age 11+	0.474	0	0	0.375

[a] Includes middle thread herring, pacific herring, pacific sardine, round herring, threadfin shad, and other herrings not identified to species.

Sources: Ecological Analysts Inc., 1981b, 1982a; Lassuy, 1989; Tenera Environmental Services, 2001; Froese and Pauly, 2002; and NMFS, 2003a.

Table B1-19: Herrings Life History Parameters 2[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000164
Larvae 6 mm	0.140	0	0	0.00000182
Larvae 7 mm	0.121	0	0	0.00000299
Larvae 8 mm	0.107	0	0	0.00000461
Larvae 9 mm	0.096	0	0	0.00000675
Larvae 10 mm	0.087	0	0	0.00000948
Larvae 11 mm	0.079	0	0	0.0000129
Larvae 12 mm	0.221	0	0	0.0000171
Larvae 13 mm	0.221	0	0	0.0000221
Larvae 14 mm	0.221	0	0	0.0000281
Larvae 15 mm	0.221	0	0	0.0000352
Larvae 16 mm	0.221	0	0	0.0000433
Larvae 17 mm	0.221	0	0	0.0000527
Larvae 18 mm	0.221	0	0	0.0000634

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Larvae 19 mm	0.221	0	0	0.0000755
Larvae 20 mm	0.221	0	0	0.0000891
Larvae 22 mm	0.221	0	0	0.000121
Larvae 23 mm	0.221	0	0	0.000140
Larvae 24 mm	0.221	0	0	0.000161
Larvae 25 mm	0.221	0	0	0.000183
Larvae 26 mm	0.221	0	0	0.000208
Larvae 27 mm	0.221	0	0	0.000235
Larvae 28 mm	0.221	0	0	0.000264
Larvae 29 mm	0.221	0	0	0.000296
Larvae 30 mm	0.221	0	0	0.000330
Juvenile	0.693	0	0	0.00161
Age 1+	0.473	0	0	0.0408
Age 2+	0.474	0	0	0.128
Age 3+	0.474	0	0	0.167
Age 4+	0.474	0	0	0.211
Age 5+	0.474	0	0	0.258
Age 6+	0.474	0	0	0.288
Age 7+	0.474	0	0	0.330
Age 8+	0.474	0	0	0.345
Age 9+	0.474	0	0	0.353
Age 10+	0.474	0	0	0.364
Age 11+	0.474	0	0	0.375

Table B1-19: Herrings Life History Parameters 2[a]

[a] Includes pacific herring and other herrings not identified to species.

Sources: Ecological Analysts Inc., 1981b; Wang, 1986; Lassuy, 1989; Tenera Environmental Services, 2001; Froese and Pauly, 2002; and NMFS, 2003a.

Table B1-20: Herrings Life History Parameters 3[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000164
Larvae 6 mm	0.107	0	0	0.00000182
Larvae 7 mm	0.107	0	0	0.00000299
Larvae 8 mm	0.107	0	0	0.00000461
Larvae 9 mm	0.107	0	0	0.00000675
Larvae 10 mm	0.107	0	0	0.00000948
Larvae 11 mm	0.107	0	0	0.0000129
Larvae 12 mm	0.107	0	0	0.0000171
Larvae 13 mm	0.214	0	0	0.0000221
Larvae 15 mm	0.107	0	0	0.0000352
Larvae 16 mm	0.107	0	0	0.0000433
Larvae 17 mm	0.107	0	0	0.0000527
Larvae 18 mm	0.107	0	0	0.0000634
Larvae 19 mm	0.107	0	0	0.0000755
Larvae 20 mm	0.107	0	0	0.0000891
Larvae 21 mm	0.107	0	0	0.000104
Larvae 22 mm	0.107	0	0	0.000121
Larvae 23 mm	0.107	0	0	0.000140
Larvae 24 mm	0.107	0	0	0.000161
Larvae 25 mm	2.36	0	0	0.000183
Larvae 47 mm	0.107	0	0	0.00141
Larvae 48 mm	0.107	0	0	0.00151
Juvenile	0.693	0	0	0.00161
Age 1+	0.473	0	0	0.0408
Age 2+	0.474	0	0	0.128
Age 3+	0.474	0	0	0.167
Age 4+	0.474	0	0	0.211
Age 5+	0.474	0	0	0.258
Age 6+	0.474	0	0	0.288
Age 7+	0.474	0	0	0.330
Age 8+	0.474	0	0	0.345
Age 9+	0.474	0	0	0.353
Age 10+	0.474	0	0	0.364
Age 11+	0.474	0	0	0.375

[a] Includes pacific herring.

Sources: Ecological Analysts Inc., 1981b, 1982a; Wang, 1986; Lassuy, 1989; Tenera Environmental Services, 2001; Froese and Pauly, 2002; and NMFS, 2003a.

Table B1-21: Longfin Smelt Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.90	0	0	0.00000115
Larvae	6.38	0	0	0.00000186
Juvenile	0.916	0	0	0.000213
Age 1+	0.670	0	1.0	0.00355
Age 2+	0.670	0	1.0	0.0157
Age 3+	0.670	0	1.0	0.0434

Sources: Wang, 1986; Buckley, 1989; USFWS, 1996b; and Froese and Pauly, 2001.

Table B1-22: Northern Anchovy Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.669	0	0	0.00000138
Larvae 5 mm	1.71	0	0	0.00000334
Larvae 6 mm	0.196	0	0	0.00000572
Larvae 7 mm	0.196	0	0	0.00000901
Larvae 8 mm	0.196	0	0	0.0000134
Larvae 9 mm	0.196	0	0	0.0000189
Larvae 10 mm	0.196	0	0	0.0000258
Larvae 11 mm	0.196	0	0	0.0000342
Larvae 12 mm	0.196	0	0	0.0000442
Larvae 13 mm	0.196	0	0	0.0000559
Larvae 14 mm	0.196	0	0	0.0000696
Larvae 15 mm	0.196	0	0	0.0000853
Larvae 16 mm	0.196	0	0	0.000103
Larvae 17 mm	0.196	0	0	0.000123
Larvae 18 mm	0.196	0	0	0.000146
Larvae 19 mm	0.196	0	0	0.000171
Larvae 20 mm	0.196	0	0	0.000199
Larvae 21 mm	0.196	0	0	0.000230
Larvae 22 mm	0.196	0	0	0.000264
Larvae 23 mm	0.196	0	0	0.000301
Larvae 24 mm	0.196	0	0	0.000341
Larvae 25 mm	0.196	0	0	0.000385
Larvae 26 mm	0.196	0	0	0.000432
Larvae 27 mm	0.196	0	0	0.000483
Larvae 28 mm	0.196	0	0	0.000538

Table B1-22: Northern Anchovy Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Larvae 29 mm	0.196	0	0	0.000597
Larvae 30 mm	0.196	0	0	0.000659
Larvae 31 mm	0.196	0	0	0.000726
Larvae 32 mm	0.196	0	0	0.000798
Larvae 33 mm	0.196	0	0	0.000873
Larvae 34 mm	0.196	0	0	0.000954
Larvae 35 mm	0.196	0	0	0.00104
Larvae 36 mm	0.196	0	0	0.00113
Larvae 37 mm	0.196	0	0	0.00122
Juvenile	2.12	0	0	0.0132
Age 1+	0.700	0.03	0.50	0.0408
Age 2+	0.700	0.03	1.0	0.0529
Age 3+	0.700	0.03	1.0	0.0609
Age 4+	0.700	0.03	1.0	0.0684
Age 5+	0.700	0.03	1.0	0.0763
Age 6+	0.700	0.03	1.0	0.0789

Sources: Ecological Analysts Inc., 1980b; Wang, 1986; Virginia Tech, 1998; Tenera Environmental Services, 2000a; and Froese and Pauly, 2002.

Table B1-23: Other Commercial Crabs Life History Parameters 1[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0	0	0	0.000000153
Zoea 1	1.58	0	0	0.00000195
Zoea 2	0.948	0	0	0.00000726
Zoea 3	0.948	0	0	0.0000177
Zoea 4	0.948	0	0	0.0000347
Zoea 5	1.26	0	0	0.0000598
Megalopae	2.31	0	0	0.000134
Age 1+	2.43	0	0	0.289
Age 2+	2.43	0	0	0.654
Age 3+	2.43	0	0	1.26
Age 4+	1.82	0.61	0.50	1.97
Age 5+	1.82	0.61	1.0	2.55
Age 6+	1.82	0.61	1.0	3.00

[a] Includes Anthony's rock crab, black clawed crab, brown rock crab, common rock crab, cryptic kelp crab, dwarf crab, elbow crab, graceful kelp crab, hairy crab, hairy rock crab, kelp crab, lined shore crab, lumpy crab, majid crab, masking crab, mole crab, moss crab, northern kelp crab, porcelain crab, purple shore crab, red crab, red rock crab, sharp nosed crab, shore crab family, slender crab, southern kelp crab, spider crab, striped shore crab, thickclaw porcelain crab, yellow crab, yellow shore crab, and other commercial crabs not identified to species.

Sources: Carroll, 1982; Tenera Environmental Services, 2000a; University of Washington, 2000; and Leet et al., 2001.

Table B1-24: Other Commercial Crabs Life History Parameters 2[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0	0	0	0.000000153
Larvae	7.99	0	0	0.0000192
Megalopae	2.31	0	0	0.000134
Age 1+	2.43	0	0	0.289
Age 2+	2.43	0	0	0.654
Age 3+	2.43	0	0	1.26
Age 4+	1.82	0.61	0.50	1.97
Age 5+	1.82	0.61	1.0	2.55
Age 6+	1.82	0.61	1.0	3.00

[a] Includes brown rock crab, European green crab, hairy rock crab, hermit crab, lined shore crab, mud crab, pacific sand crab, pea crab, pebble crab, porcelain crab, red crab, red rock crab, shore crab, slender crab, slender rock crab, spider crab, stone crab, yellow crab, yellow rock crab, yellow shore crab, and other commercial crabs not identified to species.

Sources: Carroll, 1982; Tenera Environmental Services, 2000a, 2001; University of Washington, 2000; and Leet et al., 2001.

Table B1-25: Pacific Herring Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000164
Larvae 6 mm	1.44	0	0	0.00000182
Larvae 7 mm	0.703	0	0	0.00000299
Larvae 8 mm	0.609	0	0	0.00000461
Larvae 9 mm	0.537	0	0	0.00000675
Larvae 10 mm	0.481	0	0	0.00000948
Larvae 11 mm	0.435	0	0	0.0000129
Larvae 12 mm	0.397	0	0	0.0000171
Juvenile	0.693	0	0	0.00161
Age 1+	0.473	0	0	0.243
Age 2+	0.474	0	0	0.351
Age 3+	0.474	0	0	0.388
Age 4+	0.474	0	0	0.410
Age 5+	0.474	0	0	0.434
Age 6+	0.474	0	0	0.450
Age 7+	0.474	0	0	0.472
Age 8+	0.474	0	0	0.485

Sources: Ecological Analysts Inc., 1981b; Lassuy, 1989; Washington Department of Fish and Wildlife, 1997; Tenera Environmental Services, 2001; Froese and Pauly, 2002, 2003; and NMFS, 2003a.

Table B1-26: Rockfish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Larvae	1.00	0	0	0.000181
Juvenile	1.00	0	0	0.00760
Age 1+	0.215	0	0	0.0444
Age 2+	0.215	0	0	0.150
Age 3+	0.261	0	0	0.308
Age 4+	0.131	0.13	0.25	0.458
Age 5+	0.131	0.13	0.50	0.689
Age 6+	0.131	0.13	0.75	0.878
Age 7+	0.131	0.13	1.0	1.05
Age 8+	0.131	0.13	1.0	1.21
Age 9+	0.131	0.13	1.0	1.34
Age 10+	0.131	0.13	1.0	1.46
Age 11+	0.131	0.13	1.0	1.55
Age 12+	0.131	0.13	1.0	1.63
Age 13+	0.131	0.13	1.0	1.70
Age 14+	0.131	0.13	1.0	1.75
Age 15+	0.131	0.13	1.0	1.80
Age 16+	0.131	0.13	1.0	1.83
Age 17+	0.131	0.13	1.0	1.86
Age 18+	0.131	0.13	1.0	1.88
Age 19+	0.131	0.13	1.0	1.90
Age 20+	0.131	0.13	1.0	1.92
Age 21+	0.131	0.13	1.0	1.93
Age 22+	0.131	0.13	1.0	1.94
Age 23+	0.131	0.13	1.0	1.95
Age 24+	0.131	0.13	1.0	1.95

[a] Includes aurora rockfish, black and yellow rockfish, black rockfish, blue rockfish, bocaccio, brown rockfish, calico rockfish, chilipepper, copper rockfish, flag rockfish, gopher rockfish, grass rockfish, kelp rockfish, olive rockfish, shortbelly rockfish, treefish, vermilion rockfish, yellowtail rockfish, and other rockfish not identified to species.

Sources: Russell and Hanson, 1990; Cailliet, 2000; Froese and Binohlan, 2000; Leet et al., 2001; and Tenera Environmental Services, 2001.

Table B1-27: Sacramento Splittail Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.00000352
Larvae	11.3	0	0	0.0000140
Juvenile	0.916	0	0	0.00103
Age 1+	0.370	0	1.0	0.0683
Age 2+	0.370	0	1.0	0.252
Age 3+	0.370	0	1.0	0.480
Age 4+	0.370	0	1.0	0.704
Age 5+	0.370	0	1.0	1.05
Sources: Daniels and Moyle, 1983; CDWR, 1994; and Froese and Pauly, 2001.				

Table B1-28: Salmon Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.000317
Larvae	5.04	0	0	0.000349
Juvenile	0.916	0	0	0.199
Age 1+	0.160	0.16	0.50	0.397
Age 2+	0.160	0.16	1.0	4.50
Age 3+	0.160	0.16	1.0	12.2
Age 4+	0.160	0.16	1.0	23.8
Age 5+	0.160	0.16	1.0	33.8
Sources: Beauchamp et al., 1983; Allen and Hassler, 1986; Wang, 1986; Froese and Pauly, 2001; and California Department of Fish and Game, 2003.				

Table B1-29: Sculpins Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000338
Larvae	3.79	0	0	0.00000371
Juvenile	0.916	0	0	0.0120
Age 1+	0.420	0.50	0.50	0.0400
Age 2+	0.420	0.50	1.0	0.104
Age 3+	0.420	0.50	1.0	0.219

[a] Includes bonehead sculpin, brown Irish lord, buffalo sculpin, coralline sculpin, fluffy sculpin, manacled sculpin, pacific staghorn sculpin, prickly sculpin, rosy sculpin, roughcheek sculpin, roughneck sculpin, smoothhead sculpin, snubnose sculpin, spotted scorpionfish, staghorn sculpin, tidepool sculpin, woolly sculpin, and other sculpins not identified to species.

Sources: Cailliet, 2000; Leet et al., 2001; Froese and Pauly, 2002; and personal communication with Y. DeReynier (NMFS, November 19, 2002).

Table B1-30: Silversides Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.669	0	0	0.00000924
Larvae	7.99	0	0	0.0000528
Juvenile	0.420	0	0	0.000472
Age 1+	0.420	0	0	0.0207
Age 2+	0.420	0	0	0.106
Age 3+	0.420	0	0	0.166
Age 4+	0.420	0	0	0.246
Age 5+	0.420	0	0	0.349
Age 6+	0.420	0	0	0.476
Age 7+	0.420	0	0	0.632
Age 8+	0.420	0	0	0.818
Age 9+	0.420	0	0	1.04
Age 10+	0.420	0	0	1.30
Age 11+	0.420	0	0	1.59

[a] Includes California grunion, jacksmelt, topsmelt, and other silversides not identified to species.

Sources: Wang, 1986; Cailliet, 2000; Leet et al., 2001; Froese and Pauly, 2002; and NMFS, 2003a.

Table B1-31: Smelts Life History Parameters[a]				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.90	0	0	0.00000154
Larvae	7.99	0	0	0.000389
Juvenile	0.740	0.15	0.50	0.00520
Age 1+	0.740	0.15	1.0	0.0364
Age 2+	0.740	0.15	1.0	0.147
Age 3+	0.740	0.15	1.0	0.393
Age 4+	0.740	0.15	1.0	0.738
Age 5+	0.740	0.15	1.0	1.25

[a] Includes night smelt, popeye smelt, surf smelt, and other smelts not identified to species.

Sources: Dryfoos, 1965; Buckley, 1989; Cailliet, 2000; Leet et al., 2001; and Froese and Pauly, 2002.

Table B1-32: Steelhead Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.000317
Larvae	5.04	0	0	0.000349
Juvenile	0.916	0	0	0.199
Age 1+	0.160	0	0	0.397
Age 2+	0.160	0	0.50	4.50
Age 3+	0.160	0	1.0	12.2
Age 4+	0.160	0	1.0	23.8
Age 5+	0.160	0	1.0	33.8
Age 6+	0.160	0	1.0	37.9
Age 7+	0.160	0	1.0	40.1
Age 8+	0.160	0	1.0	41.9
Age 9+	0.160	0	1.0	43.0

Sources: Beauchamp et al., 1983; Wang, 1986; and Froese and Pauly, 2001.

Table B1-33: Striped Bass Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.50	0	0	0.0000416
Larvae 5 to 6 mm	1.00	0	0	0.0000457
Larvae 7 to 10 mm	2.01	0	0	0.0000503
Larvae 11 to 14 mm	0.939	0	0	0.0000553
Larvae 15 to 18 mm	0.651	0	0	0.0000898
Larvae 19 mm	0.0610	0	0	0.000135
Larvae 20 to 24 mm	0.312	0	0	0.000207
Larvae 25 to 29 mm	0.286	0	0	0.000397
Larvae 30 to 34 mm	0.334	0	0	0.000616
Larvae 35 to 39 mm	0.375	0	0	0.000977
Larvae 40 to 44 mm	0.441	0	0	0.00136
Larvae 45 to 49 mm	0.904	0	0	0.00194
Larvae 51 to 75 mm	0.700	0	0	0.00421
Larvae 76 to 100 mm	0.350	0	0	0.0105
Juvenile	0.916	0	0	0.0174
Age 1+	0.320	0	0	0.100
Age 2+	0.320	0.18	0.06	0.500
Age 3+	0.320	0.18	0.20	2.30
Age 4+	0.320	0.18	0.63	4.30
Age 5+	0.320	0.18	0.94	6.00
Age 6+	0.320	0.18	1.0	8.50
Age 7+	0.320	0.18	1.0	11.8
Age 8+	0.320	0.18	1.0	13.8
Age 9+	0.320	0.18	1.0	16.0

Sources: Setzler et al., 1980; Ecological Analysts Inc., 1981b; PSE&G, 1999; California Department of Fish and Game, 2000a; Froese and Pauly, 2001; and Leet et al., 2001.

Table B1-34: Striped Bass Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.50	0	0	0.0000416
Larvae	7.44	0	0	0.0000457
Juvenile	0.916	0	0	0.0174
Age 1+	0.320	0	0	0.100
Age 2+	0.320	0.18	0.06	0.500
Age 3+	0.320	0.18	0.20	2.30
Age 4+	0.320	0.18	0.63	4.30
Age 5+	0.320	0.18	0.94	6.00
Age 6+	0.320	0.18	1.0	8.50
Age 7+	0.320	0.18	1.0	11.8
Age 8+	0.320	0.18	1.0	13.8
Age 9+	0.320	0.18	1.0	16.0

Sources: Setzler et al., 1980; Ecological Analysts Inc., 1981b; PSE&G, 1999; California Department of Fish and Game, 2000a; Froese and Pauly, 2001; and Leet et al., 2001.

Table B1-35: Surfperches Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Juvenile	0.560	0	0	0.00443
Age 1+	0.280	0	0	0.0429
Age 2+	0.280	0.28	0.50	0.125
Age 3+	0.280	0.28	1.0	0.203
Age 4+	0.280	0.28	1.0	0.261
Age 5+	0.280	0.28	1.0	0.300
Age 6+	0.280	0.28	1.0	0.324

[a] Includes barred surfperch, black surfperch, calico surfperch, dwarf surfperch, island surfperch, kelp surfperch, pile surfperch, pink seaperch, rainbow surfperch, rubberlip surfperch, shiner surfperch, silver surfperch, spotfin surfperch, striped surfperch, walleye surfperch, white seaperch, and other surfperches not identified to species.

Sources: Cailliet, 2000; Froese and Binohlan, 2000; Leet et al., 2001; and Froese and Pauly, 2002.

Table B1-36: Other Commercial Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] See Table B1-40 for a list of species.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table B1-37: Other Recreational Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] See Table B1-41 for a list of species.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table B1-38: Other Recreational and Commercial Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Yolk-sac larvae	2.85	0	0	0.000000728
Post yolk-sac larvae	2.85	0	0	0.00000335
Juvenile 1	1.43	0	0	0.000746
Juvenile 2	1.43	0	0	0.0472
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes barracuda, California sheephead, jack mackerel, lingcod, piked dogfish, and spiny dogfish.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table B1-39: Other Forage Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Larvae	7.70	0	0	0.00000158
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] See Table B1-42 for a list of species.

Sources: Derickson and Price, 1973; and PSE&G, 1999.

Table B1-40: Other Commercial Species[a]

Basketweave cusk-eel	Monkeyface eel	Pacific hake	Spotted cusk-eel
California moray	Monkeyface prickleback	Pricklebreast poacher	Yellow snake-eel
Catalina conger	Moray eel	Ribbon prickleback	
Leopard shark	Pacific hagfish	Rock prickleback	

[a] Includes other organisms not identified to species.

Table B1-41: Other Recreational Species[a]			
Angel shark	Chub mackerel	Pacific angel shark	Round stingray
Bat ray	Diamond stingray	Pacific bonito	Senorita
Big skate	Gray smoothhound	Pacific bumper	Sevengill shark
Black skate	Halfmoon	Pacific electric ray	Soupfin shark
Broadnose sevengill shark	Horn shark	Pacific mackerel	Striped mullet
Brown smoothhound	Kelp greenling	Pacific moonfish	Swell shark
California butterfly ray	Mexican scad	Pacific pompano	Thornback ray
California electric ray	Monterey Spanish mackerel	Painted greenling	
California ray	Opaleye	Rock wrasse	

[a] Includes other organisms not identified to species.

Table B1-42: Other Forage Species[a]			
Barcheek pipefish	Finescale triggerfish	Ocean sunfish	Sea porcupine
Bay pipefish	Flathead mullet	Ocean whitefish	Sharksucker
Bigscale goatfish	Fringehead	Onespot fringehead	Shovelnose guitarfish
Bigscale logperch	Garibaldi	Pacific butterfish	Slimy snailfish
Black bullhead	Giant kelpfish	Pacific cornetfish	Smalleye squaretail
Blacksmith	Grunt	Pacific cutlassfish	Snailfishes
Blue lanternfish	Gunnels	Pacific lamprey	Snubnose pipefish
Broadfin lampfish	Hatchet fish	Pacific sand lance	Southern poacher
Bullseye puffer	High cockscomb	Penpoint gunnel	Southern spearnose poacher
California clingfish	Hitch	Pipefishes	Specklefin midshipman
California flyingfish	Island kelpfish	Plainfin midshipman	Spotted kelpfish
California killifish	Kelp gunnel	Pygmy poacher	Spotted ratfish
California lizardfish	Kelp pipefish	Ratfish	Squid
California needlefish	Kelpfish	Red brotula	Stickleback
California tonguefish	Lampfish	Reef finspot	Striped kelpfish
Californian needlefish	Lanternfish	Ribbonfish	Sunfish family
Catfish family	Longfin lanternfish	Rockweed gunnel	Thornback
Clingfishes	Longspine combfish	Ronquils	Threespine stickleback
Clinids	Medusafish	Saddleback gunnel	Tubesnout
Codfishes	Mexican lampfish	Salema	White catfish
Combfish	Northern clingfish	Sarcastic fringehead	Zebra perch
Cortez angelfish	Northern lampfish	Sargo	
Crevice kelpfish	Northern spearnose poacher	Scarlet kelpfish	

[a] Includes other organisms not identified to species.

Appendix B2: Reductions in I&E in California Under Five Other Options Evaluated for the Proposed Section 316(b) Phase III Regulation

Table B2-1: Estimated Reductions in I&E in California Under Five Other Options Evaluated for the Proposed Section 316(b) Regulation

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
20 MGD All	771,000	56,300
2	771,000	56,300
3	391,000	28,200
4	771,000	56,300
All Phase III Facilities	771,000	56,300

Appendix B3: Commercial Fishing Benefits for Five Other Options Evaluated for Phase III Existing Facilities in the California Region

Section B3-2 in Chapter B3 displays the results of the commercial fishing benefits analysis for the 50 MGD option, the 200 MGD option, and the 100 MGD option. To facilitate comparisons among the options, this appendix displays results for the following additional options: All Potentially Regulated Phase III Existing Facilities option (All Phase III Facilities); the 20 MGD option (20 MGD All); Option 2; Option 3; and Option 4.

Table B3-1: Annualized Commercial Fishing Benefits Attributable to the All Phase III Facilities Option at Facilities in the California Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$141	$52,300	$52,400
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$56	$20,900	$21,000
Expected reduction due to rule	78%	59%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$12,300
3% discount rate			$10,100
7% discount rate			$8,000

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table B3-2: Annualized Commercial Fishing Benefits Attributable to the 20 MGD All Option at Facilities in the California Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$141	$52,300	$52,400
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$56	$20,900	$21,000
Expected reduction due to rule	78%	59%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$12,300
3% discount rate			$10,100
7% discount rate			$8,000

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table B3-3: Annualized Commercial Fishing Benefits Attributable to Option 2 at Facilities in the California Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$141	$52,300	$52,400
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$56	$20,900	$21,000
Expected reduction due to rule	78%	59%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$12,300
3% discount rate			$10,100
7% discount rate			$8,000

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table B3-4: Annualized Commercial Fishing Benefits Attributable to Option 3 at Facilities in the California Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$141	$52,300	$52,400
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$56	$20,900	$21,000
Expected reduction due to rule	78%	29%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$6,100
3% discount rate			$5,100
7% discount rate			$4,000

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table B3-5: Annualized Commercial Fishing Benefits Attributable to Option 4 at Facilities in the California Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$141	$52,300	$52,400
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$56	$20,900	$21,000
Expected reduction due to rule	78%	59%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$12,300
3% discount rate			$10,100
7% discount rate			$8,000

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Appendix B4: Recreational Use Benefits of Other Policy Options

Introduction

Chapter B4 presents EPA's estimates of the recreational benefits of the three proposed options for the section 316(b) rule for Phase III facilities, for electric generators and manufacturers in the California region. This appendix supplements Chapter B4 by presenting estimates of the recreational fishing benefits of five other options that EPA evaluated for the purpose of comparison:

- Option 3,
- Option 4,
- Option 2,
- Option 1, and
- Option 6.

Appendix Contents

Recreational fishing benefits presented in this chapter were estimated using the benefit transfer approach discussed in Chapter B4 and in Chapter A5, "Recreational Fishing Benefits Methodology."

B4-1 Recreational Fishing Benefits of the Other Evaluated Options

B4-1.1 Estimated Reductions in Recreational Fishing Losses under the Other Evaluated Options

Table B4-1 presents EPA's estimates of the annual reduction in baseline (i.e., current) recreational fishing losses from impingement and entrainment (I&E) in the California region under the other evaluated options.

Table B4-1: Reductions in Recreational Fishing Losses from I&E under the Other Evaluated Options in the California Region

	Annual Reduction in Recreational Losses (# of fish)[b]				
Species[a]	**Option 3**	**Option 4**	**Option 2**	**Option 1**	**Option 6**
Striped bass	59	89	89	89	89
Total (small game)	**59**	**89**	**89**	**89**	**89**
California halibut	277	559	559	559	559
Flounders	1	1	1	1	1
Total (flatfish)	**278**	**559**	**559**	**559**	**559**
Cabezon	175	352	352	352	352
Croakers	31	62	62	62	62
Rockfish	3,412	6,857	6,857	6,857	6,857
Sculpin	1,352	2,575	2,575	2,575	2,575
Sea bass	29	59	59	59	59
Smelts	1	1	1	1	1
Surfperch	338	338	338	338	338
Total (other saltwater)	**5,338**	**10,244**	**10,244**	**10,244**	**10,244**
Total (unidentified)	**30**	**49**	**49**	**49**	**49**
Total (all species)	***5,705***	***10,941***	***10,941***	***10,941***	***10,941***

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The 'other saltwater' group includes bottomfish and other miscellaneous species. The 'unidentified' group includes fish lost indirectly through trophic transfer.

[b] In the California region, the set of facilities with technology requirements under Option 4 is the same as under Option 2, Option 1, and Option 6. Thus, reductions in recreational losses under these options are also identical.

Source: U.S. EPA analysis for this report.

B4-1.2 Recreational Fishing Benefits of the Other Evaluated Options

Tables B4-2 and B4-3 present EPA's estimates of the annualized recreational benefits of the other evaluated options in the California region.

In the California region, all potentially regulated facilities that would install new technology under Option 4, Option 2, Option 1, or Option 6 have design intake flows greater than 20 MGD. Because the requirements under these four options are identical for this class of facilities, the I&E reductions and benefits resulting from these four options are also identical. Thus, the benefits estimates presented in Table B4-3 apply to all four options.

Table B4-2: Recreational Fishing Benefits of Option 3 in the California Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Small game	0.1	$6.08	$12.57	$26.06	$0.4	$0.7	$1.6
Flatfish	0.3	$6.65	$15.61	$36.54	$1.8	$4.3	$10.2
Other saltwater	5.3	$1.92	$4.52	$10.71	$10.3	$24.1	$57.2
Unidentified	0.0[d]	$2.20	$5.16	$12.17	$0.1	$0.2	$0.4
Total (undiscounted)	**5.7**				**$12.5**	**$29.4**	**$69.3**
Total (evaluated at 3%)	**5.7**				**$10.3**	**$24.2**	**$57.1**
Total (evaluated at 7%)	**5.7**				**$8.1**	**$19.0**	**$44.8**

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[b] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.
[d] Denotes a non-zero value less than 50 fish.

Source: U.S. EPA analysis for this report.

Table B4-3: Recreational Fishing Benefits of Option 4, Option 2, Option 1, or Option 6, in the California Region (2003$)[a]

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	0.1	$6.08	$12.57	$26.06	$0.5	$1.1	$2.3
Flatfish	0.6	$6.65	$15.61	$36.54	$3.7	$8.7	$20.4
Other saltwater	10.2	$1.92	$4.52	$10.71	$19.7	$46.3	$109.8
Unidentified	0.0	$2.20	$5.16	$12.17	$0.1	$0.3	$0.6
Total (undiscounted)	**10.9**				**$24.1**	**$56.5**	**$133.1**
Total (evaluated at 3%)	**10.9**				**$19.8**	**$46.6**	**$109.8**
Total (evaluated at 7%)	**10.9**				**$15.6**	**$36.5**	**$86.1**

[a] In the California region, the set of facilities with technology requirements under Option 4 is the same as under Option 2, Option 1, and Option 6. Thus, reductions in recreational losses under these options are also identical.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

B4-2 Comparison of Recreational Fishing Benefits by Option

Table B4-4 compares the recreational fishing benefits of the five other evaluated options. The table shows that the annual recreational welfare gain under Option 3 is only half as large as the annual recreational welfare gain under the other evaluated options.

Table B4-4: Annual Recreational Benefits of the Other Evaluated Options in the California Region

Policy Option[a]	Annual Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands; 2003$)[b]		
		Low	Mean	High
Option 3	5.7	$12.5	$29.4	$69.3
Option 4	10.9	$24.1	$56.5	$133.1
Option 2	10.9	$24.1	$56.5	$133.1
Option 1	10.9	$24.1	$56.5	$133.1
Option 6	10.9	$24.1	$56.5	$133.1

[a] In the California region, the set of facilities with technology requirements under Option 4 is the same as under Option 2, Option 1, and Option 6. Thus, reductions in recreational losses under these options are also identical.
[b] These benefit estimates were calculated using the meta-analysis approach discussed in Chapter A5 and Chapter B4. EPA did not use the RUM approach from the Phase II analysis to analyze the other evaluated options.

Source: U.S. EPA analysis for this report.

Part C: North Atlantic

Chapter C1: Background

Introduction

Chapter Contents

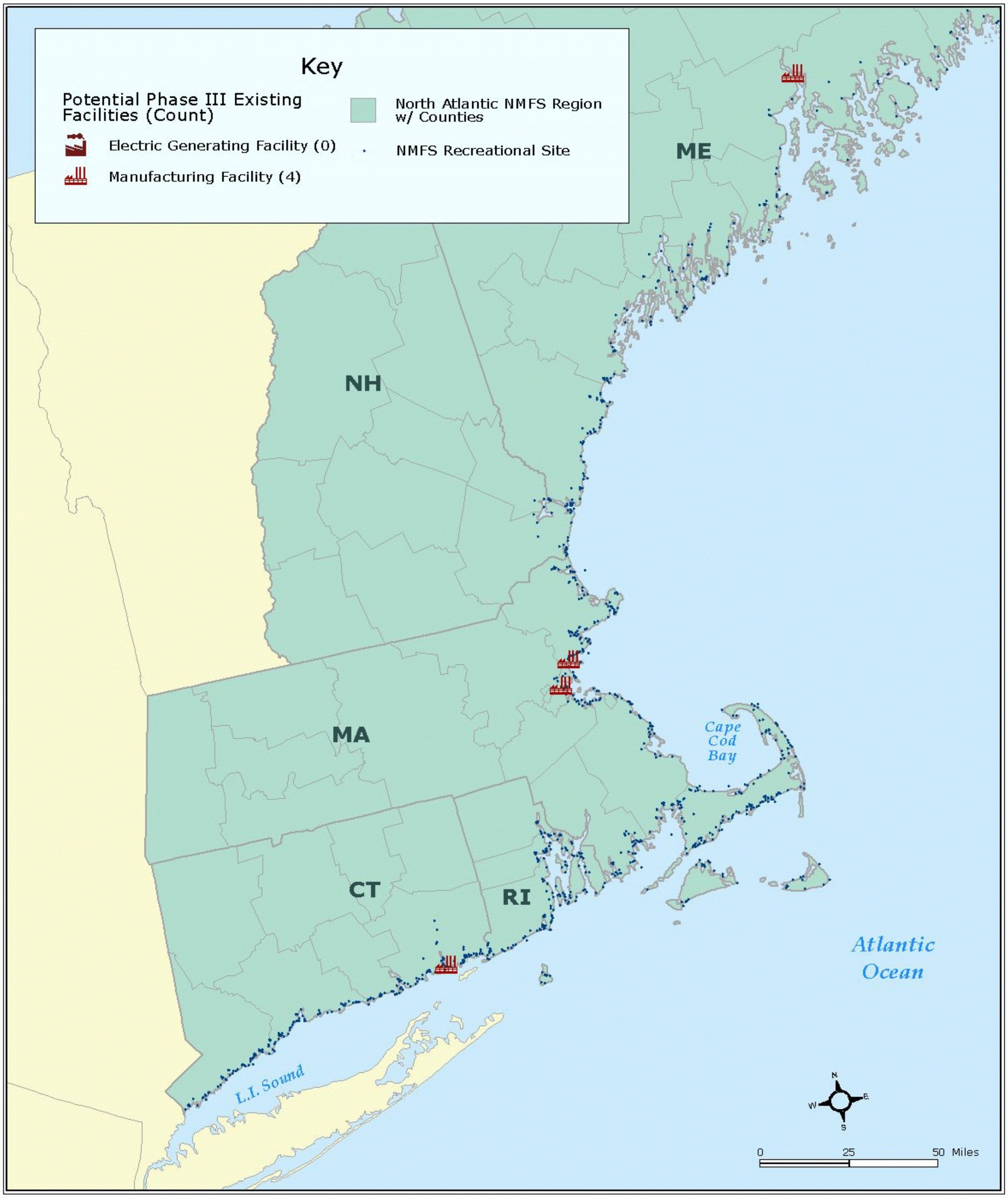
This chapter presents an overview of the potential Phase III existing facilities in the North Atlantic study region and summarizes their key cooling water and compliance characteristics. For further discussion of the technical and compliance characteristics of potential Phase III existing facilities, refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* and the *Technical Development Document for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a,b).

C1-1 Facility Characteristics

The North Atlantic Regional Study includes four sample facilities that are potentially subject to the proposed standards for Phase III existing facilities. All four facilities are manufacturing facilities. Industry-wide, these four sample facilities represent five manufacturing facilities.[1] Figure C1-1 presents a map of these facilities.

[1] EPA applied sample weights to the survey respondents to account for non-sampled facilities and facilities that did not respond to the survey. For more information on EPA's 2000 Section 316(b) Industry Survey, please refer to the Information Collection Request (U.S. EPA, 2000).

Figure C1-1: Potential Existing Phase III Facilities in the North Atlantic Regional Study



Source: U.S. EPA analysis for this report.

Table C1-1 summarizes key technical and compliance characteristics for all potentially regulated Phase III existing facilities in the North Atlantic study region and for the three proposed regulatory options considered by EPA for this proposal (the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD for Certain Waterbodies" option). Facilities with a design intake flow below the three applicability thresholds would be subject to permitting based on best professional judgment and are excluded from EPA's analyses.[2] Therefore, a different number of facilities is affected under each option.

Table C1-1 shows that five Phase III existing facilities in the North Atlantic study region would potentially be subject to the national requirements. Under the "50 MGD for All Waterbodies" option, the most inclusive of the three proposed options, five facilities would be subject to the national requirements for Phase III existing facilities. Under the less inclusive "200 MGD for All Waterbodies" option only one facility would be subject to the nation requirements. Three facilities are subject to the national standards under the "100 MGD for Certain Waterbodies" option. No facility in the North Atlantic study region has a recirculating system in the baseline. Data on design intake flow for the North Atlantic study facilities have been withheld due to data confidentiality reasons.

Table C1-1: Technical and Compliance Characteristics of Existing Phase III Facilities (Sample-Weighted)

	All Potentially Regulated Facilities	Proposed Options		
		50 MGD All	200 MGD All	100 MGD CWB
Total Number of Facilities (Sample-Weighted)	**5**	**5**	**1**	**3**
Number of Facilities with Recirculating System in BL	-	-	-	-
Design Intake Flow (MGD)	w[a]	w[a]	w[a]	w[a]
Number of Facilities by Compliance Response				
New larger intake structure with fine mesh and fish H&R	2	2	-	2
Passive fine mesh screens	2	2	1	1
None	1	1	-	-
Compliance Cost at 3%[b]	$4.56	$4.56	$0.51	$1.98
Compliance Cost at 7%[b]	$5.05	$5.05	$0.46	$2.02

[a] Data withheld because of confidentiality reasons.
[b] Annualized pre-tax compliance cost (2003$, millions)

Source: U.S. EPA, 2000; U.S. EPA analysis for this report.

[2] Also excluded are facilities that are estimated to be baseline closures. For additional information on EPA's baseline closure analyses, please refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a).

Chapter C2: Evaluation of Impingement and Entrainment in the North Atlantic Region

Chapter Contents

Background: North Atlantic Marine Fisheries

Commercial and recreational fisheries of the North Atlantic region are managed by the New England Fisheries Management Council (NEFMC) according to Fishery Management Plans (FMPs) developed by NEFMC (NMFS, 2002a). The NMFS Northeast Fisheries Science Center provides scientific and technical support for management, conservation, and fisheries development.

The multispecies groundfish fishery is the most valuable commercial fishery of the North Atlantic region, followed by American lobster (*Homarus americanus*) (NMFS, 1999a). Important groundfish species include Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), yellowtail flounder (*Pleuronectes ferrugineus*), windowpane flounder (*Scophthalmus aquosus*), and winter flounder (*Pleuronectes americanus*). Atlantic pelagic fisheries are dominated by Atlantic mackerel (*Scomber scombrus*), Atlantic herring (*Clupea harengus*), bluefish (*Pomatomus saltatrix*), and butterfish (*Peprilus triacanthus*) (NMFS, 1999a). Important recreational fisheries of the region include Atlantic cod, winter flounder, Atlantic mackerel, striped bass (*Morone saxatilis*), bluefish, and bluefin tuna (*Thunnus thynnus*) (NMFS, 1999a).

Offshore fisheries for crustaceans and molluscs, particularly American lobster (*Homarus americanus*) and sea scallop (*Placopecten magellanicus*), are among the most valuable fisheries in the Northeast (NMFS, 1999a). Surfclams (*Spisula solidissima*), ocean quahogs (*Arctica islandica*), squids (*Loligo pealeii* and *Illex illecebrosus*), northern shrimp (*Pandalus borealis*), and red crab (*Chaceon quinquedens*) also provide important invertebrate fisheries.

The Northeast lobster fishery is second in commercial value after the multispecies groundfish fishery. The most recent comprehensive stock assessment, completed in 1996, indicated that lobster fishing mortality rates for both inshore and offshore populations greatly exceed the levels needed to provide maximum yields (NMFS, 1999a). Lobster fishing mortality in the Gulf of Maine was almost double the overfishing level. Inshore from Cape Cod through Long Island Sound, fishing mortality was three times the overfishing level.

C2-1 I&E Species/Species Groups Evaluated

Table C2-1 provides a list of species/species groups evaluated by EPA that are subject to impingement and entrainment (I&E) in the North Atlantic region. Appendix C1 provides the life history parameters that were used to express these losses as age-1 equivalents and foregone fishery yield.

Table C2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in the North Atlantic Region

Species/Species Group	Recreational	Commercial	Forage
Alewife			X
American plaice		X	
American sand lance			X
American shad		X	
Atlantic cod	X	X	
Atlantic herring		X	
Atlantic mackerel	X	X	
Atlantic menhaden		X	
Atlantic silverside			X
Atlantic tomcod			X
Bay anchovy			X
Blueback herring			X
Bluefish	X	X	
Butterfish		X	
Commercial crabs		X	
Cunner	X		
Fourbeard rockling			X
Grubby			X
Hogchoker			X
Lumpfish			X
Northern pipefish			X
Other (commercial)		X	
Other (forage)			X
Other (recreational)	X		
Other (recreational and commercial)	X	X	
Pollock	X	X	
Radiated shanny			X
Rainbow smelt			X
Red hake		X	
Rock gunnel			X
Sculpin species	X	X	
Scup	X	X	
Seaboard goby			X
Searobin	X	X	
Silver hake		X	
Skate species		X	
Striped bass	X		

Table C2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in the North Atlantic Region

Species/Species Group	Recreational	Commercial	Forage
Striped killifish			X
Tautog	X	X	
Threespine stickleback			X
Weakfish	X	X	
White perch	X	X	
Windowpane		X	
Winter flounder	X	X	

C2-2 I&E Data Evaluated

Table C2-2 lists the facility I&E data evaluated by EPA to estimate current I&E rates at Phase III facilities in the North Atlantic Region. Because EPA found no I&E data for Phase III facilities in this region, EPA developed I&E estimates for these facilities by extrapolation of I&E estimates of Phase II facilities. See Chapter A1 of Part A for a discussion of extrapolation methods.

Table C2-2: Phase II Facility I&E Data Evaluated for the North Atlantic Analysis

Facility	Years of Data
Brayton Point (MA)	1974-1983
Millstone (CT)	1973-2001
Pilgrim Nuclear (MA)	1990-1998
Seabrook Nuclear (NH)	1990-1998

C2-3 EPA's Estimate of Current I&E at Phase III Facilities in the North Atlantic Region Expressed as Age-1 Equivalents and Foregone Yield

Table C2-3 provides EPA's estimates of the annual age-1 equivalents and foregone fishery yield resulting from the impingement of aquatic species at Phase III facilities located in the North Atlantic region. Table C2-4 displays this information for entrainment. Note that in these tables, "total yield" includes direct losses of harvested species and the yield of harvested species that is lost due to losses of forage species. As discussed in Chapter A1 of Part A of the section 316(b) Phase III Regional Benefits Assessment, the conversion of forage to yield contributes only a very small fraction to total yield.

The lost yield estimates presented in Tables C2-3 and C2-4 are expressed as total pounds and include losses to both commercial and recreational catch. To estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table C2-6 presents the percentage impacts assumed for each species/species group.

Table C2-3: Estimated Current Annual Impingement at Phase III Facilities in the North Atlantic Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Alewife	487	na
American plaice	<1	<1
American sand lance	924	na
American shad	<1	<1
Atlantic cod	12	4
Atlantic herring	115	16
Atlantic mackerel	<1	<1
Atlantic menhaden	8	<1
Atlantic silverside	14,100	na
Atlantic tomcod	<1	na
Bay anchovy	428	na
Blueback herring	56	na
Bluefish	<1	<1
Butterfish	203	6
Crabs (commercial)	104	<1
Cunner	41	<1
Fourbeard rockling	<1	na
Grubby	671	na
Hogchoker	268	na
Lumpfish	63	9
Northern pipefish	115	na
Other (commercial)	<1	<1
Other (forage)	665	na
Other (recreational)	2	<1
Other (recreational and commercial)	5	1
Pollock	<1	<1
Radiated shanny	9	na
Rainbow smelt	708	na
Red hake	2	<1
Rock gunnel	106	na
Sculpins	22	1
Scup	4	<1
Searobin	20	<1
Silver hake	43	6
Skates	67	14
Striped bass	<1	<1
Striped killifish	81	na

Table C2-3: Estimated Current Annual Impingement at Phase III Facilities in the North Atlantic Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Tautog	6	3
Threespine stickleback	220	na
Trophic transfer[a]	na	8
Weakfish	2	<1
White perch	<1	<1
Windowpane	47	<1
Winter flounder	542	65

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table C2-4: Estimated Current Annual Entrainment at Phase III Facilities in the North Atlantic Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Alewife	53	na
American plaice	161	28
American sand lance	177,000	na
Atlantic cod	426	153
Atlantic herring	5,450	771
Atlantic mackerel	927	128
Atlantic menhaden	1,730	201
Atlantic silverside	928	na
Bay anchovy	153,000	na
Bluefish	<1	<1
Butterfish	5	<1
Cunner	188,000	1,030
Fourbeard rockling	55,900	na
Grubby	131,000	na
Hogchoker	3,960	na
Lumpfish	8	1
Northern pipefish	86	na
Other (commercial)	2	<1
Other (forage)	801	na
Other (recreational)	2	<1
Other (recreational and commercial)	<1	<1
Pollock	<1	1
Radiated shanny	195,000	na
Rainbow smelt	5,890	na
Rock gunnel	848,000	na

Table C2-4: Estimated Current Annual Entrainment at Phase III Facilities in the North Atlantic Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Sculpins	84,800	5,220
Scup	59	9
Seaboard goby	176,000	na
Searobin	455	17
Silver hake	45	6
Tautog	4,980	2,780
Threespine stickleback	76	na
Trophic transfer[a]	na	286
Weakfish	62	13
White perch	<1	<1
Windowpane	915	18
Winter flounder	283,000	34,200

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

C2-4 Reductions in I&E at Phase III Facilities in the North Atlantic Region Under Three Alternative Options

Table C2-5 presents estimated reductions in I&E under the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD forCertain Waterbodies" option. Reductions under all other options are presented in Appendix C2.

Table C2-5: Estimated Reductions in I&E Under Three Alternative Options

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
50 MGD All Option	930,000	17,900
200 MGD All Option	198,000	3,800
100 MGD	754,000	14,500

C2-5 Assumptions Used in Calculating Recreational and Commercial Losses

The lost yield estimates presented in Tables C2-3 and C2-4 are expressed as total pounds and include losses to both commercial and recreational catch. To estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table C2-6 presents the percentage impacts assumed for each species/species group.

Table C2-6: Percentage of Total Impacts Occurring to Commercial and Recreational Fisheries in the North Atlantic Region as a Result of Impingement and Entrainment at Phase III Facilities

Species/Species Group	Percent Impact to Recreational Fishery[a,b]	Percent Impact to Commercial Fishery[a,b]
American plaice	0.0%	100.0%
American shad	0.0%	100.0%
Atlantic cod	50.0%	50.0%
Atlantic herring	0.0%	100.0%
Atlantic mackerel	22.2%	77.8%
Atlantic menhaden	0.0%	100.0%
Bluefish	89.1%	10.9%
Butterfish	0.0%	100.0%
Commercial crabs	0.0%	100.0%
Cunner	100.0%	0.0%
Other (commercial)	0.0%	100.0%
Other (recreational)	100.0%	0.0%
Other (recreational and commercial)	50.0%	50.0%
Pollock[c]	50.0%	50.0%
Red hake	0.0%	100.0%
Sculpins	79.0%	21.0%
Scup[c]	50.0%	50.0%
Searobin	83.9%	16.1%
Silver hake	0.0%	100.0%
Skate species	0.0%	100.0%
Striped bass	100.0%	0.0%
Tautog	92.2%	7.8%
Trophic transfer[c]	50.0%	50.0%
Weakfish	14.6%	85.4%
White perch	78.8%	21.2%
Windowpane	0.0%	100.0%
Winter flounder[d]	50.0%	50.0%

[a] Based on landings from 1993 to 2001.
[b] Calculated using recreational landings data from NMFS (2003b, http://www.st.nmfs.gov/recreational/queries/catch/snapshot.html) and commercial landings data from NMFS (2003a, http://www.st.nmfs.gov/commercial/landings/annual_landings.html).
[c] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).
[d] A 50%, 50% split was assumed because landings, which largely occur in the ocean, are not considered to be an accurate indicator of impact for these species, which are largely caught near-shore.

See Chapter C3 for results of the commercial fishing benefits analysis and Chapter C4 for recreational fishing results. As discussed in Chapter A8, benefits were discounted to account for 1) the time to achieve compliance once the rule goes into effect in 2007, and 2) the time it takes for fish spared from I&E to reach a harvestable age. For the North Atlantic region, EPA assumes the average compliance year will be 2010 for all options.

Chapter C3: Commercial Fishing Valuation

Introduction

This chapter presents the results of the commercial fishing benefits analysis for the North Atlantic region. Section C3-1 details the estimated losses under current, or baseline, conditions. Section C3-2 presents expected benefits under three alternative options. Chapter A4 details the methods used in this analysis.

Chapter Contents

C3-1 Baseline Losses

Table C3-1 provides EPA's estimate of the value of gross revenues lost in commercial fisheries resulting from the impingement of aquatic species at facilities in the North Atlantic region. Table C3-2 displays this information for entrainment. Total annualized revenue losses are approximately $23,000 (undiscounted).

Table C3-1: Annualized Commercial Fishing Gross Revenues Lost due to Impingement at Facilities in the North Atlantic Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
Atlantic cod	2	$1.03	$2
Butterfish	6	$0.60	$4
Silver hake	6	$0.39	$2
Skate species	14	$0.16	$2
Trophic transfer[b]	4	$1.02	$4
Winter flounder	33	$1.26	$41

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table C3-2: Annualized Commercial Fishing Gross Revenues Lost due to Entrainment at Facilities in the North Atlantic Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
American plaice	28	$1.24	$35
Atlantic cod	77	$1.03	$79
Atlantic herring	771	$0.06	$48
Atlantic mackerel	100	$0.23	$23
Atlantic menhaden	201	$0.06	$12
Sculpins	1,100	$0.60	$662
Scup	5	$1.09	$5
Silver hake	6	$0.39	$2
Tautog	217	$1.13	$245
Trophic transfer[b]	143	$1.02	$146
Weakfish	11	$0.92	$10
Windowpane	18	$1.72	$30
Winter flounder	17,100	$1.26	$21,600

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

C3-2 Expected Benefits Under Three Alternative Options

As described in Chapter A4, EPA estimates that 0 to 40% of the gross revenue losses represent surplus losses to producers, assuming no change in prices or fishing costs. The 0% estimate, of course, results in loss estimates of $0. The 40% estimates, as presented in Tables C3-3, C3-4, and C3-5 total approximately $9,200 (undiscounted).

The expected reductions in impingement and entrainment (I&E) attributable to changes at facilities required by the "50 MGD for All Waterbodies" option (50 MGD option) are 39% for impingement and 29% for entrainment, for the "200 MGD for All Waterbodies" option (200 MGD option) are 11% for impingement and 8% for entrainment, and for the "100 MGD for Certain Waterbodies" option (100 MGD option) are 43% for impingement and 32% for entrainment. Total annualized benefits are estimated by applying these estimated reductions to the annual producer surplus loss. As presented in Tables C3-3, C3-4, and C3-5, this results in total annualized benefits of up to approximately $3,000 for the 50 MGD option, $600 for the 200 MGD option, and $2,400 for the 100 MGD option, assuming a 3% discount rate.

Table C3-3: Annualized Commercial Fishing Benefits Attributable to the 50 MGD Option at Facilities in the North Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$60	$22,900	$23,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$24	$9,160	$9,200
Expected reduction due to rule	43%	40%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$3,700
3% discount rate			$3,000
7% discount rate			$2,300

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table C3-4: Annualized Commercial Fishing Benefits Attributable to the 200 MGD Option at Facilities in the North Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$60	$22,900	$23,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$24	$9,160	$9,200
Expected reduction due to rule	11%	8%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$800
3% discount rate			$600
7% discount rate			$500

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table C3-5: Annualized Commercial Fishing Benefits Attributable to the 100 MGD Option at Facilities in the North Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$60	$22,900	$23,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$24	$9,160	$9,200
Expected reduction due to rule	43%	32%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$3,000
3% discount rate			$2,400
7% discount rate			$1,900

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Chapter C4: Recreational Use Benefits

Introduction

This chapter presents the results of the recreational fishing benefits analysis for the North Atlantic region. The chapter presents EPA's estimates of baseline (i.e., current) annual recreational fishery losses from impingement and entrainment (I&E) at potentially regulated facilities in the North Atlantic region and annual reduction in these losses under the three proposed regulatory options for Phase III existing facilities:[1]

- the "50 MGD for All Waterbodies" option,
- the "200 MGD for All Waterbodies" option, and
- the "100 MGD for Certain Waterbodies" option.

The chapter then presents the estimated welfare gain to North Atlantic anglers from eliminating baseline recreational fishing losses from I&E and the expected benefits under the three proposed options.

EPA estimated the recreational benefits of reducing and eliminating I&E losses using a benefit transfer methodology based on a meta-analysis of the marginal value of catching different species of fish. This meta-analysis is discussed in detail in Chapter A5, "Recreational Fishing Benefits Methodology." To validate these results, this chapter also presents the results of a random utility model (RUM) analysis for the North Atlantic region. A detailed discussion of the RUM analysis for the North Atlantic region can be found in Chapter D4 of the final Phase II Regional Studies report (U.S. EPA, 2004; Hicks et al., 1999).

EPA considered a wide range of policy options in developing this regulation. Results of the recreational fishing benefits analysis for five other options evaluated by EPA are presented in Appendix C4.

Chapter Contents

[1] See the introduction to this report for a description of the three proposed options.

C4-1 Benefit Transfer Approach Based on Meta-Analysis

EPA estimated the recreational welfare gain from the reduction in annual I&E losses expected under the policy options, and the welfare gain from eliminating I&E at potentially regulated facilities, using a benefit transfer approach. As discussed in Chapter A5, the Agency used the meta-analysis regression equation to estimate the marginal recreational value per additional fish caught by anglers, for different species in different regions. Since I&E at potentially regulated facilities affects a variety of species, EPA assigned each species with I&E losses to one of the general species groups used in the meta-analysis. The Agency then calculated the economic value of reducing or eliminating baseline I&E losses, for each species group, by multiplying the value per fish for that species group by the number of fish in the group that are lost in the baseline or saved under the policy options.[2]

In general, the fit between the species with I&E losses and the species groups in the meta-analysis was good. However, EPA's estimates of baseline I&E losses and reductions in I&E under the policy options included losses of 'unidentified' species. The 'unidentified' group includes fish lost indirectly through trophic transfer, as well as species for which no species information was available.[3] Rather than using the meta-analysis regression to try to predict the value per fish for an "unidentified" species, EPA assumed that per-fish values for these species can be approximated by the weighted average value per fish for all species affected by I&E in the North Atlantic region.[4]

C4-1.1 Estimated Changes in Recreational Fishery Losses under the Proposed Regulation

Table C4-1 presents EPA's estimates of baseline (i.e., current) annual recreational I&E losses at potentially regulated facilities, and annual reductions in these losses under each of the proposed options, in the North Atlantic region. The table shows that total baseline losses to recreational fisheries are 33.5 thousand fish per year. In comparison, the "50 MGD for All Waterbodies" option prevents losses of 13.3 thousand fish per year, the "200 MGD for All Waterbodies" option prevents losses of 2.8 thousand fish per year, and the "100 MGD for Certain Waterbodies" option prevents losses of 10.8 thousand fish per year. Of all the affected species, sculpin and winter flounder have the highest losses in the baseline and the highest prevented losses under the proposed options.

[2] Note that the estimates of I&E presented in this chapter include only the fraction of impinged and entrained recreational fish that would otherwise be caught by anglers. The total amount of I&E of recreational species is actually much higher.

[3] In addition to recreational fish that are lost because they are impinged or entrained, some recreational fish are lost because the forage fish that they feed on are impinged or entrained, and thus removed from the food chain. These trophic transfer losses of recreational species are included in EPA's estimates of total I&E losses. However, since it is difficult to predict which recreational species would be affected by losses of forage fish, these losses are classified as 'unidentified' recreational species. Also included in the 'unidentified' group are losses of fish that were reported by facilities without information about their exact species.

[4] EPA used the estimated level of baseline recreational losses for each species group as a weighting factor.

Table C4-1: Baseline Recreational Fishing Losses from I&E at Potentially Regulated Phase III Facilities and Reductions in Recreational Losses under the Proposed Regulatory Options in the North Atlantic Region

Species[a]	Baseline Annual Recreational Fishing Losses (# of fish)	Annual Reductions in Recreational Fishing Losses (# of fish)		
		50 MGD All	200 MGD All	100 MGD CWB
Atlantic mackerel	40	16	3	13
Weakfish	2	1	0	1
Total (small game)	**42**	**17**	**4**	**13**
Winter flounder	13,795	5,485	1,165	4,438
Total (flatfish)	**13,795**	**5,485**	**1,165**	**4,438**
Atlantic cod	42	17	4	13
Cunner	4,746	1,887	401	1,526
Sculpin	14,099	5,605	1,190	4,534
Scup	5	2	0	2
Searobin	29	12	3	10
Tautog	640	255	54	206
Total (other saltwater)	**19,562**	**7,777**	**1,651**	**6,290**
Total (unidentified)	**149**	**59**	**13**	**48**
Total (all species)	***33,548***	***13,338***	***2,832***	***10,790***

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The ‘other saltwater’ group includes bottomfish and other miscellaneous species. The ‘unidentified’ group includes fish lost indirectly through trophic transfer.

Source: U.S. EPA analysis for this report.

C4-1.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table C4-2 shows the results of EPA’s analysis of the welfare gain to recreational anglers from eliminating baseline recreational fishery losses at potentially regulated facilities in the North Atlantic region. The table presents baseline annual recreational I&E losses, the estimated value per fish, and the monetized annual welfare gain from eliminating recreational losses, for each species group. Total baseline recreational fishing losses for the North Atlantic region are 33.5 thousand fish per year. The undiscounted annual welfare gain to North Atlantic anglers from eliminating these losses is $0.19 million (2003$), with lower and upper bounds of $0.09 million and $0.43 million. Evaluated at 3% and 7%, the mean annualized welfare gain of eliminating these losses is $0.18 million and $0.17 million, respectively. The majority of monetized recreational losses from I&E under baseline conditions are attributable to losses of species in the flatfish group, specifically winter flounder, and species in the ‘other saltwater’ group, such as sculpin and cunner.

Table C4-2: Recreational Fishing Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the North Atlantic Region (2003$)

Species Group	Baseline Annual Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Benefits from Eliminating Recreational Fishing Losses (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	0.0[e]	$2.82	$7.64	$20.45	$0.1	$0.3	$0.9
Flatfish	13.8	$3.70	$8.06	$17.61	$51.0	$111.1	$243.0
Other saltwater	19.6	$1.94	$4.20	$9.18	$37.9	$82.2	$179.7
Unidentified	0.1	$2.66	$5.80	$12.68	$0.4	$0.9	$1.9
Total (undiscounted)	**33.5**				**$89.4**	**$194.6**	**$425.4**
Total (evaluated at 3%)	**33.5**				**$84.2**	**$183.2**	**$400.6**
Total (evaluated at 7%)	**33.5**				**$78.0**	**$169.8**	**$371.4**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying baseline losses by the estimated value per fish.
[d] Annualized values represent the total welfare gain over the time frame of the analysis from eliminating recreational losses, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] Denotes a positive value less than 50 fish.

Source: U.S. EPA analysis for this report.

C4-1.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table C4-3 shows the results of EPA's analysis of the recreational benefits of the "50 MGD for All Waterbodies" option for the North Atlantic region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 13.3 thousand fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.08 million (2003$), with lower and upper bounds of $0.04 million and $0.17 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.06 million and $0.05 million, respectively. The majority of benefits result from reduced losses of species in the flatfish group, specifically winter flounder, and species in the 'other saltwater' group, such as sculpin and cunner.

Table C4-3: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the North Atlantic Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	0.0[e]	$2.82	$7.64	$20.45	$0.0[f]	$0.1	$0.3
Flatfish	5.5	$3.70	$8.06	$17.61	$20.3	$44.2	$96.6
Other saltwater	7.8	$1.94	$4.20	$9.18	$15.1	$32.7	$71.4
Unidentified	0.1	$2.66	$5.80	$12.68	$0.2	$0.3	$0.8
Total (undiscounted)	**13.3**				**$35.5**	**$77.4**	**$169.1**
Total (evaluated at 3%)	**13.3**				**$29.0**	**$63.2**	**$138.2**
Total (evaluated at 7%)	**13.3**				**$22.5**	**$48.9**	**$106.9**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] Denotes a positive value less than 50 fish.
[f] Denotes a positive value less than $50.

Source: U.S. EPA analysis for this report.

C4-1.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

Table C4-4 shows the results of EPA's analysis of the recreational benefits of the "200 MGD for All Waterbodies" option for the North Atlantic region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 2.8 thousand fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.016 million (2003$), with lower and upper bounds of $0.008 million and $0.036 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.013 million and $0.010 million, respectively. The majority of benefits result from reduced losses of species in the flatfish group, specifically winter flounder, and species in the 'other saltwater' group, such as sculpin and cunner.

Table C4-4: Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option in the North Atlantic Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	0.0[e]	$2.82	$7.64	$20.45	$0.0[f]	$0.0[f]	$0.1
Flatfish	1.2	$3.70	$8.06	$17.61	$4.3	$9.4	$20.5
Other saltwater	1.7	$1.94	$4.20	$9.18	$3.2	$6.9	$15.2
Unidentified	0.0[e]	$2.66	$5.80	$12.68	$0.0[f]	$0.1	$0.2
Total (undiscounted)	**2.8**				**$7.5**	**$16.4**	**$35.9**
Total (evaluated at 3%)	**2.8**				**$6.0**	**$13.0**	**$28.3**
Total (evaluated at 7%)	**2.8**				**$4.4**	**$9.6**	**$20.9**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] Denotes a positive value less than 50 fish.
[f] Denotes a positive value less than $50.

Source: U.S. EPA analysis for this report.

C4-1.5 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

Table C4-5 shows the results of EPA's analysis of the recreational benefits of the "100 MGD for Certain Waterbodies" option for the North Atlantic region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 10.8 thousand fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.063 million (2003$), with lower and upper bounds of $0.029 million and $0.137 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.052 million and $0.040 million, respectively. The majority of benefits result from reduced losses of species in the flatfish group, specifically winter flounder, and species in the 'other saltwater' group, such as sculpin and cunner.

Table C4-5: Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option in the North Atlantic Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	0.0[e]	$2.82	$7.64	$20.45	$0.0[f]	$0.1	$0.3
Flatfish	4.4	$3.70	$8.06	$17.61	$16.4	$35.8	$78.2
Other saltwater	6.3	$1.94	$4.20	$9.18	$12.2	$26.4	$57.8
Unidentified	0.0[e]	$2.66	$5.80	$12.68	$0.1	$0.3	$0.6
Total (undiscounted)	**10.8**				**$28.7**	**$62.6**	**$136.8**
Total (evaluated at 3%)	**10.8**				**$23.7**	**$51.6**	**$112.8**
Total (evaluated at 7%)	**10.8**				**$18.5**	**$40.3**	**$88.1**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] Denotes a positive value less than 50 fish.
[f] Denotes a positive value less than $50.

Source: U.S. EPA analysis for this report.

C4-2 RUM Approach

To validate the results of the benefit transfer approach, EPA applied the RUM model presented in Chapter F4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004) to the baseline losses and reductions in losses at potentially regulated Phase III existing facilities. This section presents the results of the recreational fishing benefits analysis for the North Atlantic region based on the Phase II RUM approach.

C4-2.1 RUM Methodology: North Atlantic Region

EPA's methodology for evaluating the change in welfare resulting from a change in recreational losses from I&E consists of four basic steps: (1) calculating the change in historical catch rates under a given policy scenario, (2) estimating the per-trip welfare gain to anglers based on the Phase II RUM model, (3) estimating the number of fishing trips taken by anglers, and (4) combining fishing participation data with the estimated per-trip welfare gain to calculate the total annual welfare gain. These steps are briefly described in the following sections. For a more detailed discussion of the RUM methodology, see Chapters A11 and F4 of *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004).

C4-2.1.1 Estimating Changes in the Quality of Fishing Sites

The first step in EPA's analysis was to combine estimates of recreational I&E losses at potentially regulated facilities with state-level recreational fishery landings data to estimate the percentage change in historical catch rates under each policy option. Because most species considered in this analysis (e.g., striped bass, bluefish, and flounder) are found throughout North Atlantic waters (i.e., from Connecticut to Maine), EPA made the assumption that changes in I&E will result in uniform changes in catch rates across all marine fishing sites in this region.[5] Thus, EPA used five-year National Marine Fisheries Service (NMFS) recreational landings data (1996 through 2000) for state waters to calculate the average statewide landings per year for all species groups.[6] EPA then divided baseline recreational I&E losses by total recreational landings to calculate the percentage change in historical catch rates from completely eliminating recreational fishing losses from I&E. Similarly, the Agency also estimated the percentage changes to historic catch rates that would result under each policy option.

C4-2.1.2 Estimating Per-Trip Benefits from Reducing I&E

EPA's second step was to use the recreational behavior model described in Chapter F4 of the Phase II Regional Studies document to estimate an angler's per-trip welfare gain from changes in the historical catch rates in the North Atlantic region. The Agency estimated welfare gains to recreational anglers under four scenarios: eliminating baseline recreational fishing losses from I&E at potentially regulated facilities, and reducing recreational fishing losses from I&E by implementing the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, or the "100 MGD for Certain Waterbodies" option. EPA assumed that the welfare gain per fishing trip is independent of the number of days fished per trip and therefore equivalent for both single- and multiple-day trips. Thus, a multiple-day trip is valued the same as a single-day trip.[7] EPA estimated separate per-day welfare gains for different categories of anglers, based on their target species and fishing mode.[8]

C4-2.1.3 Estimating Recreational Angler Participation

The third step in EPA's analysis was to estimate baseline and post-regulatory fishing participation, measured by the total number of fishing trips taken by North Atlantic anglers.[9] Because the policy options for Phase III facilities are expected to result in relatively small improvements in fishing quality, EPA assumed that increases in recreational fishing participation under the policy options will be negligible. Thus, to estimate both baseline and post-regulatory participation, EPA used the total number of fishing trips taken by North Atlantic anglers in 2002. The total number of trips to the North Atlantic fishing sites was calculated from data provided by NMFS. To estimate the proportion of recreational fishing trips taken by no-target anglers and by anglers targeting each species of concern, EPA used the Marine Recreational Fisheries Statistics Survey (MRFSS) sample. The Agency then applied those percentages to the total number of fishing trips taken by North Atlantic anglers to calculate the number of anglers.

C4-2.1.4 Estimating Total Benefits from Eliminating or Reducing I&E

The final step in EPA's analysis was to calculate the total annual benefits of the policy options. To calculate total benefits for each subcategory of anglers targeting a particular species with a particular fishing mode, EPA multiplied the per-trip welfare gain for an angler with that particular species/fishing mode combination by the total number of fishing trips taken by all anglers with that species/fishing mode combination. EPA then summed benefits for all subcategories of anglers to calculate the total welfare change in the North Atlantic region. Finally,

[5] Fish lost to I&E are most often very small fish that are too small to catch. Because of the migratory nature of most affected species, by the time these fish have grown to catchable size, they may have traveled some distance from the facility where I&E occurs. Without collecting extensive data on migratory patterns of all affected fish, it is not possible to evaluate whether catch rates will change uniformly or in some other pattern. Thus, EPA assumed that catch rates will change uniformly across the entire region.

[6] State waters include sounds, inlets, tidal portions of rivers, bays, estuaries, and other areas of salt or brackish water, plus ocean waters to three nautical miles from shore (NMFS, 2003a).

[7] See section C4-5.2 of Chapter C4 of the 316(b) Phase II document for limitations and uncertainties associated with this assumption.

[8] EPA used the per-day values for private/rental boat anglers to estimate welfare gains for charter boat anglers.

[9] See Chapter B4 of the section 316(b) Phase II Case Study document for a detailed description of the angler participation estimates in the North Atlantic.

as discussed in Chapter A8, EPA discounted and annualized the benefits estimates, using both 3% and 7% discount rates.

C4-2.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table C4-6 presents the baseline level of recreational landings at potentially regulated facilities and the estimated change in catch rates that would result from eliminating recreational fishing losses from I&E in the North Atlantic Region. The table shows that I&E has the largest effect on catch rates for flatfish, which would increase by 0.6% if I&E were eliminated.

Table C4-6: Estimated Changes in Historical Catch Rates from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the North Atlantic Region

Species Group	Annual Recreational Landings (thousands of fish)[a]	Baseline Annual Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Eliminating I&E
Small game	13,713.2	0.1	0.00%[c]
Flatfish	2,377.7	13.8	0.58%
Bottomfish	6,106.1	19.6	0.32%
No target	23,904.6[d]	33.6	0.14%

[a] Annual recreational landings are calculated as a five-year average (1997-2001) for state waters.
[b] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[c] Denotes a positive value less than 0.005%.
[d] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table C4-7 presents the per-trip welfare gain for anglers targeting different species, the number of fishing trips taken by anglers targeting those species, and the total annual welfare gain from eliminating baseline I&E. The table shows that the total undiscounted value of baseline losses in the North Atlantic region is $0.26 million (2003$), and the annualized value of those losses is $0.25 million and $0.23 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bottomfish and flatfish. The table shows that eliminating baseline recreational fishing losses from I&E would result in per-trip welfare gains of two cents or less per angler.

Table C4-7: Recreational Fishing Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the North Atlantic Region (2003$)

Species Group	Per-Trip Welfare Gain	Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
Small game	$0.00[c]		$0.2
Flatfish	$0.01		$110.3
Bottomfish	$0.02		$145.7
No target	$0.00[c]		$4.0
Total, All Species (undiscounted)		**7,923**	**$260.2**
Total, All Species (discounted at 3%)		**7,923**	**$245.1**
Total, All Species (discounted at 7%)		**7,923**	**$227.2**

[a] Since EPA used a nested model to estimate the expected utility, welfare changes were calculated based on the total number of fishing trips for all species groups.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.

Source: U.S. EPA analysis for this report.

C4-2.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table C4-8 presents the estimated change in historical catch rates that would result from reductions in I&E under the "50 MGD for All Waterbodies" option. In the North Atlantic, catch rates for anglers targeting flatfish would increase the most under this option, by 0.23%.

Table C4-8: Estimated Changes in Historical Catch Rates from Reducing I&E under the "50 MGD for All Waterbodies" Option in the North Atlantic Region

Species Group	Annual Recreational Landings (thousands of fish)[a]	Annual Reduction in Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Reducing I&E
Small game	13,713.2	0.1	0.00%[c]
Flatfish	2,377.7	5.5	0.23%
Bottomfish	6,106.1	7.8	0.13%
No target	23,904.6[d]	13.3	0.06%

[a] Annual recreational landings are calculated as a five-year average (1997-2001) for state waters.
[b] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[c] Denotes a positive value less than 0.005%.
[d] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table C4-9 presents the recreational benefits of the "50 MGD for All Waterbodies" option for the North Atlantic region. The table shows that the total undiscounted benefits of this option are $0.10 million (2003$), and the annualized value of those benefits is $0.09 million and $0.07 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bottomfish and flatfish. The table shows that this option would result in per-trip welfare gains of one cent or less per angler.

Table C4-9: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the North Atlantic Region (2003$)

Species Group[a]	Per-Trip Welfare Gain	Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
Small game	$0.00[c]		$0.1
Flatfish	$0.01		$43.8
Bottomfish	$0.01		$57.9
No target	$0.00[c]		$1.6
Total, All Species (undiscounted)		**7,923**	**$103.5**
Total, All Species (discounted at 3%)		**7,923**	**$84.6**
Total, All Species (discounted at 7%)		**7,923**	**$65.4**

[a] Since EPA used a nested model to estimate the expected utility, welfare changes were calculated based on the total number of fishing trips for all species groups.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.

Source: U.S. EPA analysis for this report.

C4-2.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

Table C4-10 presents the estimated change in historical catch rates that would result from reductions in I&E under the "200 MGD for All Waterbodies" option. In the North Atlantic region, catch rates for anglers targeting flatfish would increase the most under this option, by 0.05%.

Table C4-10: Estimated Changes in Historical Catch Rates from Reducing I&E under the "200 MGD for All Waterbodies" Option in the North Atlantic Region

Species Group	Annual Recreational Landings (thousands of fish)[a]	Annual Reduction in Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Reducing I&E
Small game	13,713.2	0.0[c]	0.00%[d]
Flatfish	2,377.7	1.2	0.05
Bottomfish	6,106.1	1.7	0.03
No target	23,904.6	2.8	0.01

[a] Annual recreational landings are calculated as a five-year average (1997-2001) for state waters.
[b] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[c] Denotes a positive value less than 50 fish.
[d] Denotes a positive value less than 0.005%.
[e] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table C4-11 presents the recreational benefits of the "200 MGD for All Waterbodies" option for the North Atlantic region. The table shows that the total annual undiscounted benefits of this option are $0.022 million (2003$), and the annualized value of those benefits is $0.017 million and $0.013 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bottomfish and flatfish. The table shows that this option would result in per-trip welfare gains of less than one cent per angler.

Table C4-11: Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option in the North Atlantic Region (2003$)

Species Group[a]	Per-Trip Welfare Gain	Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
Small game	$0.00[c]		$0.0[d]
Flatfish	$0.00[c]		$9.3
Bottomfish	$0.00[c]		$12.3
No target	$0.00[c]		$0.3
Total, All Species (undiscounted)		**7,923**	**$21.9**
Total, All Species (discounted at 3%)		**7,923**	**$17.2**
Total, All Species (discounted at 7%)		**7,923**	**$12.8**

[a] Since EPA used a nested model to estimate the expected utility, welfare changes were calculated based on the total number of fishing trips for all species groups.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.
[d] Denotes a positive value less than $50.

Source: U.S. EPA analysis for this report.

C4-2.5 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

Table C4-12 presents the estimated change in historical catch rates that would result from reductions in I&E under the "100 MGD for Certain Waterbodies" option. In the North Atlantic, catch rates for anglers targeting flatfish would increase the most under this option, by 0.19%.

Table C4-12: Estimated Changes in Historical Catch Rates from Reducing I&E under the "100 MGD for All Waterbodies" Option in the North Atlantic Region

Species Group	Annual Recreational Landings (thousands of fish)[a]	Annual Reduction in Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Reducing I&E
Small game	13,713.2	0.0[c]	0.00%[d]
Flatfish	2,377.7	4.4	0.19%
Bottomfish	6,106.1	6.3	0.10%
No Target	23904.6[e]	10.8	0.05%

[a] Annual recreational landings are calculated as a five-year average (1997-2001) for state waters.
[b] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[c] Denotes a positive value less than 50 fish.
[d] Denotes a positive value less than 0.005%.
[e] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table C4-13 presents the recreational benefits of the "100 MGD for Certain Waterbodies" option for the North Atlantic region. The table shows that the total annual undiscounted benefits of this option are $0.084 million (2003$), and the annualized value of those benefits is $0.069 million and $0.054 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bottomfish and flatfish. The table shows that this option would result in per-trip welfare gains of one cent or less per angler.

Table C4-13: Recreational Fishing Benefits of the "100 MGD for All Waterbodies" Option in the North Atlantic Region (2003$)

Species Group[a]	Per-Trip Welfare Gain	Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
Small Game	$0.00[c]		$0.1
Flatfish	$0.00[c]		$35.5
Bottomfish	$0.01		$46.8
No Target	$0.00[c]		$1.3
Total, All Species (undiscounted)		**7,923**	**$83.6**
Total, All Species (discounted at 3%)		**7,923**	**$68.9**
Total, All Species (discounted at 7%)		**7,923**	**$53.8**

[a] Since EPA used a nested model to estimate the expected utility, welfare changes were calculated based on the total number of fishing trips for all species groups.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.

Source: U.S. EPA analysis for this report.

C4-3 Validation of Benefit Transfer Results Based on RUM Results

Table C4-14 compares the undiscounted results of the benefit transfer based on the meta-analysis with the results of the RUM analysis. The table shows that for the North Atlantic region, based on the meta-analysis, the recreational welfare gain from eliminating baseline I&E losses is $0.19 million (2003$), based on the meta-analysis, and $0.26 million, based on the RUM. The benefits estimates based on both the meta-analysis and the RUM show that benefits are highest under the "50 MGD for All Waterbodies" option and lowest under the "200 MGD for All Waterbodies" option. In general, the RUM-based results fall within the range of values estimated based on the meta-model. That the values from the two independent analyses are relatively close corroborates the use of meta-analysis in estimating the value of incremental recreational fishing improvements resulting from the section 316(b) regulation for Phase III facilities.

Table C4-14: Recreational Fishing Benefits in the North Atlantic Region Calculated from Meta-Analysis Approach and RUM Approach

Policy Option	Estimated Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands, 2003$)			
		Based on Meta-Analysis			Based on RUM
		Low	Mean	High	
Eliminating baseline recreational fishing losses from I&E	33.5	$89.4	$194.6	$425.4	$260.3
50 MGD All	13.3	$35.5	$77.4	$169.1	$103.5
200 MGD All	2.8	$7.5	$16.4	$35.9	$21.9
100 MGD CWB	10.8	$28.7	$62.6	$136.8	$83.6

Source: U.S. EPA analysis for this report.

C4-4 Limitations and Uncertainty

C4-4.1 Limitations and Uncertainty: Meta-Analysis

The results of the benefit transfer based on the meta-analysis results represent EPA's best estimate of the recreational benefits of the proposed options. Nonetheless, there are a number of limitations and uncertainties inherent in these estimates. General limitations pertaining to the development of the meta-analysis model, the use of the model to estimate per-fish values, and the validity of the benefit transfer are discussed in section A5-3.3e and section A5-5.3 of Chapter A5.

C4-4.2 Limitations and Uncertainty: RUM Approach

The results of the benefit transfer based on the RUM analysis results serve to confirm that EPA's estimates of the recreational benefits of the proposed options are reasonable. However, there are a number of limitations and uncertainties inherent in these estimates. Some general limitations pertaining to the RUM model are discussed in Chapter A11 of the 316(b) Phase II document. Some additional region-specific limitations are discussed in Chapter C4 of the 316(b) Phase II document.

Although the estimated total welfare gain to the North Atlantic recreational anglers based on the regional RUM model is likely to be accurate, the estimated average per-trip welfare gain presented in Tables C4-7, C4-9, C4-11, and C4-13 must be used and understood in the context of the regional model developed by EPA for the Phase II analysis and as it was created by Hicks et al., 1999. The regional RUM model assumes uniform changes in catch rates at all sites across the region. Given that there are only five potentially regulated facilities in the North Atlantic region and the total intake flow associated with these facilities is relatively small, catch rate improvements are more likely to occur locally rather than regionally. These local improvements in catch rates and the associated average per-trip welfare gain are likely to be greater than those presented in the tables in section C4-2. However, the number of anglers benefitting from these improvements would be smaller, and so the resulting aggregate benefits are likely to be similar.

Appendix C1: Life History Parameter Values Used to Evaluate I&E in the North Atlantic Region

The tables in this appendix present the life history parameter values used by EPA to calculate age-1 equivalents and fishery yields from impingement and entrainment (I&E) data for the North Atlantic Region. Because of differences in the number of life stages represented in the loss data, there are cases where more than one life stage sequence was needed for a given species or species group. Alternative parameter sets were developed for this purpose and are indicated with a number following the species or species group name (i.e., Winter flounder 1, Winter flounder 2).

Table C1-1: Alewife Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.544	0	0	0.00000128
Larvae	5.50	0	0	0.00000141
Juvenile	2.57	0	0	0.00478
Age 1+	1.04	0	0	0.0443
Age 2+	1.04	0	0	0.139
Age 3+	1.04	0	0	0.264
Age 4+	1.04	0	0	0.386
Age 5+	1.04	0	0	0.489
Age 6+	1.04	0	0	0.568
Age 7+	1.04	0	0	0.626
Age 8+	1.04	0	0	0.667
Age 9+	1.04	0	0	0.696

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-2: American Plaice Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.0000115
Larvae	8.22	0	0	0.0000126
Juvenile	0.916	0	0	0.000110
Age 1+	0.200	0	0	0.00903
Age 2+	0.200	0.32	0.50	0.0871
Age 3+	0.200	0.32	1.0	0.190
Age 4+	0.200	0.32	1.0	0.328
Age 5+	0.200	0.32	1.0	0.494
Age 6+	0.200	0.32	1.0	0.711
Age 7+	0.200	0.32	1.0	0.986
Age 8+	0.200	0.32	1.0	1.24
Age 9+	0.200	0.32	1.0	1.53
Age 10+	0.200	0.32	1.0	1.86
Age 11+	0.200	0.32	1.0	2.24
Age 12+	0.200	0.32	1.0	2.68
Age 13+	0.200	0.32	1.0	3.17
Age 14+	0.200	0.32	1.0	3.52
Age 15+	0.200	0.32	1.0	3.91
Age 16+	0.200	0.32	1.0	4.32
Age 17+	0.200	0.32	1.0	4.77
Age 18+	0.200	0.32	1.0	5.24
Age 19+	0.200	0.32	1.0	5.75
Age 20+	0.200	0.32	1.0	6.28
Age 21+	0.200	0.32	1.0	6.86
Age 22+	0.200	0.32	1.0	7.46
Age 23+	0.200	0.32	1.0	8.11
Age 24+	0.200	0.32	1.0	8.44
Age 25+	0.200	0.32	1.0	8.55

Sources: Stone & Webster Engineering Corporation, 1977; Scott and Scott, 1988; NOAA, 1993; O'Brien, 2000; Schultz, 2000; and Froese and Pauly, 2001.

Table C1-3: American Sand Lance Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	1.41	0	0	0.00000126
Larvae	2.97	0	0	0.00000139
Juvenile	2.90	0	0	0.00119
Age 1+	1.89	0	0	0.00384
Age 2+	0.364	0	0	0.00730
Age 3+	0.364	0	0	0.0113
Age 4+	0.364	0	0	0.0153
Age 5+	0.364	0	0	0.0191
Age 6+	0.364	0	0	0.0225
Age 7+	0.720	0	0	0.0255
Age 8+	0.720	0	0	0.0280
Age 9+	0.720	0	0	0.0301
Age 10+	0.720	0	0	0.0319
Age 11+	0.720	0	0	0.0333
Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.				

Table C1-4: American Shad Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	0.496	0	0	0.000000716
Yolksac larvae	0.496	0	0	0.000000728
Post-yolksac larvae	2.52	0	0	0.00000335
Juvenile	7.40	0	0	0.000746
Age 1+	0.300	0	0	0.309
Age 2+	0.300	0	0	1.17
Age 3+	0.300	0	0	2.32
Age 4+	0.540	0.21	0.45	3.51
Age 5+	1.02	0.21	0.90	4.56
Age 6+	1.50	0.21	1.0	5.47
Age 7+	1.50	0.21	1.0	6.20
Age 8+	1.50	0.21	1.0	6.77
Sources: USFWS, 1978; Able and Fahay, 1998; PSE&G, 1999; and Froese and Pauly, 2001.				

Table C1-5: Atlantic Cod Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	4.87	0	0	0.00000567
Larvae	5.83	0	0	0.00000624
Juvenile	0.916	0	0	0.000337
Age 1+	0.400	0	0	0.0225
Age 2+	0.200	0.29	0.50	0.245
Age 3+	0.200	0.29	1.0	0.628
Age 4+	0.200	0.29	1.0	1.29
Age 5+	0.200	0.29	1.0	2.45
Age 6+	0.200	0.29	1.0	3.33

Sources: Scott and Scott, 1988; Entergy Nuclear Generation Company, 2000; Mayo and O'Brien, 2000; Froese and Pauly, 2001, 2003; and NOAA, 2001b.

Table C1-6: Atlantic Herring Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	3.36	0	0	0.00000473
Larvae	3.26	0	0	0.00000531
Juvenile	3.26	0	0	0.00126
Age 1+	0.200	0.28	0.50	0.0314
Age 2+	0.200	0.28	1.0	0.173
Age 3+	0.200	0.28	1.0	0.302
Age 4+	0.200	0.28	1.0	0.420
Age 5+	0.200	0.28	1.0	0.463
Age 6+	0.200	0.28	1.0	0.525
Age 7+	0.200	0.28	1.0	0.588
Age 8+	0.200	0.28	1.0	0.642
Age 9+	0.200	0.28	1.0	0.699
Age 10+	0.200	0.28	1.0	0.732
Age 11+	0.200	0.28	1.0	0.766
Age 12+	0.200	0.28	1.0	0.848
Age 13+	0.200	0.28	1.0	0.855
Age 14+	0.200	0.28	1.0	0.862
Age 15+	0.200	0.28	1.0	0.869
Age 16+	0.200	0.28	1.0	0.877

[a] Includes Atlantic herring, hickory shad, round herring, and other herring not identified to species.

Sources: Scott and Scott, 1988; Able and Fahay, 1998; Entergy Nuclear Generation Company, 2000; ASMFC, 2001a; Froese and Pauly, 2001; NOAA, 2001b; and Overholtz, 2002a.

Table C1-7: Atlantic Mackerel Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.39	0	0	0.00000176
Larvae	5.30	0	0	0.00000193
Juvenile	5.30	0	0	0.000833
Age 1+	0.520	0	0	0.309
Age 2+	0.370	0.25	0.50	0.510
Age 3+	0.370	0.25	1.0	0.639
Age 4+	0.370	0.25	1.0	0.752
Age 5+	0.370	0.25	1.0	0.825
Age 6+	0.370	0.25	1.0	0.918
Age 7+	0.370	0.25	1.0	1.02
Age 8+	0.370	0.25	1.0	1.10
Age 9+	0.370	0.25	1.0	1.13
Age 10+	0.370	0.25	1.0	1.15
Age 11+	0.370	0.25	1.0	1.22
Age 12+	0.370	0.25	1.0	1.22
Age 13+	0.370	0.25	1.0	1.22
Age 14+	0.370	0.25	1.0	1.22

Sources: Scott and Scott, 1988; Overholtz et al., 1991; Studholme et al., 1999; Entergy Nuclear Generation Company, 2000; Froese and Pauly, 2001, 2003; NOAA, 2001b; and Overholtz, 2002b.

Table C1-8: Atlantic Menhaden Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.20	0	0	0.00000482
Larvae	4.47	0	0	0.00000530
Juvenile	6.19	0	0	0.000684
Age 1+	0.540	0	0	0.0251
Age 2+	0.450	1.1	1.0	0.235
Age 3+	0.450	1.1	1.0	0.402
Age 4+	0.450	1.1	1.0	0.586
Age 5+	0.450	1.1	1.0	0.863
Age 6+	0.450	1.1	1.0	1.08
Age 7+	0.450	1.1	1.0	1.27
Age 8+	0.450	1.1	1.0	1.43

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-9: Atlantic Silverside Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.41	0	0	0.00000473
Larvae	5.81	0	0	0.00000520
Juvenile 1	2.63	0	0	0.00490
Age 1+	3.00	0	0	0.0205
Age 2+	6.91	0	0	0.0349

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-10: Atlantic Tomcod Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	8.46	0	0	0.00000126
Larvae	8.46	0	0	0.0000185
Juvenile	8.46	0	0	0.0145
Age 1+	8.46	0	0	0.0804
Age 2+	2.83	0	0	0.270
Age 3+	2.83	0	0	0.486

Sources: Stewart and Auster, 1987; McLaren et al., 1988; Virginia Tech, 1998; and NMFS, 2003a.

Table C1-11: Bay Anchovy Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.10	0	0	0.000000517
Larvae	7.19	0	0	0.000000569
Juvenile	2.09	0	0	0.00104
Age 1+	2.30	0	0	0.00370
Age 2+	2.30	0	0	0.00765
Age 3+	2.30	0	0	0.0126

[a] Includes bay anchovy, striped anchovy, and other anchovies not identified to species.

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-12: Blueback Herring Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.558	0	0	0.00000115
Yolksac larvae	1.83	0	0	0.00321
Post-yolksac larvae	1.74	0	0	0.00640
Juvenile 1	3.13	0	0	0.00959
Juvenile 2	3.13	0	0	0.0128
Age 1+	0.300	0	0	0.0160
Age 2+	0.300	0	0	0.0905
Age 3+	0.300	0	0	0.204
Age 4+	0.900	0	0	0.318
Age 5+	1.50	0	0	0.414
Age 6+	1.50	0	0	0.488
Age 7+	1.50	0	0	0.540
Age 8+	1.50	0	0	0.576

Sources: PSE&G, 1999; and PG&E National Energy Group, 2001.

Table C1-13: Bluefish Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.35	0	0	0.0000123
Larvae	8.24	0	0	0.0000135
Juvenile	5.07	0.06	1.0	0.194
Age 1+	0.350	0.28	1.0	1.06
Age 2+	0.350	0.28	1.0	2.81
Age 3+	0.350	0.28	1.0	5.21
Age 4+	0.350	0.28	1.0	7.95
Age 5+	0.350	0.28	1.0	10.7
Age 6+	0.350	0.28	1.0	13.4
Age 7+	0.350	0.28	1.0	15.9
Age 8+	0.350	0.28	1.0	18.0
Age 9+	0.350	0.28	1.0	19.9
Age 10+	0.350	0.28	1.0	21.6
Age 11+	0.350	0.28	1.0	22.9
Age 12+	0.350	0.28	1.0	24.1
Age 13+	0.350	0.28	1.0	25.0
Age 14+	0.350	0.28	1.0	25.8

Sources: Wang and Kernehan, 1979; and PG&E National Energy Group, 2001.

Table C1-14: Butterfish Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000000396
Larvae	6.64	0	0	0.000000436
Juvenile	0.916	0	0	0.000251
Age 1+	0.800	0.28	0.50	0.0272
Age 2+	0.800	0.28	1.0	0.0986
Age 3+	0.800	0.28	1.0	0.944

Sources: Stone & Webster Engineering Corporation, 1977; Scott and Scott, 1988; Able and Fahay, 1998; Froese and Pauly, 2001; and NOAA, 2001a.

Table C1-15: Commercial Crab Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Megalops	1.30	0	0	0.00000291
Juvenile	1.73	0.48	0.50	0.00000293
Age 1+	1.10	0.48	1.0	0.00719
Age 2+	1.38	0.48	1.0	0.113
Age 3+	1.27	0.48	1.0	0.326

[a] Includes green crab, jonah crab, lady crab, lesser blue crab, narrow mud crab, and spider crab.

Sources: Hartman, 1993; and PSE&G, 1999.

Table C1-16: Cunner Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	3.49	0	0	0.000000787
Larvae	2.90	0	0	0.00000236
Juvenile	2.90	0	0	0.0000814
Age 1+	0.831	0	0	0.00311
Age 2+	0.831	0.10	0.50	0.0246
Age 3+	0.286	0.10	1.0	0.0749
Age 4+	0.342	0.10	1.0	0.145
Age 5+	0.645	0.10	1.0	0.229
Age 6+	1.26	0.10	1.0	0.624

Sources: Serchuk and Cole, 1974; Scott and Scott, 1988; Able and Fahay, 1998; and Entergy Nuclear Generation Company, 2000.

Table C1-17: Fourbeard Rockling Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.000000637
Larvae	4.25	0	0	0.000000700
Juvenile	0.916	0	0	0.00187
Age 1+	0.490	0	0	0.0142
Age 2+	0.490	0	0	0.0209
Age 3+	0.490	0	0	0.0402
Age 4+	0.490	0	0	0.0617
Age 5+	0.490	0	0	0.0906
Age 6+	0.490	0	0	0.151
Age 7+	0.490	0	0	0.188
Age 8+	0.490	0	0	0.251
Age 9+	0.490	0	0	0.323
Sources: Deree, 1999; Froese and Pauly, 2001, 2003; and NMFS, 2003a.				

Table C1-18: Grubby Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.00000473
Larvae	3.79	0	0	0.00000520
Juvenile	0.916	0	0	0.0000197
Age 1+	0.460	0	0	0.00633
Age 2+	0.460	0	0	0.0115
Age 3+	0.460	0	0	0.0190
Age 4+	0.460	0	0	0.0292
Age 5+	0.460	0	0	0.0424
Age 6+	0.460	0	0	0.0592
Age 7+	0.460	0	0	0.0799
Age 8+	0.460	0	0	0.105
Age 9+	0.460	0	0	0.135
Sources: Clayton et al., 1978; Scott and Scott, 1988; Able and Fahay, 1998; Froese and Pauly, 2001, 2003; and NMFS, 2003a.				

Table C1-19: Hogchoker Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.000000487
Larvae	5.20	0	0	0.00110
Juvenile	2.31	0	0	0.00207
Age 1+	2.56	0	0	0.0113
Age 2+	0.705	0	0	0.0313
Age 3+	0.705	0	0	0.0610
Age 4+	0.705	0	0	0.0976
Age 5+	0.705	0	0	0.138
Age 6+	0.705	0	0	0.178

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-20: Lumpfish Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000317
Larvae	8.48	0	0	0.0000169
Juvenile	0.916	0	0	0.00472
Age 1+	0.190	0.26	0.50	0.0138
Age 2+	0.190	0.26	1.0	0.0573
Age 3+	0.190	0.26	1.0	0.149
Age 4+	0.190	0.26	1.0	0.686
Age 5+	0.190	0.26	1.0	1.86

Sources: Bigelow and Schroeder, 1953; Scott and Scott, 1988; Able and Fahay, 1998; Froese and Pauly, 2001; and NMFS, 2003a.

Table C1-21: Northern Pipefish Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.000000773
Larvae	2.40	0	0	0.0000122
Juvenile	0.916	0	0	0.00785
Age 1+	0.750	0	0	0.0151
Age 2+	0.750	0	0	0.0180
Age 3+	0.750	0	0	0.0212
Age 4+	0.750	0	0	0.0247
Age 5+	0.750	0	0	0.0285
Sources: Scott and Scott, 1988; Able and Fahay, 1998; Froese and Pauly, 2001; and NMFS, 2003a.				

Table C1-22: Pollock Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	0.922	0	0	0.00000154
Larvae	4.07	0	0	0.00000169
Juvenile	6.93	0	0	0.00166
Age 1+	0.200	0	0	0.657
Age 2+	0.200	0.20	0.50	1.30
Age 3+	0.200	0.20	1.0	1.73
Age 4+	0.200	0.20	1.0	3.24
Age 5+	0.200	0.20	1.0	4.93
Age 6+	0.200	0.20	1.0	5.70
Age 7+	0.200	0.20	1.0	6.83
Age 8+	0.200	0.20	1.0	8.46
Age 9+	0.200	0.20	1.0	9.93
Age 10+	0.200	0.20	1.0	12.0
Age 11+	0.200	0.20	1.0	14.8
Age 12+	0.200	0.20	1.0	16.4
Age 13+	0.200	0.20	1.0	18.1
Age 14+	0.200	0.20	1.0	19.9
Age 15+	0.200	0.20	1.0	21.2
Sources: Saila et al., 1997; Able and Fahay, 1998; Froese and Pauly, 2001; and NOAA, 2001b.				

Table C1-23: Radiated Shanny Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.30	0	0	0.00000430
Larvae	2.20	0	0	0.00000473
Juvenile	0.916	0	0	0.0000559
Age 1+	0.440	0	0	0.000472
Age 2+	0.440	0	0	0.00163
Age 3+	0.440	0	0	0.00374
Age 4+	0.440	0	0	0.00719
Age 5+	0.440	0	0	0.00988
Age 6+	0.440	0	0	0.0132
Age 7+	0.440	0	0	0.0258
Age 8+	0.440	0	0	0.0448
Sources: Scott and Scott, 1988; Froese and Pauly, 2001; Pepin et al., 2002; and NMFS, 2003a.				

Table C1-24: Rainbow Smelt Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	4.44	0	0	0.000000990
Larvae	3.12	0	0	0.00110
Juvenile	1.39	0	0	0.00395
Age 1+	1.00	0	0	0.0182
Age 2+	1.00	0	0	0.0460
Age 3+	1.00	0	0	0.0850
Age 4+	1.00	0	0	0.131
Age 5+	1.00	0	0	0.180
Age 6+	1.00	0	0	0.228
Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.				

Table C1-25: Red Hake Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.22	0	0	0.000000487
Larvae 2 mm	0.670	0	0	0.000000536
Larvae 2.5 mm	0.670	0	0	0.000000589
Larvae 3.0 mm	0.670	0	0	0.000000744
Larvae 3.5 mm	0.670	0	0	0.00000118
Larvae 4.0 mm	0.670	0	0	0.00000176
Larvae 4.5 mm	3.35	0	0	0.00000251
Juvenile	4.83	0	0	0.00345
Age 1+	0.400	0.39	0.50	0.231
Age 2+	0.400	0.39	1.0	0.805
Age 3+	0.400	0.39	1.0	0.991
Age 4+	0.400	0.39	1.0	1.22
Age 5+	0.400	0.39	1.0	1.55
Age 6+	0.400	0.39	1.0	1.93
Age 7+	0.400	0.39	1.0	2.36
Age 8+	0.400	0.39	1.0	2.86
Age 9+	0.400	0.39	1.0	3.42
Age 10+	0.400	0.39	1.0	3.66

[a] Includes red hake, spotted hake, and white hake.

Sources: Scott and Scott, 1988; Saila et al., 1997; Able and Fahay, 1998; Froese and Pauly, 2001; and NOAA, 2001b.

Table C1-26: Rock Gunnel Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000924
Larvae	1.66	0	0	0.0000102
Juvenile	0.916	0	0	0.000701
Age 1+	0.440	0	0	0.00382
Age 2+	0.440	0	0	0.0128
Age 3+	0.440	0	0	0.0223
Age 4+	0.440	0	0	0.0371
Age 5+	0.440	0	0	0.0490

Sources: Scott and Scott, 1988; Froese and Pauly, 2001; and NMFS, 2003a.

Table C1-27: Sculpin Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.0000107
Larvae	3.79	0	0	0.0000118
Juvenile	0.916	0	0	0.000754
Age 1+	0.460	0.50	0.50	0.00404
Age 2+	0.460	0.50	1.0	0.139
Age 3+	0.460	0.50	1.0	0.332
Age 4+	0.460	0.50	1.0	0.420
Age 5+	0.460	0.50	1.0	0.475
Age 6+	0.460	0.50	1.0	0.541
Age 7+	0.460	0.50	1.0	0.576
Age 8+	0.460	0.50	1.0	0.612
Age 9+	0.460	0.50	1.0	0.637

[a] Includes longhorn sculpin, moustache sculpin, shorthorn sculpin, and other sculpin not identified to species.

Sources: Clayton et al., 1978; Scott and Scott, 1988; Froese and Pauly, 2001; and personal communication with Y. DeReynier (NMFS, November 19, 2002).

Table C1-28: Scup Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.43	0	0	0.000000773
Larvae	4.55	0	0	0.00110
Juvenile	3.36	0	0	0.0280
Age 1+	0.383	0	0	0.132
Age 2+	0.383	0	0	0.322
Age 3+	0.383	0.26	1.0	0.572
Age 4+	0.383	0.26	1.0	0.845
Age 5+	0.383	0.26	1.0	1.12
Age 6+	0.383	0.26	1.0	1.37
Age 7+	0.383	0.26	1.0	1.59
Age 8+	0.383	0.26	1.0	1.78
Age 9+	0.383	0.26	1.0	1.94
Age 10+	0.383	0.26	1.0	2.07
Age 11+	0.383	0.26	1.0	2.23

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-29: Seaboard Goby Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.0000164
Larvae	4.09	0	0	0.0000180
Juvenile	2.30	0	0	0.000485
Age 1+	2.55	0	0	0.00205

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-30: Searobin Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000132
Larvae	3.66	0	0	0.00000145
Juvenile	0.916	0	0	0.000341
Age 1+	0.420	0.10	0.50	0.0602
Age 2+	0.420	0.10	1.0	0.176
Age 3+	0.420	0.10	1.0	0.267
Age 4+	0.420	0.10	1.0	0.386
Age 5+	0.420	0.10	1.0	0.537
Age 6+	0.420	0.10	1.0	0.721
Age 7+	0.420	0.10	1.0	0.944
Age 8+	0.420	0.10	1.0	1.21

[a] Includes northern searobin, striped searobin, and other searobin not identified to species.

Sources: Virginia Tech, 1998; Entergy Nuclear Generation Company, 2000; and Froese and Pauly, 2001, 2003.

Table C1-31: Silver Hake Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.43	0	0	0.0000203
Larvae	6.62	0	0	0.0000223
Juvenile	4.58	0	0	0.00516
Age 1+	0.400	0	0	0.0729
Age 2+	0.400	0	0	0.242
Age 3+	0.400	0.40	1.0	0.456
Age 4+	0.400	0.40	1.0	0.646
Age 5+	0.400	0.40	1.0	0.788
Age 6+	0.400	0.40	1.0	0.889
Age 7+	0.400	0.40	1.0	0.958
Age 8+	0.400	0.40	1.0	1.00
Age 9+	0.400	0.40	1.0	1.03
Age 10+	0.400	0.40	1.0	1.05
Age 11+	0.400	0.40	1.0	1.06
Age 12+	0.400	0.40	1.0	1.06

Source: PG&E National Energy Group, 2001.

Table C1-32: Skate Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	3.00	0	0	0.0125
Larvae	2.30	0	0	0.0138
Juvenile	0.916	0	0	0.0593
Age 1+	0.400	0.40	0.50	0.157
Age 2+	0.400	0.40	1.0	0.394
Age 3+	0.400	0.40	1.0	0.750
Age 4+	0.400	0.40	1.0	1.15
Age 5+	0.400	0.40	1.0	1.51
Age 6+	0.400	0.40	1.0	1.62
Age 7+	0.400	0.40	1.0	1.65
Age 8+	0.400	0.40	1.0	1.72

[a] Includes clearnose skate, little skate and other skates not identified to level.

Sources: Scott and Scott, 1988; NOAA, 1993, 2001b; and Froese and Pauly, 2000.

Table C1-33: Striped Bass Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.28	0	0	0.0000282
Larvae	6.28	0	0	0.0000310
Juvenile	5.63	0	0	0.0405
Age 1+	1.11	0	0	0.386
Age 2+	0.150	0.02	1.0	1.37
Age 3+	0.150	0.06	1.0	3.06
Age 4+	0.150	0.20	1.0	5.35
Age 5+	0.150	0.29	1.0	8.07
Age 6+	0.150	0.31	1.0	11.0
Age 7+	0.150	0.31	1.0	14.1
Age 8+	0.150	0.31	1.0	17.1
Age 9+	0.150	0.31	1.0	20.0
Age 10+	0.150	0.31	1.0	22.8
Age 11+	0.150	0.31	1.0	25.3
Age 12+	0.150	0.31	1.0	27.6
Age 13+	0.150	0.31	1.0	29.7
Age 14+	0.150	0.31	1.0	31.6
Age 15+	0.150	0.31	1.0	33.3
Age 16+	0.150	0.31	1.0	34.7
Age 17+	0.150	0.31	1.0	36.0
Age 18+	0.150	0.31	1.0	37.2
Age 19+	0.150	0.31	1.0	38.2
Age 20+	0.150	0.31	1.0	39.0
Age 21+	0.150	0.31	1.0	39.8
Age 22+	0.150	0.31	1.0	40.4
Age 23+	0.150	0.31	1.0	41.0
Age 24+	0.150	0.31	1.0	41.5

Source: PG&E National Energy Group, 2001.

Table C1-34: Striped Killifish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.0000180
Larvae	3.00	0	0	0.0000182
Juvenile	0.916	0	0	0.000157
Age 1+	0.777	0	0	0.0121
Age 2+	0.777	0	0	0.0327
Age 3+	0.777	0	0	0.0551
Age 4+	0.777	0	0	0.0778
Age 5+	0.777	0	0	0.0967
Age 6+	0.777	0	0	0.113
Age 7+	0.777	0	0	0.158

[a] Includes mummichog, striped killifish, and other killifish not identified to species.

Sources: Carlander, 1969; Meredith and Lotrich, 1979; Able and Fahay, 1998; and NMFS, 2003a.

Table C1-35: Tautog Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.40	0	0	0.00000123
Larvae	5.86	0	0	0.0221
Juvenile	5.02	0	0	0.0637
Age 1+	0.175	0	0	0.217
Age 2+	0.175	0	0	0.440
Age 3+	0.175	0	0	0.734
Age 4+	0.175	0	0	1.08
Age 5+	0.175	0	0	1.48
Age 6+	0.175	0	0	1.89
Age 7+	0.175	0	0	2.32
Age 8+	0.175	0	0	2.76
Age 9+	0.175	0.24	1.0	3.18
Age 10+	0.175	0.24	1.0	3.60
Age 11+	0.175	0.24	1.0	4.00
Age 12+	0.175	0.24	1.0	4.38
Age 13+	0.175	0.24	1.0	4.73
Age 14+	0.175	0.24	1.0	5.07
Age 15+	0.175	0.24	1.0	5.38
Age 16+	0.175	0.24	1.0	5.67
Age 17+	0.175	0.24	1.0	5.94
Age 18+	0.175	0.24	1.0	6.19
Age 19+	0.175	0.24	1.0	6.42
Age 20+	0.175	0.24	1.0	6.63
Age 21+	0.175	0.24	1.0	6.82
Age 22+	0.175	0.24	1.0	6.99
Age 23+	0.175	0.24	1.0	7.15
Age 24+	0.175	0.24	1.0	10.0

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-36: Threespine Stickleback Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.00000567
Larvae	2.12	0	0	0.00110
Juvenile	1.70	0	0	0.00377
Age 1+	1.42	0	0	0.00917
Age 2+	1.42	0	0	0.0112
Age 3+	1.42	0	0	0.0116

[a] Includes blackspotted stickleback, fourspine stickleback, ninespine stickleback, threespine stickleback, and other stickleback not identified to species.

Sources: Wang, 1986; and PG&E National Energy Group, 2001.

Table C1-37: Weakfish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.498	0	0	0.00000115
Larvae	2.84	0	0	0.0650
Juvenile 1	3.39	0	0	0.130
Juvenile 2	5.47	0	0	0.195
Age 1+	0.694	0.25	1.0	0.260
Age 2+	0.730	0.50	1.0	0.680
Age 3+	0.657	0.50	1.0	1.12
Age 4+	0.511	0.50	1.0	1.79
Age 5+	0.511	0.50	1.0	2.91
Age 6+	0.511	0.50	1.0	6.21
Age 7+	0.511	0.50	1.0	7.14
Age 8+	0.511	0.50	1.0	9.16
Age 9+	0.511	0.50	1.0	10.8
Age 10+	0.511	0.50	1.0	12.5
Age 11+	0.511	0.50	1.0	12.5
Age 12+	0.511	0.50	1.0	12.5
Age 13+	0.511	0.50	1.0	12.5
Age 14+	0.511	0.50	1.0	12.5
Age 15+	0.511	0.50	1.0	12.5

[a] Includes northern kingcroaker and weakfish.

Sources: PSE&G, 1999; PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-38: White Perch Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.42	0	0	0.000000842
Larvae	4.59	0	0	0.00110
Juvenile	9.06	0	0	0.00302
Age 1+	0.693	0	0	0.0516
Age 2+	0.693	0	0	0.156
Age 3+	0.543	0.15	1.0	0.248
Age 4+	0.543	0.15	1.0	0.331
Age 5+	1.46	0.15	1.0	0.423
Age 6+	1.46	0.15	1.0	0.523
Age 7+	1.46	0.15	1.0	0.613
Age 8+	1.46	0.15	1.0	0.658
Age 9+	1.46	0.15	1.0	0.794

Sources: Stanley and Danie, 1983; and PG&E National Energy Group, 2001.

Table C1-39: Windowpane Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.41	0	0	0.00000154
Larvae	6.99	0	0	0.00165
Juvenile	2.98	0	0	0.00223
Age 1+	0.420	0	0	0.0325
Age 2+	0.420	0	0	0.122
Age 3+	0.420	0	0	0.265
Age 4+	0.420	0	0	0.433
Age 5+	0.420	0	0	0.603
Age 6+	0.420	0.10	1.0	0.761
Age 7+	0.420	0.10	1.0	0.899
Age 8+	0.420	0.10	1.0	1.01
Age 9+	0.420	0.10	1.0	1.11
Age 10+	0.420	0.10	1.0	1.19

[a] Includes American fourspot flounder, smallmouth flounder, summer flounder, and windowpane.

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table C1-40: Winter Flounder Life History Parameters 1[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.00000115
Larvae 1	2.05	0	0	0.00441
Larvae 2	3.42	0	0	0.0110
Larvae 3	3.52	0	0	0.0176
Larvae 4	0.177	0	0	0.0221
Juvenile	2.38	0	0	0.0330
Age 1+	1.10	0.0066	1.0	0.208
Age 2+	0.924	0.082	1.0	0.562
Age 3+	0.200	0.20	1.0	0.997
Age 4+	0.200	0.33	1.0	1.42
Age 5+	0.200	0.33	1.0	1.78
Age 6+	0.200	0.33	1.0	2.07
Age 7+	0.200	0.33	1.0	2.29
Age 8+	0.200	0.33	1.0	2.45
Age 9+	0.200	0.33	1.0	2.57
Age 10+	0.200	0.33	1.0	2.65
Age 11+	0.200	0.33	1.0	2.71
Age 12+	0.200	0.33	1.0	2.75
Age 13+	0.200	0.33	1.0	2.78
Age 14+	0.200	0.33	1.0	2.80
Age 15+	0.200	0.33	1.0	2.82
Age 16+	0.200	0.33	1.0	2.83

[a] Includes winter flounder, yellowtail founder, and other flounder not identified to species.

Sources: Able and Fahay, 1998; and PG&E National Energy Group, 2001.

Table C1-41: Winter Flounder Life History Parameters 2[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.00000115
Larvae 3.0 mm	0.705	0	0	0.00000127
Larvae 3.5 mm	0.705	0	0	0.00000137
Larvae 4.0 mm	0.705	0	0	0.00000146
Larvae 4.5 mm	0.705	0	0	0.00000156
Larvae 5.0 mm	0.705	0	0	0.00000216
Larvae 5.5 mm	0.705	0	0	0.00000291
Larvae 6.0 mm	0.705	0	0	0.00000382
Larvae 6.5 mm	0.705	0	0	0.00000489
Larvae 7.0 mm	0.705	0	0	0.00000616
Larvae 7.5 mm	0.705	0	0	0.00000764
Larvae 8.0 mm	0.705	0	0	0.00000933
Larvae 8.5 mm	0.705	0	0	0.0000113
Larvae 9.0 mm	0.705	0	0	0.0000135
Juvenile	2.38	0	0	0.0330
Age 1+	1.10	0.0066	1.0	0.208
Age 2+	0.924	0.082	1.0	0.562
Age 3+	0.200	0.20	1.0	0.997
Age 4+	0.200	0.33	1.0	1.42
Age 5+	0.200	0.33	1.0	1.78
Age 6+	0.200	0.33	1.0	2.07
Age 7+	0.200	0.33	1.0	2.29
Age 8+	0.200	0.33	1.0	2.45
Age 9+	0.200	0.33	1.0	2.57
Age 10+	0.200	0.33	1.0	2.65
Age 11+	0.200	0.33	1.0	2.71
Age 12+	0.200	0.33	1.0	2.75
Age 13+	0.200	0.33	1.0	2.78
Age 14+	0.200	0.33	1.0	2.80
Age 15+	0.200	0.33	1.0	2.82
Age 16+	0.200	0.33	1.0	2.83

[a] Includes winter flounder, witch founder, and other flounder not identified to species.

Sources: Saila et al., 1997; Able and Fahay, 1998; Colarusso, 2000; and PG&E National Energy Group, 2001.

Table C1-42: Winter Flounder Life History Parameters 3[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0.00	0.00	0.00000115
Larvae	9.17	0.00	0.00	0.00441
Juvenile	2.38	0.00	0.00	0.0330
Age 1+	1.10	0.0066	1.0	0.208
Age 2+	0.924	0.082	1.0	0.562
Age 3+	0.200	0.20	1.0	0.997
Age 4+	0.200	0.33	1.0	1.42
Age 5+	0.200	0.33	1.0	1.78
Age 6+	0.200	0.33	1.0	2.07
Age 7+	0.200	0.33	1.0	2.29
Age 8+	0.200	0.33	1.0	2.45
Age 9+	0.200	0.33	1.0	2.57
Age 10+	0.200	0.33	1.0	2.65
Age 11+	0.200	0.33	1.0	2.71
Age 12+	0.200	0.33	1.0	2.75
Age 13+	0.200	0.33	1.0	2.78
Age 14+	0.200	0.33	1.0	2.80
Age 15+	0.200	0.33	1.0	2.82
Age 16+	0.200	0.33	1.0	2.83

[a] Includes fourspot flounder, smooth flounder, witch flounder, yellowtail flounder, and other flounder not identified to species.

Sources: Able and Fahay, 1998; Colarusso, 2000; and PG&E National Energy Group, 2001.

Table C1-43: Other Commercial Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes goosefish, redfish, spot, and wolffish.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table C1-44: Other Recreational Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes Atlantic torpedo, blue runner, cownose ray, dusky smooth hound, flathead mullet, northern puffer, smooth dogfish, striped cusk-eel, white catfish, and white mullet.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table C1-45: Other Recreational and Commercial Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile 1	1.43	0	0	0.000746
Juvenile 2	1.43	0	0	0.0472
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes American eel, black sea bass, conger eel, and piked dogfish.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table C1-46: Other Forage Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Larvae	7.70	0	0	0.00000158
Juvenile	1.29	0	0	0.000480
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] See Table C1-47 for a list of species.

Sources: Derickson and Price, 1973; and PSE&G, 1999.

Table C1-47: Other Forage Species[a]

African pompano	Cornet fish	Northern shortfin squid	Sea lamprey
Alligatorfish	Crevalle jack	Ocean pout	Sheepshead minnow
Atlantic bigeye	Flying gurnard	Orange filefish	Short bigeye
Atlantic moonfish	Glasseye	Oyster toadfish	Silver rag
Atlantic seasnail	Gulf snailfish	Pearlside	Spotfin butterflyfish
Banded rudderfish	Long finned squid	Planehead filefish	Striped burrfish
Bigeye scad	Lookdown	Rough scad	Trumpetfish
Black ruff	Mackerel scad	Round scad	Wrymouth
Brown trout	Northern sennet	Sand tiger	

[a] Includes other organisms not identified to species.

Appendix C2: Reductions in I&E in the North Atlantic Region Under Five Other Options Evaluated for the Proposed Section 316(b) Phase III Regulation

Table C2-1: Estimated Reductions in I&E in the North Atlantic Region Under Five Other Options Evaluated for the Proposed Section 316(b) Regulation

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
20 MGD All	930,000	17,900
2	930,000	17,900
3	930,000	17,900
4	930,000	17,900
All Phase III Facilities	930,000	17,900

Appendix C3: Commercial Fishing Benefits for Five Other Options Evaluated for Phase III Existing Facilities in the North Atlantic Region

Section C3-2 in Chapter C3 displays the results of the commercial fishing benefits analysis for the 50 MGD option, the 200 MGD option, and the 100 MGD option. To facilitate comparisons among the options, this appendix displays results for the following additional options: All Potentially Regulated Phase III Existing Facilities option (All Phase III Facilities); the 20 MGD option (20 MGD All); Option 2; Option 3; and Option 4.

Table C3-1: Annualized Commercial Fishing Benefits Attributable to the All Phase III Facilities Option at Facilities in the North Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$60	$22,900	$23,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$24	$9,160	$9,200
Expected reduction due to rule	43%	40%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$3,700
3% discount rate			$3,000
7% discount rate			$2,300

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table C3-2: Annualized Commercial Fishing Benefits Attributable to the 20 MGD All Option at Facilities in the North Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$60	$22,900	$23,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$24	$9,160	$9,200
Expected reduction due to rule	43%	40%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$3,700
3% discount rate			$3,000
7% discount rate			$2,300

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table C3-3: Annualized Commercial Fishing Benefits Attributable to Option 2 at Facilities in the North Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$60	$22,900	$23,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$24	$9,160	$9,200
Expected reduction due to rule	43%	40%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$3,700
3% discount rate			$3,000
7% discount rate			$2,300

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table C3-4: Annualized Commercial Fishing Benefits Attributable to Option 3 at Facilities in the North Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$60	$22,900	$23,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$24	$9,160	$9,200
Expected reduction due to rule	43%	40%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$3,700
3% discount rate			$3,000
7% discount rate			$2,300

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table C3-5: Annualized Commercial Fishing Benefits Attributable to Option 4 at Facilities in the North Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$60	$22,900	$23,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$24	$9,160	$9,200
Expected reduction due to rule	43%	40%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$3,700
3% discount rate			$3,000
7% discount rate			$2,300

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Appendix C4: Recreational Use Benefits of Other Policy Options

Introduction

Chapter C4 presents EPA's estimates of the recreational benefits of the three proposed options for the section 316(b) rule for Phase III facilities, for electric generators and manufacturers in the North Atlantic region. This appendix supplements Chapter C4 by presenting estimates of the recreational fishing benefits of five other options that EPA evaluated for the purpose of comparison:

- Option 3,
- Option 4,
- Option 2,
- Option 1, and
- Option 6.

Appendix Contents

Recreational fishing benefits presented in this chapter were estimated using the benefit transfer approach discussed in Chapter C4 and in Chapter A5, "Recreational Fishing Benefits Methodology."

C4-1 Recreational Fishing Benefits of the Other Evaluated Options

C4-1.1 Estimated Reductions in Recreational Fishing Losses under the Other Evaluated Options

Table C4-1 presents EPA's estimates of the annual reduction in baseline (i.e., current) recreational fishing losses from impingement and entrainment (I&E) in the North Atlantic region under the other evaluated options.

Table C4-1: Reductions in Recreational Fishing Losses from I&E under the Other Evaluated Options in the North Atlantic Region

	Annual Reduction in Recreational Losses (# of fish)[b]				
Species[a]	**Option 3**	**Option 4**	**Option 2**	**Option 1**	**Option 6**
Atlantic mackerel	16	16	16	16	16
Weakfish	1	1	1	1	1
Total (small game)	**17**	**17**	**17**	**17**	**17**
Winter flounder	5,485	5,485	5,485	5,485	5,485
Total (flatfish)	**5,485**	**5,485**	**5,485**	**5,485**	**5,485**
Atlantic cod	17	17	17	17	17
Cunner	1,887	1,887	1,887	1,887	1,887
Sculpin	5,605	5,605	5,605	5,605	5,605
Scup	2	2	2	2	2
Searobin	12	12	12	12	12
Tautog	255	255	255	255	255
Total (other saltwater)	**7,777**	**7,777**	**7,777**	**7,777**	**7,777**
Total (unidentified)	**59**	**59**	**59**	**59**	**59**
Total (all species)	***13,338***	***13,338***	***13,338***	***13,338***	***13,338***

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The ‘other saltwater’ group includes bottomfish and other miscellaneous species. The ‘unidentified’ group includes fish lost indirectly through trophic transfer.

[b] In the North Atlantic region, the set of facilities with technology requirements under Option 3 is the same as under Option 4, Option 2, Option 1, and Option 6. Thus, reductions in recreational losses under these options are also identical.

Source: U.S. EPA analysis for this report.

C4-1.2 Recreational Fishing Benefits of the Other Evaluated Options

Tables C4-2 presents EPA's estimates of the annualized recreational benefits of the other evaluated options in the North Atlantic region.

In the North Atlantic region, all potentially regulated facilities that would install new technology under Option 3, Option 4, Option 2, Option 1, or Option 6 have design intake flows greater than 50 MGD. Because the requirements under these five options are identical for this class of facilities, the I&E reductions and benefits resulting from these five options are also identical. Thus, the benefits estimates presented in Table C4-2 apply to all five options.

Table C4-2: Recreational Fishing Benefits of Option 3, Option 4, Option 2, Option 1, or Option 6, in the North Atlantic Region (2003$)[a]

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	0.0[e]	$2.82	$7.64	$20.45	$0.0[e]	$0.1	$0.3
Flatfish	5.5	$3.70	$8.06	$17.61	$20.3	$44.2	$96.6
Other saltwater	7.8	$1.94	$4.20	$9.18	$15.1	$32.7	$71.4
Unidentified	0.1	$2.66	$5.80	$12.68	$0.2	$0.3	$0.8
Total (undiscounted)	**13.3**				**$35.5**	**$77.4**	**$169.1**
Total (evaluated at 3%)	**13.3**				**$29.0**	**$63.2**	**$138.2**
Total (evaluated at 7%)	**13.3**				**$22.5**	**$48.9**	**$106.9**

[a] In the North Atlantic region, the set of facilities with technology requirements under Option 3 is the same as under Option 4, Option 2, Option 1, and Option 6. Thus, reductions in recreational losses under these options are also identical.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.
[e] Denotes a positive value less than 50 fish or $50.

Source: U.S. EPA analysis for this report.

C4-2 Comparison of Recreational Fishing Benefits by Option

Table C4-3 compares the recreational fishing benefits of the five other evaluated options. The table shows that recreational fishing benefits are identical under all five options.

Table C4-3: Annual Recreational Benefits of the Other Evaluated Options in the North Atlantic Region

Policy Option[a]	Annual Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands; 2003$)[b]		
		Low	Mean	High
Option 3	13.3	$35.5	$77.4	$169.1
Option 4	13.3	$35.5	$77.4	$169.1
Option 2	13.3	$35.5	$77.4	$169.1
Option 1	13.3	$35.5	$77.4	$169.1
Option 6	13.3	$35.5	$77.4	$169.1

[a] In the North Atlantic region, the set of facilities with technology requirements under Option 3 is the same as under Option 4, Option 2, Option 1, and Option 6. Thus, reductions in recreational losses under these options are also identical.

[b] These benefit estimates were calculated using the meta-analysis approach discussed in Chapter A5 and Chapter C4. EPA did not use the RUM approach from the Phase II analysis to analyze the other evaluated options.

Source: U.S. EPA analysis for this report.

Part D: Mid-Atlantic Region

Chapter D1: Background

Introduction

Chapter Contents

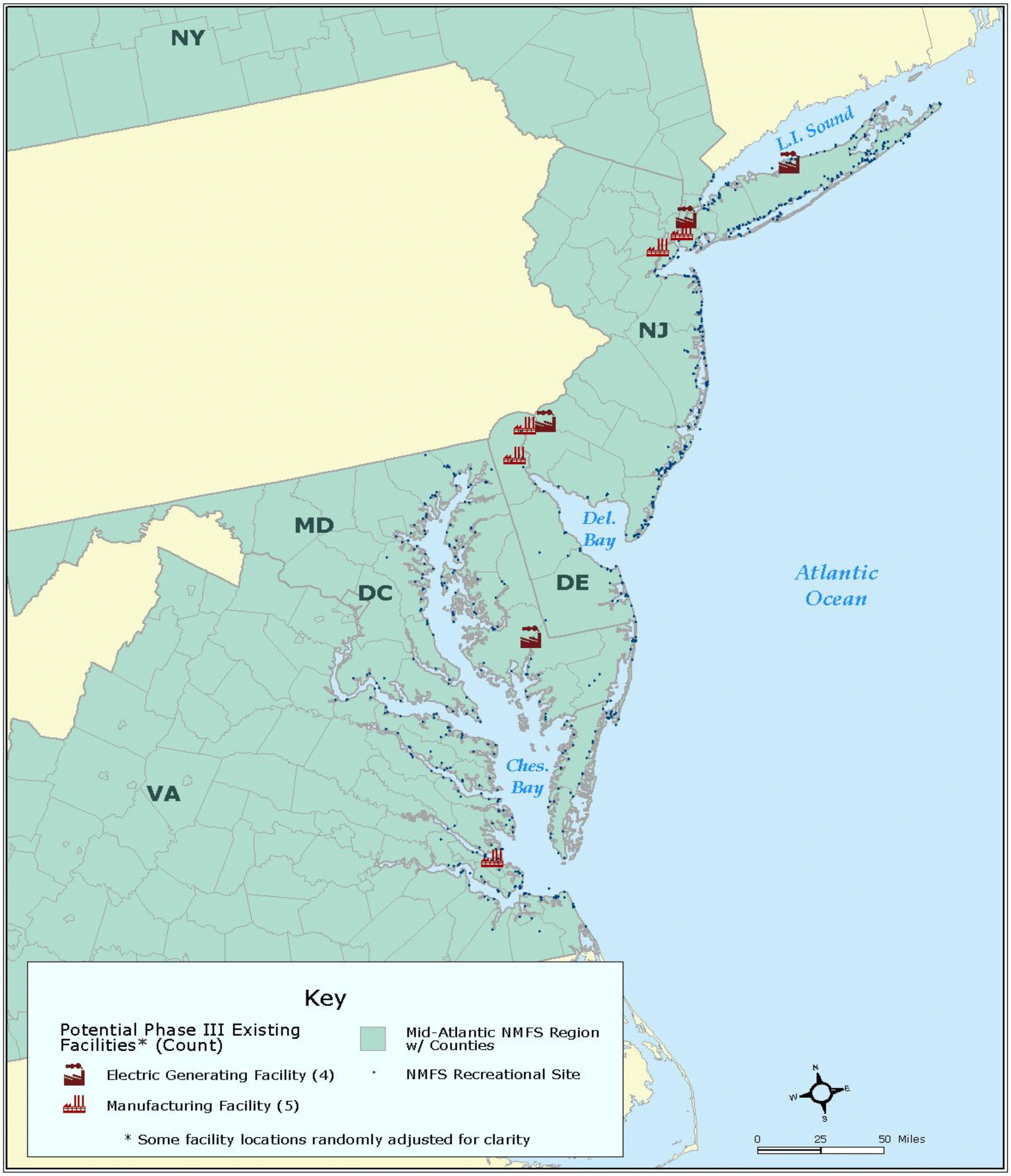
This chapter presents an overview of the potential Phase III existing facilities in the Mid-Atlantic study region and summarizes their key cooling water and compliance characteristics. For further discussion of the technical and compliance characteristics of potential Phase III existing facilities, refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* and the *Technical Development Document for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a,b).

D1-1 Facility Characteristics

The Mid-Atlantic Regional Study includes nine sample facilities that are potentially subject to the proposed standards for Phase III existing facilities. Five of them are manufacturing facilities and four are electric generators. Industry-wide, these nine sample facilities represent 13 facilities.[1] Figure D1-1 presents a map of these facilities.

[1] EPA applied sample weights to the survey respondents to account for non-sampled facilities and facilities that did not respond to the survey. For more information on EPA's 2000 Section 316(b) Industry Survey, please refer to the Information Collection Request (U.S. EPA, 2000).

Figure D1-1: Potential Existing Phase III Facilities in the Mid-Atlantic Regional Study



Source: U.S. EPA analysis for this report.

Table D1-1 summarizes key technical and compliance characteristics for all potentially regulated Phase III existing facilities in the Mid-Atlantic study region and for the three proposed regulatory options considered by EPA for this proposal (the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD for Certain Waterbodies" option). Facilities with a design intake flow below the three applicability thresholds would be subject to permitting based on best professional judgment and are excluded from EPA's analyses.[2] Therefore, a different number of facilities is affected under each option.

Table D1-1 shows that 13 Phase III existing facilities in the Mid-Atlantic study region would potentially be subject to the national requirements. Under the "50 MGD for All Waterbodies" option, the most inclusive of the three proposed options, three facilities would be subject to the national requirements for Phase III existing facilities. Under the less inclusive "200 MGD for All Waterbodies" option and "100 MGD for Certain Waterbodies" option, two facilities would be subject to the national requirements. Two facilities in the Mid-Atlantic study region have a recirculating system in the baseline.

Table D1-1: Technical and Compliance Characteristics of Existing Phase III Facilities (Sample-Weighted)

	All Potentially Regulated Facilities	Proposed Options		
		50 MGD All	200 MGD All	100 MGD CWB
Total Number of Facilities (Sample-Weighted)	**13**	**3**	**2**	**2**
Number of Facilities with Recirculating System in BL	**2**	**-**	**-**	**-**
Design Intake Flow (MGD)	**982**	**w[a]**	**w[a]**	**w[a]**
Number of Facilities by Compliance Response				
Fine mesh traveling screens with fish H&R	2	1	1	1
New larger intake structure with fine mesh and fish H&R	1	1	-	-
Passive fine mesh screens	2	1	1	1
None	7	-	-	-
Compliance Cost at 3%[b]	$3.51	$2.56	$1.96	$1.96
Compliance Cost at 7%[b]	$3.30	$2.44	$1.78	$1.78

[a] Data withheld because of confidentiality reasons.
[b] Annualized pre-tax compliance cost (2003$, millions)

Source: U.S. EPA, 2000; U.S. EPA analysis for this report.

[2] Also excluded are facilities that are estimated to be baseline closures. For additional information on EPA's baseline closure analyses, please refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a).

Chapter D2: Evaluation of Impingement and Entrainment in the Mid-Atlantic Region

Chapter Contents

Background: Mid-Atlantic Marine Fisheries

The Mid-Atlantic Fishery Management Council (MAFMC) manages fisheries in Federal waters off the Mid-Atlantic coast. States with voting representation on the MAFMC include New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, and North Carolina. North Carolina is represented on both the MAFMC and the South Atlantic Fishery Management Council.

The MAFMC has fishery management plans in place for Atlantic mackerel (*Scomber scombrus*), squid (*Loligo pealeii* and *Illex illecebrosus*), butterfish (*Peprilus triacanthus*), Atlantic surf clam (*Spisula solidissima*), ocean quahog (*Arctica islandica*), Atlantic bluefish (*Pomatomus saltatrix*), summer flounder (*Paralichthys dentatus*), scup (*Stenotomus chrysops*), black sea bass (*Centropristis striata*), and monkfish (*Lophius americanus*). Mid-Atlantic groundfish fisheries are primarily for summer flounder, scup, goosefish (*Lophius americanus*), and black seabass (NMFS, 1999a). Summer flounder is one of the most valuable groundfish species in the region, and is targeted by both recreational and commercial fishermen (NMFS, 1999a).

D2-1 I&E Species/Species Groups Evaluated

Table D2-1 provides a list of species/species groups in the Mid-Atlantic region that are subject to impingement and entrainment (I&E) and the species groups that were evaluated in EPA's analysis of regional I&E.

Table D2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in the Mid-Atlantic Region

Species/Species Group	Recreational	Commercial	Forage
Alewife		X	
American shad		X	
Atlantic croaker	X	X	
Atlantic herring	X	X	X
Atlantic menhaden		X	
Atlantic silverside			X
Atlantic tomcod			X
Bay anchovy			X
Black crappie	X	X	X
Blue crab		X	

Table D2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in the Mid-Atlantic Region

Species/Species Group	Recreational	Commercial	Forage
Blueback herring			X
Bluefish	X	X	X
Bluntnose minnow	X	X	X
Butterfish	X	X	X
Carp	X	X	X
Cunner	X	X	X
Freshwater drum	X	X	X
Gizzard shad	X	X	X
Gobies	X	X	X
Grubby	X	X	X
Herring	X	X	X
Hogchoker			X
Northern pipefish	X	X	X
Other (commercial)		X	
Other (forage)			X
Other (recreational)	X		
Other (recreational and commercial)	X	X	
Rainbow smelt	X	X	X
Red hake	X	X	X
Scup	X	X	X
Seaboard goby			X
Searobin	X	X	X
Silver hake	X	X	X
Silver perch	X	X	X
Silversides			X
Spot	X	X	
Striped bass	X	X	
Striped killifish	X	X	X
Summer flounder	X	X	
Sunfish	X	X	X
Tautog	X	X	X
Threespine stickleback	X	X	X
Weakfish	X	X	
White perch	X	X	
Windowpane		X	
Winter flounder	X	X	

The life history data used in EPA's analysis and associated data sources are provided in Appendix D1 of this report.

D2-2 I&E Data Evaluated

Table D2-2 lists the facility I&E data evaluated by EPA to estimate current I&E rates for the Mid-Atlantic Region. I&E data were available for one Phase III facility (Bayway); other data evaluated were from Phase II facilities. See Chapter A1 of Part A for a discussion of methods used to extrapolate I&E data from these model facilities to Phase III facilities without I&E data.

Table D2-2: Facility I&E Data Evaluated for the Mid-Atlantic Region Analysis

Facility	Phase	Years of Data
Bayway Refinery Company (NJ)	III	1975-1994
Calvert Cliffs Nuclear (MD)	II	1975-1995
Chalk Point (MD)	II	1976-1979
Indian Point Nuclear (NY)	II	1981-1990
Indian River (DE)	II	1975-1976
Morgantown (MD)	II	1976
Salem Nuclear (NJ)	II	1978-1998

D2-3 EPA's Estimate of Current I&E at Phase III Facilities in the Mid-Atlantic Region Expressed as Age-1 Equivalents and Foregone Yield

Table D2-3 provides EPA's estimate of the annual age-1 equivalents and foregone fishery yield resulting from the impingement of aquatic species at facilities located in the Mid-Atlantic region. Table D2-4 displays this information for entrainment. Note that in these tables, "total yield" includes direct losses of harvested species and the yield of harvested species that is lost due to losses of forage species. As discussed in Chapter A1 of Part A of the section 316(b) Phase III Regional Benefits Assessment, the conversion of forage to yield contributes only a very small fraction to total yield.

Table D2-3: Estimated Current Annual Impingement at Phase III Facilities in the Mid-Atlantic Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Alewife	533	5
American shad	1	<1
Atlantic croaker	22,400	4,620
Atlantic menhaden	2,420,000	478,000
Atlantic silverside	29	na
Atlantic tomcod	<1	na
Bay anchovy	504,000	na
Black crappie	<1	<1
Blue crab	187,000	1,730

Table D2-3: Estimated Current Annual Impingement at Phase III Facilities in the Mid-Atlantic Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Blueback herring	1,810	na
Bluefish	1	2
Bluntnose minnow	<1	na
Butterfish	5	<1
Carp	<1	na
Cunner	1	<1
Gizzard shad	12	na
Gobies	5	na
Grubby	15	na
Herring	1	na
Hogchoker	17,600	na
Northern pipefish	28	na
Other (commercial)	10,200	2,020
Other (forage)	70,900	na
Other (recreational)	463	92
Other (recreational and commercial)	25,200	4,980
Rainbow smelt	7	<1
Red hake	2	<1
Scup	1	<1
Seaboard goby	286	na
Searobin	3	<1
Silver hake	29	4
Silver perch	1	<1
Silversides	15	na
Spot	265,000	29,700
Striped bass	2,900	4,040
Striped killifish	4,770	na
Summer flounder	1,830	2,580
Sunfish	24	<1
Tautog	<1	<1
Threespine stickleback	17	na
Trophic transfer[a]	na	2,060
Weakfish	12,000	9,430
White perch	338,000	149
Windowpane	14	<1
Winter flounder	1,700	183

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table D2-4: Estimated Current Annual Entrainment at Phase III Facilities in the Mid-Atlantic Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Alewife	61	<1
American shad	187	46
Atlantic croaker	550,000	113,000
Atlantic herring	<1	<1
Atlantic menhaden	85,700	16,900
Atlantic silverside	<1	na
Bay anchovy	12,500,000	na
Blue crab	2,930,000	27,100
Blueback herring	254	na
Freshwater drum	<1	<1
Goby	1	na
Grubby	5	na
Herring	<1	na
Hogchoker	90,600	na
Northern pipefish	2	na
Other (commercial)	411	81
Other (forage)	189,000	na
Other (recreational)	<1	<1
Other (recreational and commercial)	278,000	54,900
Seaboard goby	1,380,000	na
Searobin	<1	<1
Silverside	<1	na
Spot	944,000	106,000
Striped bass	21,100	29,400
Striped killifish	<1	na
Tautog	<1	<1
Trophic transfer[a]	na	688
Weakfish	40,000	31,500
White perch	328,000	145
Windowpane	<1	<1
Winter flounder	5,770	622

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

D2-4 Reductions in I&E at Phase III Facilities in the Mid-Atlantic Region Under Three Alternative Options

Table D2-5 presents estimated reductions in I&E under the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD for Certain Waterbodies" option. Reductions under all other options are presented in Appendix D2.

Table D2-5: Estimated Reductions in I&E Under Three Alternative Options

Option	Age-One Equivalents (#s)	Foregone Fishery Yield (lbs)
50 MGD All Option	13,400,000	600,000
200 MGD All Option	11,900,000	534,000
100 MGD Option	11,900,000	534,000

D2-5 Assumptions Used in Calculating Recreational and Commercial Losses

The lost yield estimates presented in Tables D2-3 and D2-4 are expressed as total pounds and include losses to both commercial and recreational catch. To estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table D2-6 presents the percentage impacts assumed for each species/species group.

See Chapter D3 for results of the commercial fishing benefits analysis and Chapter D4 for recreational fishing results. As discussed in Chapter A8, benefits were discounted to account for 1) the time to achieve compliance once the rule goes into effect in 2007, and 2) the time it takes for fish spared from I&E to reach a harvestable age.

Table D2-6: Percentage of Total Impacts Occurring to the Commercial and Recreational Fisheries and Commercial Value per Pound for Species Impinged and Entrained at Mid-Atlantic Facilities

Species/Species Group	Percent Impact to Recreational Fishery[a,b]	Percent Impact to Commercial Fishery[a,b]
American shad	100.0%	0.0%
Black crappie	100.0%	0.0%
Blue crab	0.0%	100.0%
Freshwater drum	100.0%	0.0%
Other (commercial)	0.0%	100.0%
Other (recreational)	100.0%	0.0%
Other (recreational and commercial)[c]	100.0%	0.0%
Rainbow smelt	100.0%	0.0%
Spot	52.4%	47.6%
Striped bass	100.0%	0.0%
Striped killifish	100.0%	0.0%
Summer flounder	88.0%	12.0%
Sunfish	100.0%	0.0%
Trophic transfer[d]	100.0%	0.0%
White perch	100.0%	0.0%

[a] Based on landings from 1993 to 2001.
[b] Calculated using recreational landings data from NMFS (2003b, http://www.st.nmfs.gov/recreational/queries/catch/snapshot.html) and commercial landings data from NMFS (2003a, http://www.st.nmfs.gov/commercial/landings/annual_landings.html).
[c] Assumed equally likely to be caught by recreational or commercial fishermen. Commercial value calculated as overall average for region based on data from NMFS (2003a).
[d] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Chapter D3: Commercial Fishing Valuation

Introduction

This chapter presents the results of the commercial fishing benefits analysis for the Mid-Atlantic region. Section D3-1 details the estimated losses under current, or baseline, conditions. Section D3-2 presents expected benefits under three alternative options. Chapter A4 details the methods used in this analysis.

Chapter Contents

D3-1 Baseline Losses

Table D3-1 provides EPA's estimate of the value of gross revenues lost in commercial fisheries resulting from the impingement of aquatic species at facilities in the Mid-Atlantic region. Table D3-2 displays this information for entrainment. Total annualized revenue losses are approximately $125,000 (undiscounted).

Table D3-1: Annualized Commercial Fishing Gross Revenues Lost due to Impingement at Facilities in the Mid-Atlantic Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
Atlantic croaker	1,560	$0.33	$519
Atlantic menhaden	478,000	$0.07	$32,300
Blue crab	1,730	$0.78	$1,340
Other (species are only commercially fished, not recreationally)	2,020	$0.54	$1,100
Other (species are fished both recreationally and commercially)	2,490	$0.54	$1,350
Spot	14,100	$0.44	$6,210
Striped bass	184	$1.73	$318
Summer flounder	309	$1.58	$488
Trophic transfer[b]	1,030	$0.40	$410
Weakfish	2,150	$0.67	$1,440
White perch	51	$0.62	$31
Winter flounder	68	$1.22	$83

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table D3-2: Annualized Commercial Fishing Gross Revenues Lost due to Entrainment at Facilities in the Mid-Atlantic Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
American shad	46	$0.62	$29
Atlantic croaker	38,100	$0.33	$12,700
Atlantic menhaden	16,900	$0.07	$1,140
Blue crab	27,100	$0.78	$21,000
Other (species are only commercially fished, not recreationally)	81	$0.54	$44
Other (species are fished both recreationally and commercially)	27,500	$0.54	$14,900
Spot	50,400	$0.44	$22,100
Striped bass	1,340	$1.73	$2,310
Trophic transfer[b]	344	$0.40	$137
Weakfish	7,170	$0.67	$4,820
White perch	49	$0.62	$30
Winter flounder	230	$1.22	$281

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

D3-2 Expected Benefits Under Three Alternative Options

As described in Chapter A4, EPA estimates that 0 to 40% of the gross revenue losses represent surplus losses to producers, assuming no change in prices or fishing costs. The 0% estimate, of course, results in loss estimates of $0. The 40% estimates, as presented in Tables D3-3, D3-4, and D3-5 for the "50 MGD for All Waterbodies" option (50 MGD option), "200 MGD for All Waterbodies" option (200 MGD option), and 100 MGD for Certain Waterbodies" option (100 MGD option), total approximately $50,100 (undiscounted).

The expected reductions in impingement and entrainment (I&E) attributable to changes at facilities required by the 50 MGD option are 73% for impingement and 55% for entrainment, for the 200 MGD option are 65% for impingement and 49% for entrainment, and for the 100 MGD option are 65% for impingement and 49% for entrainment. Total annualized benefits are estimated by applying these estimated reductions to the annual producer surplus loss. As presented in Tables D3-3, D3-4, and D3-5, this results in total annualized benefits of up to approximately $24,900 for the 50 MGD option; and $22,000 for the 200 MGD option and the 100 MGD option, assuming a 3% discount rate.

Table D3-3: Annualized Commercial Fishing Benefits Attributable to the 50 MGD Option at Facilities in the Mid-Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$45,600	$79,600	$125,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$18,200	$31,800	$50,100
Expected reduction due to rule	73%	55%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$30,600
3% discount rate			$24,900
7% discount rate			$19,100

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table D3-4: Annualized Commercial Fishing Benefits Attributable to the 200 MGD Option at Facilities in the Mid-Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$45,600	$79,600	$125,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$18,200	$31,800	$50,100
Expected reduction due to rule	65%	49%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$27,300
3% discount rate			$22,000
7% discount rate			$16,700

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table D3-5: Annualized Commercial Fishing Benefits Attributable to the 100 MGD Option at Facilities in the Mid-Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$45,600	$79,600	$125,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$18,200	$31,800	$50,100
Expected reduction due to rule	65%	49%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$27,300
3% discount rate			$22,000
7% discount rate			$16,700

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Chapter D4: Recreational Use Benefits

Introduction

This chapter presents the results of the recreational fishing benefits analysis for the Mid-Atlantic region. The chapter presents EPA's estimates of baseline (i.e., current) annual recreational fishery losses from impingement and entrainment (I&E) at potentially regulated facilities in the Mid-Atlantic region and annual reduction in these losses under the three proposed regulatory options for Phase III existing facilities:[1]

- the "50 MGD for All Waterbodies" option,
- the "200 MGD for All Waterbodies" option, and
- the "100 MGD for Certain Waterbodies" option.

The chapter then presents the estimated welfare gain to Mid-Atlantic anglers from eliminating baseline recreational fishing losses from I&E and the expected benefits under the three proposed options.

EPA estimated the recreational benefits of reducing and eliminating I&E losses using a benefit transfer methodology based on a meta-analysis of the marginal value of catching different species of fish. This meta-analysis is discussed in detail in Chapter A5, "Recreational Fishing Benefits Methodology." To validate these results, this chapter also presents the results of a random utility model (RUM) analysis for the Mid-Atlantic region. A detailed discussion of the RUM analysis for the Mid-Atlantic region can be found in Chapter D4 of the final Phase II Regional Studies report (U.S. EPA, 2004).

EPA considered a wide range of policy options in developing this regulation. Results of the recreational fishing benefits analysis for five other options evaluated by EPA are presented in Appendix D4.

Chapter Contents

[1] See the introduction to this report for a description of the three proposed options.

D4-1 Benefit Transfer Approach Based on Meta-Analysis

EPA estimated the recreational welfare gain from the reduction in annual I&E losses expected under the policy options, and the welfare gain from eliminating I&E at potentially regulated facilities, using a benefit transfer approach. As discussed in Chapter A5, the Agency used the meta-analysis regression equation to estimate the marginal recreational value per additional fish caught by anglers, for different species in different regions. Since I&E at potentially regulated facilities affects a variety of species, EPA assigned each species with I&E losses to one of the general species groups used in the meta-analysis. The Agency then calculated the economic value of reducing or eliminating baseline I&E losses, for each species group, by multiplying the value per fish for that species group by the number of fish in the group that are lost in the baseline or saved under the policy options.[2]

In general, the fit between the species with I&E losses and the species groups in the meta-analysis was good. However, EPA's estimates of baseline I&E losses and reductions in I&E under the policy options included losses of 'unidentified' species. The 'unidentified' group includes fish lost indirectly through trophic transfer, as well as species for which no species information was available.[3] Rather than using the meta-analysis regression to try to predict the value per fish for an "unidentified" species, EPA assumed that per-fish values for these species can be approximated by the weighted average value per fish for all species affected by I&E in the Mid-Atlantic region.[4]

D4-1.1 Estimated Changes in Recreational Fishery Losses under the Proposed Regulation

Table D4-1 presents EPA's estimates of baseline (i.e., current) annual recreational I&E losses at potentially regulated facilities, and annual reductions in these losses under each of the proposed regulatory options, in the Mid-Atlantic region. The table shows that total baseline losses to recreational fisheries are 0.28 million fish per year. In comparison, the "50 MGD for All Waterbodies" option prevents losses of 0.16 million fish per year, and the "200 MGD for All Waterbodies" option and the "100 MGD for Certain Waterbodies" option both prevent losses of 0.14 million fish per year. Of all the affected species, spot and Atlantic croaker have the highest losses in the baseline and the highest prevented losses under the proposed options.

---

[2] Note that the estimates of I&E presented in this chapter include only the fraction of impinged and entrained recreational fish that would otherwise be caught by anglers. The total amount of I&E of recreational species is actually much higher.

[3] In addition to recreational fish that are lost because they are impinged or entrained, some recreational fish are lost because the forage fish that they feed on are impinged or entrained, and thus removed from the food chain. These trophic transfer losses of recreational species are included in EPA's estimates of total I&E losses. However, since it is difficult to predict which recreational species would be affected by losses of forage fish, these losses are classified as 'unidentified' recreational species. Also included in the 'unidentified' group are losses of fish that were reported by facilities without information about their exact species.

[4] EPA used the estimated level of baseline recreational losses for each species group as a weighting factor.

Table D4-1: Baseline Recreational Fishing Losses from I&E at Potentially Regulated Phase III Facilities and Reductions in Recreational Losses under the Proposed Regulatory Options in the Mid-Atlantic Region

Species[a]	Annual Baseline Recreational Fishing Losses (# of fish)	Annual Reductions in Recreational Fishing Losses (# of fish)		
		50 MGD All	200 MGD All	100 MGD CWB
Striped bass	2,865	1,626	1,448	1,448
Weakfish	5,771	3,390	3,018	3,018
Total (small game)	**8,637**	**5,016**	**4,466**	**4,466**
Summer flounder	436	317	282	282
Winter flounder	300	176	157	157
Total (flatfish)	**736**	**493**	**439**	**439**
Atlantic croaker	46,578	25,741	22,916	22,916
Spot	170,953	100,073	89,090	89,090
White perch	834	532	474	474
Total (other saltwater)	**218,366**	**126,347**	**112,480**	**112,480**
Total (unidentified)	**47,332**	**26,725**	**23,792**	**23,792**
Total (all species)	***275,072***	***158,582***	***141,178***	***141,178***

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The 'other saltwater' group includes bottomfish and other miscellaneous species. The 'unidentified' group includes fish lost indirectly through trophic transfer.

Source: U.S. EPA analysis for this report.

D4-1.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table D4-2 shows the results of EPA's analysis of the welfare gain to recreational anglers from eliminating baseline recreational fishery losses at potentially regulated facilities in the Mid-Atlantic region. The table presents baseline annual recreational I&E losses, the estimated value per fish, and the monetized annual welfare gain from eliminating recreational losses, for each species group. Total baseline recreational fishing losses for the Mid-Atlantic region are 0.28 million fish per year. The undiscounted annual welfare gain to Mid-Atlantic anglers from eliminating these losses is $1.06 million (2003$), with lower and upper bounds of $0.50 million and $2.26 million. Evaluated at 3% and 7%, the mean annualized welfare gain of eliminating these losses is $1.00 million and $0.93 million, respectively. The majority of monetized recreational losses from I&E under baseline conditions are attributable to losses of species in the 'other saltwater' group, including spot and Atlantic croaker.

Table D4-2: Recreational Fishing Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the Mid-Atlantic Region (2003$)

Species Group	Baseline Annual Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Benefits from Eliminating Recreational Fishing Losses (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	8.6	$2.74	$6.87	$16.94	$23.6	$59.3	$146.3
Flatfish	0.7	$3.28	$6.91	$14.71	$2.4	$5.1	$10.8
Other saltwater	218.4	$1.79	$3.73	$7.83	$389.8	$814.5	$1,710.0
Unidentified	47.3	$1.83	$3.86	$8.20	$86.4	$182.7	$388.1
Total (undiscounted)	**275.1**				**$502.3**	**$1,061.6**	**$2,255.3**
Total (evaluated at 3%)	**275.1**				**$473.0**	**$999.7**	**$2,123.9**
Total (evaluated at 7%)	**275.1**				**$438.5**	**$926.7**	**$1,968.8**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying baseline losses by the estimated value per fish.
[d] Annualized values represent the total welfare gain over the time frame of the analysis from eliminating recreational losses, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

D4-1.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table D4-3 shows the results of EPA's analysis of the recreational benefits of the "50 MGD for All Waterbodies" option for the Mid-Atlantic region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 0.16 million fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.61 million (2003$), with lower and upper bounds of $0.29 million and $1.30 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.50 million and $0.38 million, respectively. The majority of benefits result from reduced losses of species in the 'other saltwater' group, including spot and Atlantic croaker.

Table D4-3: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the Mid-Atlantic Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	5.0	$2.74	$6.87	$16.94	$13.7	$34.5	$85.0
Flatfish	0.5	$3.28	$6.91	$14.71	$1.6	$3.4	$7.3
Other saltwater	126.3	$1.79	$3.73	$7.83	$225.5	$471.3	$989.4
Unidentified	26.7	$1.83	$3.86	$8.20	$48.8	$103.2	$219.2
Total (undiscounted)	**158.6**				**$289.7**	**$612.3**	**$1,300.8**
Total (evaluated at 3%)	**158.6**				**$235.4**	**$497.5**	**$1,056.9**
Total (evaluated at 7%)	**158.6**				**$180.6**	**$381.6**	**$810.8**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

D4-1.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

Table D4-4 shows the results of EPA's analysis of the recreational benefits of the "200 MGD for All Waterbodies" option for the Mid-Atlantic region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 0.14 million fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.55 million (2003$), with lower and upper bounds of $0.26 million and $1.16 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.44 million and $0.33 million, respectively. The majority of benefits result from reduced losses of species in the 'other saltwater' group, including spot and Atlantic croaker.

Table D4-4: Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option in the Mid-Atlantic Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	4.5	$2.74	$6.87	$16.94	$12.2	$30.7	$75.7
Flatfish	0.4	$3.28	$6.91	$14.71	$1.4	$3.0	$6.5
Other saltwater	112.5	$1.79	$3.73	$7.83	$200.8	$419.5	$880.8
Unidentified	23.8	$1.83	$3.86	$8.20	$43.5	$91.8	$195.1
Total (undiscounted)	**141.2**				**$257.9**	**$545.1**	**$1,158.1**
Total (evaluated at 3%)	**141.2**				**$208.0**	**$439.6**	**$933.9**
Total (evaluated at 7%)	**141.2**				**$157.9**	**$333.7**	**$709.0**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

D4-1.5 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

In the Mid-Atlantic region, all Phase III facilities that would have to install technology under the "200 MGD for All Waterbodies" option or the "100 MGD for Certain Waterbodies" option have design intake flows that are greater than 200 million gallons per day (MGD) and are located on coastal waterbodies or Great Lakes. Because the requirements under these two options are identical for this class of facilities, the I&E reductions and welfare gain resulting from these two options are also identical. Thus, the benefits estimates presented for the 200 MGD option in Table D4-4 also apply to the 100 MGD option. The table shows that this option reduces recreational losses by 0.14 million fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.55 million (2003$), with lower and upper bounds of $0.26 million and $1.16 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.44 million and $0.33 million, respectively.

D4-2 RUM Approach

To validate the results of the benefit transfer approach, EPA applied the RUM model presented in Chapter F4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004) to the baseline losses and reductions in losses at potentially regulated Phase III existing facilities. This section presents the results of the recreational fishing benefits analysis for the Mid-Atlantic region based on the Phase II RUM approach.

D4-2.1 RUM Methodology: Mid-Atlantic Region

EPA's methodology for evaluating the change in welfare resulting from a change in recreational losses from I&E consists of four basic steps: (1) calculating the change in historical catch rates under a given policy scenario, (2) estimating the per-trip welfare gain to anglers based on the Phase II RUM model, (3) estimating the number of fishing trips taken by anglers, and (4) combining fishing participation data with the estimated per-trip welfare gain to calculate the total annual welfare gain. These steps are briefly described in the following sections. For a more detailed discussion of the RUM methodology, see Chapters A11 and F4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004).

D4-2.1.1 Estimating Changes in the Quality of Fishing Sites

The first step in EPA's analysis was to combine estimates of recreational I&E losses at potentially regulated facilities with state-level recreational fishery landings data to estimate the percentage change in historical catch rates under each policy option. Because most species considered in this analysis (e.g., weakfish, striped bass, bottomfish, and flatfish) are found throughout Mid-Atlantic waters (i.e., from Virginia to New York), EPA made the assumption that changes in I&E will result in uniform changes in catch rates across all marine fishing sites in this region.[5] Thus, EPA used five-year National Marine Fisheries Service (NMFS) recreational landings data (1996 through 2000) for state waters to calculate the average statewide landings per year for all species groups.[6] EPA then divided baseline recreational I&E losses by total recreational landings to calculate the percentage change in historical catch rates from completely eliminating recreational fishing losses from I&E. Similarly, the Agency also estimated the percentage changes to historic catch rates that would result under each policy option.

D4-2.1.2 Estimating Per-Trip Benefits from Reducing I&E

EPA's second step was to use the recreational behavior model described in Chapter F4 of the Phase II Regional Studies document to estimate an angler's per-trip welfare gain from changes in the historical catch rates in the Mid-Atlantic region. The Agency estimated welfare gains to recreational anglers under four scenarios: eliminating baseline recreational fishing losses from I&E at potentially regulated facilities, and reducing recreational fishing losses from I&E by implementing the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, or the "100 MGD for Certain Waterbodies" option. EPA assumed that the welfare gain per fishing trip is independent of the number of days fished per trip and therefore equivalent for both single- and multiple-day trips. Thus, a multiple-day trip is valued the same as a single-day trip.[7] EPA estimated separate per-day welfare gains for different categories of anglers, based on their target species and fishing mode.[8]

D4-2.1.3 Estimating Angler Participation

The third step in EPA's analysis was to estimate baseline and post-regulatory fishing participation, measured by the total number of fishing trips taken by Mid-Atlantic anglers.[9] Because the policy options for Phase III facilities are expected to result in relatively small improvements in fishing quality, EPA assumed that increases in recreational fishing participation under the policy options will be negligible. Thus, to estimate both baseline and post-regulatory participation, EPA used the total number of fishing trips taken by Mid-Atlantic anglers in 2002. The total number of trips to the Mid-Atlantic fishing sites was calculated from data provided by NMFS. To

---

[5] Fish lost to I&E are most often very small fish that are too small to catch. Because of the migratory nature of most affected species, by the time these fish have grown to catchable size, they may have traveled some distance from the facility where I&E occurs. Without collecting extensive data on migratory patterns of all affected fish, it is not possible to evaluate whether catch rates will change uniformly or in some other pattern. Thus, EPA assumed that catch rates will change uniformly across the entire region.

[6] State waters include sounds, inlets, tidal portions of rivers, bays, estuaries, and other areas of salt or brackish water plus ocean waters to three nautical miles from shore (NMFS, 2003a).

[7] See section D4-5.1 of Chapter D4 of the 316(b) Phase II document for limitations and uncertainties associated with this assumption.

[8] EPA used the per-day values for private/rental boat anglers to estimate welfare gains for charter boat anglers.

[9] See Chapter B4 of the section 316(b) Phase II Case Study document for a detailed description of the angler participation estimates in the Mid-Atlantic.

estimate the proportion of recreational fishing trips taken by no-target anglers and by anglers targeting each species of concern, EPA used the Marine Recreational Fisheries Statistics Survey (MRFSS) sample. The Agency then applied those percentages to the total number of fishing trips taken by Mid-Atlantic anglers to calculate the number of anglers.

D4-2.1.4 Estimating Total Benefits from Eliminating or Reducing I&E

The final step in EPA's analysis was to calculate the total benefits of the policy options. To calculate total benefits for each subcategory of anglers targeting a particular species with a particular fishing mode, EPA multiplied the per-trip welfare gain for an angler with that particular species/fishing mode combination by the total number of fishing trips taken by all anglers with that species/fishing mode combination. EPA then summed benefits for all subcategories of anglers to calculate the total welfare change in the Mid-Atlantic region. Finally, as discussed in Chapter A8, EPA discounted and annualized the benefits estimates, using both 3% and 7% discount rates.

D4-2.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table D4-6 presents the baseline level of recreational landings at potentially regulated facilities and the estimated change in catch rates that would result from eliminating recreational fishing losses from I&E in the Mid-Atlantic region. The table shows that I&E has the largest effect on catch rates for bottomfish, which would increase by 0.62% if I&E were eliminated.

Table D4-6: Estimated Changes in Historical Catch Rates from Eliminating Recreational Fishing Losses from I&E at Potentially Regulated Phase III Facilities in the Mid-Atlantic Region

Species Group	Annual Recreational Landings (thousands of fish)[a]	Baseline Annual Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Eliminating I&E
Striped bass	7,024.8	7.1	0.10%
Flatfish	20,734.4	13.1	0.06%
Bottomfish	39,234.6	241.8	0.62%
Weakfish	4,798.2	8.6	0.18%
Small game	7,335.0	4.4	0.06%
No target	79,127.0[c]	275.1	0.35%

[a] Total recreational landings are calculated as a five-year average (1997-2001) for state waters.
[b] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[c] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table D4-7 presents the per-trip welfare gain for anglers targeting different species, the number of fishing trips taken by anglers targeting those species, and the total annual welfare gain from eliminating baseline I&E. The table shows that the total undiscounted value of baseline losses in the Mid-Atlantic region is $0.96 million (2003$) and the annualized value of those losses is $0.91 million and $0.84 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bottomfish and no-target species. The table shows that eliminating baseline recreational fishing losses from I&E would result in per-trip welfare gains of up to 20 cents per angler.

Table D4-7: Recreational Fishing Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the Mid-Atlantic Region (2003$)

Species Group	Per-Trip Welfare Gain		Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
	Boat Anglers	Shore Anglers		
Striped bass	$0.03	$0.03	2,216	$70.4
Flatfish	$0.02	$0.02	5,055	$101.4
Bottomfish	$0.20	$0.19	1,786	$347.5
Weakfish	$0.06	$0.06	597	$34.2
Small game	$0.02	$0.02	842	$46.5
No target	$0.11	$0.11	3,324	$362.1
Total, All Species (undiscounted)			**15,622**	**$962.1**
Total, All Species (evaluated at 3%)			**15,622**	**$906.0**
Total, All Species (evaluated at 7%)			**15,622**	**$839.9**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

D4-2.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table D4-8 presents the estimated change in historical catch rates that would result from reductions in I&E under the "50 MGD for All Waterbodies" option. In the Mid-Atlantic, catch rates for anglers targeting bottomfish would increase the most under this option, by 0.36%.

Table D4-8: Estimated Changes in Historical Catch Rates from Reducing I&E under the "50 MGD for All Waterbodies" Option in the Mid-Atlantic Region

Species Group	Annual Recreational Landings (thousands of fish)[a]	Annual Reduction in Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Reducing I&E
Striped bass	7,024.8	4.0	0.06%
Flatfish	20,734.4	7.5	0.04%
Bottomfish	39,234.6	139.6	0.36%
Weakfish	4,798.2	5.0	0.10%
Small game	7,335.0	2.5	0.03%
No target	79,127.0[c]	158.6	0.20%

[a] Annual recreational landings are calculated as a five-year average (1997-2001) for state waters.
[b] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[c] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table D4-9 presents the recreational benefits of the "50 MGD for All Waterbodies" option for the Mid-Atlantic region. The table shows that the total undiscounted benefits of this option are $0.55 million (2003$), and the annualized value of those benefits is $0.45 million and $0.34 million evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bottomfish and 'no-target' species. The table shows that this option would result in per-trip welfare gains of up to eleven cents per angler.

Table D4-9: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the Mid-Atlantic Region (2003$)

Species Group	Per-Trip Welfare Gain		Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
	Boat Anglers	Shore Anglers		
Striped bass	$0.02	$0.02	2,216	$39.8
Flatfish	$0.01	$0.01	5,055	$57.8
Bottomfish	$0.11	$0.11	1,786	$200.7
Weakfish	$0.03	$0.03	597	$19.8
Small game	$0.01	$0.01	842	$26.3
No target	$0.06	$0.06	3,324	$208.8
Total, All Species (undiscounted)			**15,622**	**$553.2**
Total, All Species (evaluated at 3%)			**15,622**	**$449.5**
Total, All Species (evaluated at 7%)			**15,622**	**$344.8**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

D4-2.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

Table D4-10 presents the estimated change in historical catch rates that would result from reductions in I&E under the "200 MGD for All Waterbodies" option. In the Mid-Atlantic region, catch rates for anglers targeting bottomfish would increase the most under the "200 MGD for All Waterbodies" option, by 0.32%.

Table D4-10: Estimated Changes in Historical Catch Rates from Reducing I&E under the "200 MGD for All Waterbodies" Option in the Mid-Atlantic Region

Species Group	Annual Recreational Landings (thousands of fish)[a]	Annual Reduction in Recreational Fishing Losses (thousands of fish)[b]	Percent Increase in Recreational Catch from Reducing I&E
Striped bass	7,024.8	3.6	0.05%
Flatfish	20,734.4	6.7	0.03%
Bottomfish	39,234.6	124.3	0.32%
Weakfish	4,798.2	4.5	0.09%
Small game	7,335.0	2.2	0.03%
No target	79,127.0[c]	141.2	0.18%

[a] Annual recreational landings are calculated as a five-year average (1997-2001) for state waters.
[b] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[c] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table D4-11 presents the recreational benefits of the "200 MGD for All Waterbodies" option for the Mid-Atlantic region. The table shows that the total undiscounted benefits of this option are $0.49 million (2003$), and the annualized value of those benefits is $0.40 million and $0.30 million, evaluated at 3% and 7%, respectively . The majority of benefits in this region are attributable to changes in catch rates for bottomfish and 'no-target' species. The table shows that this option would result in per-trip welfare gains of up to ten cents per angler.

Table D4-11: Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option in the Mid-Atlantic Region (2003$)

Species Group	Per-Trip Welfare Gain		Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
	Boat Anglers	Shore Anglers		
Striped bass	$0.02	$0.02	2,216	$35.7
Flatfish	$0.01	$0.01	5,055	$51.2
Bottomfish	$0.10	$0.10	1,786	$178.7
Weakfish	$0.03	$0.03	597	$17.6
Small game	$0.01	$0.01	842	$23.3
No target	$0.06	$0.05	3,324	$185.4
Total, All Species (undiscounted)			**15,622**	**$491.8**
Total, All Species (evaluated at 3%)			**15,622**	**$396.6**
Total, All Species (evaluated at 7%)			**15,622**	**$301.1**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

D4-2.5 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

In the Mid-Atlantic region, all Phase III facilities that would have to install technology under the "200 MGD for All Waterbodies" option or the "100 MGD for Certain Waterbodies" option have design intake flows that are greater than 200 million gallons per day (MGD) and are located on coastal waterbodies or Great Lakes. Because the requirements under these two options are identical for this class of facilities, the I&E reductions and welfare gain resulting from these two options are also identical. Thus, the benefits estimates presented for the 200 MGD option in Table D4-11 also apply to the 100 MGD option. The table shows that this option results in an undiscounted welfare gain to recreational anglers of $0.49 million (2003$). Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.40 million and $0.30 million, respectively.

D4-3 Validation of Benefit Transfer Results Based on RUM Results

Table D4-12 compares the undiscounted results of the benefit transfer based on the meta-analysis with the results of the RUM analysis. The table shows that in both models, the "50 MGD for All Waterbodies" option results a larger welfare gain than the "200 MGD for All Waterbodies" option and the "100 MGD for Certain Waterbodies" option. In general, the RUM-based results are very close to the values estimated based on the meta-model. That the values from the two independent analyses are relatively similar corroborates the use of meta-analysis in estimating the value of incremental recreational fishing improvements resulting from the section 316(b) regulation for Phase III facilities.

Table D4-12: Recreational Fishing Benefits in the Mid-Atlantic Region Calculated from Meta-Analysis Approach and RUM Approach

Policy Option	Estimated Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands, 2003$)			
		Based on Meta-Analysis			Based on RUM
		Low	Mean	High	
Eliminating baseline recreational fishing losses from I&E	275.1	$502.3	$1,061.6	$2,255.3	$962.1
50 MGD All	158.6	$289.7	$612.3	$1,300.8	$553.2
200 MGD All[a]	141.2	$257.9	$545.1	$1,158.0	$491.8
100 MGD CWB[a]	141.2	$257.9	$545.1	$1,158.0	$491.8

[a] Because all Phase III facilities that would have to install technology under the "200 MGD for All Waterbodies" option or the "100 MGD for Certain Waterbodies" option have design intake flows that are greater than 200 million gallons per day (MGD) and are located on coastal waterbodies or Great Lakes, recreational fishing benefits resulting from these two options are identical.

Source: U.S. EPA analysis for this report.

D4-4 Limitations and Uncertainty

D4-4.1 Limitations and Uncertainty: Meta-Analysis

The results of the benefit transfer based on the meta-analysis results represent EPA's best estimate of the recreational benefits of the proposed options. Nonetheless, there are a number of limitations and uncertainties inherent in these estimates. General limitations pertaining to the development of the meta-analysis model, the use of the model to estimate per-fish values, and the validity of the benefit transfer are discussed in section A5-3.3e and section A5-5.3 of Chapter A5.

D4-4.2 Limitations and Uncertainty: RUM Approach

The results of the benefit transfer based on the RUM analysis results serve to confirm that EPA's estimates of the recreational benefits of the proposed options are reasonable. However, there are a number of limitations and uncertainties inherent in these estimates. Some general limitations pertaining to the RUM model are discussed in Chapter A11 of the 316(b) Phase II document. Additional region-specific limitations are discussed in Chapter D4 of the 316(b) Phase II document.

Although the estimated total welfare gain to the Mid-Atlantic recreational anglers based on the regional RUM model is likely to be accurate, the estimated average per-trip welfare gain presented in Tables D4-7, D4-9 and D4-11 must be used and understood in the context of the regional model developed by EPA for the Phase II analysis. The regional RUM model assumes uniform changes in catch rates at all sites across the region. Given that there are only 14 potentially regulated facilities in the Mid-Atlantic region and the total intake flow associated with these facilities is relatively small, catch rate improvements are more likely to occur locally rather than regionally. These local improvements in catch rates and the associated average per-trip welfare gain are likely to be greater than those presented in the tables in section D4-2. However, the number of anglers benefitting from these improvements would be smaller, and so the resulting aggregate benefits are likely to be similar.

Appendix D1: Life History Parameter Values Used to Evaluate I&E in the Mid-Atlantic Region

The tables in this appendix present the life history parameter values used by EPA to calculate age-1 equivalents and fishery yields from impingement and entrainment (I&E) data for the Mid-Atlantic Region. Because of differences in the number of life stages represented in the loss data, there are cases where more than one life stage sequence was needed for a given species or species group. Alternative parameter sets were developed for this purpose and are indicated with a number following the species or species group name (i.e., Alewife 1, Alewife 2).

Table D1-1: Alewife Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.554	0	0	0.000000716
Yolksac larvae	1.81	0	0	0.000000728
Post-yolksac larvae	1.72	0	0	0.00000335
Juvenile 1	3.11	0	0	0.000746
Juvenile 2	3.11	0	0	0.0155
Age 1\+	0.300	0	0	0.0303
Age 2+	0.300	0	0	0.125
Age 3+	0.300	0	0	0.254
Age 4+	0.900	0.1	0.45	0.379
Age 5+	1.50	0.1	0.9	0.485
Age 6+	1.50	0.1	1	0.565
Age 7+	1.50	0.1	1	0.625
Age 8+	1.50	0.1	1	0.666

Source: PSE&G, 1999.

Table D1-2: Alewife Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.554	0	0	0.000000716
Larvae	3.53	0	0	0.00000204
Juvenile	6.21	0	0	0.000746
Age 1+	0.300	0	0	0.0303
Age 2+	0.300	0	0	0.125
Age 3+	0.300	0	0	0.254
Age 4+	0.900	0.1	0.45	0.379
Age 5+	1.50	0.1	0.9	0.485
Age 6+	1.50	0.1	1.0	0.565
Age 7+	1.50	0.1	1.0	0.625
Age 8+	1.50	0.1	1.0	0.666

Source: PSE&G, 1999.

Table D1-3: American Shad Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.496	0	0	0.000000716
Yolksac larvae	0.496	0	0	0.000000728
Post-yolksac larvae	2.52	0	0	0.00000335
Juvenile	7.4	0	0	0.000746
Age 1+	0.3	0	0	0.309
Age 2+	0.3	0	0	1.17
Age 3+	0.3	0	0	2.32
Age 4+	0.54	0.21	0.45	3.51
Age 5+	1.02	0.21	0.90	4.56
Age 6+	1.5	0.21	1.0	5.47
Age 7+	1.5	0.21	1.0	6.20
Age 8+	1.5	0.21	1.0	6.77

Sources: USFWS, 1978; Able and Fahay, 1998; PSE&G, 1999; and Froese and Pauly, 2001.

Table D1-4: Atlantic Croaker Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.817	0	0	0.0000000128
Yolksac larvae	3.27	0	0	0.0000000441
Post-yolksac larvae	4.90	0	0	0.000000246
Juvenile 1	1.18	0	0	0.0000120
Juvenile 2	2.20	0	0	0.000113
Age 1+	1.09	0.3	0.50	0.220
Age 2+	0.300	0.3	1.0	0.672
Age 3+	0.300	0.3	1.0	1.24
Age 4+	0.300	0.3	1.0	1.88
Age 5+	0.300	0.3	1.0	2.43
Age 6+	0.300	0.3	1.0	3.26
Age 7+	0.300	0.3	1.0	3.26
Age 8+	0.300	0.3	1.0	3.26

Source: PSE&G, 1999.

Table D1-5: Atlantic Croaker Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.817	0	0	0.0000000128
Larvae	8.10	0	0	0.000000145
Juvenile	3.38	0	0	0.0000624
Age 1+	1.09	0.3	0.50	0.220
Age 2+	0.300	0.3	1.0	0.672
Age 3+	0.300	0.3	1.0	1.24
Age 4+	0.300	0.3	1.0	1.88
Age 5+	0.300	0.3	1.0	2.43
Age 6+	0.300	0.3	1.0	3.26
Age 7+	0.300	0.3	1.0	3.26
Age 8+	0.300	0.3	1.0	3.26

Source: PSE&G, 1999.

Table D1-6: Atlantic Menhaden Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Yolksac larvae	2.85	0	0	0.000000728
Post-yolksac larvae	2.85	0	0	0.00000335
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.8	0.50	0.356
Age 3+	0.450	0.8	1.0	0.679
Age 4+	0.450	0.8	1.0	0.974
Age 5+	0.450	0.8	1.0	1.21
Age 6+	0.450	0.8	1.0	1.38

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Entergy Nuclear Generation Company, 2000; ASMFC, 2001b; and Froese and Pauly, 2001.

Table D1-7: Atlantic Menhaden Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.07	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.45	0	0	0.0937
Age 2+	0.45	0.8	0.50	0.356
Age 3+	0.45	0.8	1.0	0.679
Age 4+	0.45	0.8	1.0	0.974
Age 5+	0.45	0.8	1.0	1.21
Age 6+	0.45	0.8	1.0	1.38

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Entergy Nuclear Generation Company, 2000; ASMFC, 2001b; and Froese and Pauly, 2001.

Table D1-8: Atlantic Tomcod Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	8.46	0	0	0.00000126
Larvae	8.46	0	0	0.0000185
Juvenile	8.46	0	0	0.0145
Age 1+	8.46	0	0	0.080
Age 2+	2.83	0	0	0.270
Age 3+	2.83	0	0	0.486

Sources: Stewart and Auster, 1987; McLaren et al., 1988; Virginia Tech, 1998; and NMFS, 2003a.

Table D1-9: Bay Anchovy Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Yolksac larvae	1.57	0	0	0.0000000441
Post-yolksac larvae 1	2.11	0	0	0.0000000929
Post-yolksac larvae 2	4.02	0	0	0.00000461
Juvenile 1	0.0822	0	0	0.0000495
Juvenile 2	0.0861	0	0	0.000199
Juvenile 3	0.129	0	0	0.000532
Juvenile 4	0.994	0	0	0.00114
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

Sources: Derickson and Price, 1973; PSE&G, 1999; and NMFS, 2003a.

Table D1-10: Bay Anchovy Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Larvae	7.70	0	0	0.00000158
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

Sources: Derickson and Price, 1973; PSE&G, 1999; and NMFS, 2003a.

Table D1-11: Bay Anchovy Life History Parameters 3

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Yolksac larvae	1.57	0	0	0.0000000441
Post-yolksac larvae	6.12	0	0	0.00000235
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

Sources: Derickson and Price, 1973; PSE&G, 1999; and NMFS, 2003a.

Table D1-12: Blue Crab Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Megalops	1.30	0	0	0.00000291
Juvenile	1.73	0.48	0.5	0.00000293
Age 1+	1.10	0.48	1	0.007
Age 2+	1.38	0.48	1	0.113
Age 3+	1.27	0.48	1	0.326

Sources: Hartman, 1993; and PSE&G, 1999.

Table D1-13: Blueback Herring Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.558	0	0	0.000000716
Yolksac larvae	1.83	0	0	0.000000728
Post-yolksac larvae	1.74	0	0	0.00000335
Juvenile 1	3.13	0	0	0.000746
Juvenile 2	3.13	0	0	0.00836
Age 1+	0.300	0	0	0.0160
Age 2+	0.300	0	0	0.0905
Age 3+	0.300	0	0	0.204
Age 4+	0.900	0	0	0.318
Age 5+	1.50	0	0	0.414
Age 6+	1.50	0	0	0.488
Age 7+	1.50	0	0	0.540
Age 8+	1.50	0	0	0.576

Sources: PSE&G, 1999; and NMFS, 2003a.

Table D1-14: Blueback Herring Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.558	0	0	0.000000716
Larvae	3.18	0	0	0.00000204
Juvenile	6.26	0	0	0.000746
Age 1+	0.300	0	0	0.0160
Age 2+	0.300	0	0	0.0905
Age 3+	0.300	0	0	0.204
Age 4+	0.900	0	0	0.318
Age 5+	1.50	0	0	0.414
Age 6+	1.50	0	0	0.488
Age 7+	1.50	0	0	0.540
Age 8+	1.50	0	0	0.576

Sources: PSE&G, 1999; and NMFS, 2003a.

Table D1-15: Hogchoker Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.000000487
Larvae	5.20	0	0	0.00110
Juvenile	2.31	0	0	0.00207
Age 1+	2.56	0	0	0.0113
Age 2+	0.705	0	0	0.0313
Age 3+	0.705	0	0	0.0610
Age 4+	0.705	0	0	0.0976
Age 5+	0.705	0	0	0.138
Age 6+	0.705	0	0	0.178

Sources: PG&E National Energy Group, 2001; Froese and Pauly, 2003; and NMFS, 2003a.

Table D1-16: Naked Goby Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.0000370
Larvae	4.09	0	0	0.000221
Juvenile	2.30	0	0	0.000485
Age 1+	2.55	0	0	0.00205

Sources: PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table D1-17: Spot Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.825	0	0	0.000000131
Yolksac larvae	3.30	0	0	0.000000154
Post-yolksac larvae	4.12	0	0	0.000000854
Juvenile 1	1.58	0	0	0.0000226
Juvenile 2	0.99	0.247	0.30	0.000220
Age 1+	0.463	0.40	1.0	0.0791
Age 2+	0.400	0.40	1.0	0.299
Age 3+	0.400	0.40	1.0	0.507
Age 4+	0.400	0.40	1.0	0.648
Age 5+	0.400	0.40	1.0	0.732
Age 6+	0.400	0.40	1.0	0.779
Age 7+	0.400	0.40	1.0	0.779
Age 8+	0.400	0.40	1.0	0.779
Age 9+	0.400	0.40	1.0	0.779
Age 10+	0.400	0.40	1.0	0.779
Age 11+	0.400	0.40	1.0	0.779
Age 12+	0.400	0.40	1.0	0.779
Age 13+	0.400	0.40	1.0	0.779
Age 14+	0.400	0.40	1.0	0.779
Age 15+	0.400	0.40	1.0	0.779

Sources: Schwartz et al., 1979; and PSE&G, 1984, 1999.

Table D1-18: Spot Life History Parameters 2				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	0.825	0	0	0.000000131
Larvae	7.40	0	0	0.000000504
Juvenile	2.57	0	0	0.000121
Age 1+	0.463	0.40	1.0	0.0791
Age 2+	0.400	0.40	1.0	0.299
Age 3+	0.400	0.40	1.0	0.507
Age 4+	0.400	0.40	1.0	0.648
Age 5+	0.400	0.40	1.0	0.732
Age 6+	0.400	0.40	1.0	0.779
Age 7+	0.400	0.40	1.0	0.779
Age 8+	0.400	0.40	1.0	0.779
Age 9+	0.400	0.40	1.0	0.779
Age 10+	0.400	0.40	1.0	0.779
Age 11+	0.400	0.40	1.0	0.779
Age 12+	0.400	0.40	1.0	0.779
Age 13+	0.400	0.40	1.0	0.779
Age 14+	0.400	0.40	1.0	0.779
Age 15+	0.400	0.40	1.0	0.779

Sources: Schwartz et al., 1979; and PSE&G, 1984, 1999.

Table D1-19: Striped Bass Life History Parameters 1				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	1.39	0	0	0.000000224
Yolksac larvae	2.22	0	0	0.000000243
Post-yolksac larvae	5.11	0	0	0.0000119
Juvenile 1	2.28	0	0	0.000154
Juvenile 2	1.00	0	0	0.0216
Age 1+	1.10	0	0	0.485
Age 2+	0.150	0.31	0.06	2.06
Age 3+	0.150	0.31	0.20	3.31
Age 4+	0.150	0.31	0.63	4.93
Age 5+	0.150	0.31	0.94	6.50
Age 6+	0.150	0.31	1.0	8.58
Age 7+	0.150	0.31	0.90	12.3
Age 8+	0.150	0.31	0.90	14.3
Age 9+	0.150	0.31	0.90	16.1
Age 10+	0.150	0.31	0.90	18.8
Age 11+	0.150	0.31	0.90	19.6
Age 12+	0.150	0.31	0.90	22.4
Age 13+	0.150	0.31	0.90	27.0
Age 14+	0.150	0.31	0.90	34.6
Age 15+	0.150	0.31	0.90	41.5

Sources: Bason, 1971; and PSE&G, 1999.

Table D1-20: Striped Bass Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.39	0	0	0.000000224
Larvae	7.32	0	0	0.00000606
Juvenile	3.29	0	0	0.0109
Age 1+	1.10	0	0	0.485
Age 2+	0.150	0.31	0.06	2.06
Age 3+	0.150	0.31	0.20	3.31
Age 4+	0.150	0.31	0.63	4.93
Age 5+	0.150	0.31	0.94	6.5
Age 6+	0.150	0.31	1.0	8.58
Age 7+	0.150	0.31	0.90	12.3
Age 8+	0.150	0.31	0.90	14.3
Age 9+	0.150	0.31	0.90	16.1
Age 10+	0.150	0.31	0.90	18.8
Age 11+	0.150	0.31	0.90	19.6
Age 12+	0.150	0.31	0.90	22.4
Age 13+	0.150	0.31	0.90	27
Age 14+	0.150	0.31	0.90	34.6
Age 15+	0.150	0.31	0.90	41.5

Sources: Bason, 1971; and PSE&G, 1999.

Table D1-21: Striped Bass Life History Parameters 3

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.39	0	0	0.000000224
Yolksac larvae	2.22	0	0	0.000000243
Post-yolksac larvae	5.11	0	0	0.0000119
Juvenile	3.29	0	0	0.248
Age 1+	1.10	0	0	0.485
Age 2+	0.150	0.31	0.06	2.06
Age 3+	0.150	0.31	0.20	3.31
Age 4+	0.150	0.31	0.63	4.93
Age 5+	0.150	0.31	0.94	6.50
Age 6+	0.150	0.31	1.0	8.58
Age 7+	0.150	0.31	0.90	12.3
Age 8+	0.150	0.31	0.90	14.3
Age 9+	0.150	0.31	0.90	16.1
Age 10+	0.150	0.31	0.90	18.8
Age 11+	0.150	0.31	0.90	19.6
Age 12+	0.150	0.31	0.90	22.4
Age 13+	0.150	0.31	0.90	27
Age 14+	0.150	0.31	0.90	34.6
Age 15+	0.150	0.31	0.90	41.5

Sources: Bason, 1971; and PSE&G, 1999.

Table D1-22: Summer Flounder Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.00000109
Larvae	4.37	0	0	0.00000532
Juvenile	2.38	0	0	0.208
Age 1+	0.200	0.26	0.50	0.919
Age 2+	0.200	0.26	1.0	1.02
Age 3+	0.200	0.26	1.0	2.50
Age 4+	0.200	0.26	1.0	3.56
Age 5+	0.200	0.26	1.0	5.09
Age 6+	0.200	0.26	1.0	5.83
Age 7+	0.200	0.26	1.0	6.64
Age 8+	0.200	0.26	1.0	8.16
Age 9+	0.200	0.26	1.0	9.90
Age 10+	0.200	0.26	1.0	11.9
Age 11+	0.200	0.26	1.0	14.1
Age 12+	0.200	0.26	1.0	16.6
Age 13+	0.200	0.26	1.0	19.4
Age 14+	0.200	0.26	1.0	22.5

Sources: Wang and Kernehan, 1979; Grimes et al., 1989; Bolz et al., 2000; Packer et al., 1999; NOAA, 2001b; PG&E National Energy Group, 2001; and Froese and Pauly, 2003.

Table D1-23: Weakfish Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000787
Yolksac larvae	1.34	0	0	0.0000000882
Post-yolksac larvae	6.33	0	0	0.000000382
Juvenile 1	2.44	0	0	0.0000184
Juvenile 2	1.48	0	0	0.0502
Age 1+	0.349	0.25	0.10	0.260
Age 2+	0.250	0.25	0.50	0.680
Age 3+	0.250	0.25	1.0	1.12
Age 4+	0.250	0.25	1.0	1.79
Age 5+	0.250	0.25	1.0	2.91
Age 6+	0.250	0.25	1.0	6.21
Age 7+	0.250	0.25	1.0	7.14
Age 8+	0.250	0.25	1.0	9.16
Age 9+	0.250	0.25	1.0	10.8
Age 10+	0.250	0.25	1.0	12.5
Age 11+	0.250	0.25	1.0	12.5
Age12+	0.250	0.25	1.0	12.5
Age 13+	0.250	0.25	1.0	12.5
Age 14+	0.250	0.25	1.0	12.5
Age 15+	0.250	0.25	1.0	12.5

Sources: Thomas, 1971; and PSE&G, 1999.

Table D1-24: Weakfish Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000787
Larvae	7.70	0	0	0.000000235
Juvenile	3.92	0	0	0.0251
Age 1+	0.349	0.25	0.10	0.260
Age 2+	0.250	0.25	0.50	0.680
Age 3+	0.250	0.25	1.0	1.12
Age 4+	0.250	0.25	1.0	1.79
Age 5+	0.250	0.25	1.0	2.91
Age 6+	0.250	0.25	1.0	6.21
Age 7+	0.250	0.25	1.0	7.14
Age 8+	0.250	0.25	1.0	9.16
Age 9+	0.250	0.25	1.0	10.8
Age 10+	0.250	0.25	1.0	12.5
Age 11+	0.250	0.25	1.0	12.5
Age12+	0.250	0.25	1.0	12.5
Age 13+	0.250	0.25	1.0	12.5
Age 14+	0.250	0.25	1.0	12.5
Age 15+	0.250	0.25	1.0	12.5

Sources: Thomas, 1971; and PSE&G, 1999.

Table D1-25: White Perch Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.75	0	0	0.000000330
Yolksac larvae	2.10	0	0	0.000000353
Post-yolksac larvae	3.27	0	0	0.00000507
Juvenile 1	0.947	0	0	0.000317
Juvenile 2	0.759	0	0	0.00486
Age 1+	0.693	0	0	0.0198
Age 2+	0.693	0	0	0.0567
Age 3+	0.693	0.15	0.00080	0.103
Age 4+	0.689	0.15	0.027	0.150
Age 5+	1.58	0.15	0.21	0.214
Age 6+	1.54	0.15	0.48	0.265
Age 7+	1.48	0.15	0.84	0.356
Age 8+	1.46	0.15	1.0	0.387
Age 9+	1.46	0.15	1.0	0.516
Age 10+	1.46	0.15	1.0	0.619

Sources: Horseman and Shirey, 1974; and PSE&G, 1999.

Table D1-26: White Perch Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.75	0	0	0.000000330
Larvae	5.37	0	0	0.00000271
Juvenile	1.71	0	0	0.00259
Age 1+	0.693	0	0	0.0198
Age 2+	0.693	0	0	0.0567
Age 3+	0.693	0.15	0.00080	0.103
Age 4+	0.689	0.15	0.027	0.150
Age 5+	1.58	0.15	0.21	0.214
Age 6+	1.54	0.15	0.48	0.265
Age 7+	1.48	0.15	0.84	0.356
Age 8+	1.46	0.15	1.0	0.387
Age 9+	1.46	0.15	1.0	0.516
Age 10+	1.46	0.15	1.0	0.619

Sources: Horseman and Shirey, 1974; and PSE&G, 1999.

Table D1-27: White Perch Life History Parameters 3

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.75	0	0	0.000000330
Yolksac larvae	2.10	0	0	0.000000353
Post-yolksac larvae	3.27	0	0	0.00000507
Juvenile	1.71	0	0	0.00259
Age 1+	0.693	0	0	0.0198
Age 2+	0.693	0	0	0.0567
Age 3+	0.693	0.15	0.00080	0.103
Age 4+	0.689	0.15	0.027	0.150
Age 5+	1.58	0.15	0.21	0.214
Age 6+	1.54	0.15	0.48	0.265
Age 7+	1.48	0.15	0.84	0.356
Age 8+	1.46	0.15	1.0	0.387
Age 9+	1.46	0.15	1.0	0.516
Age 10+	1.46	0.15	1.0	0.619

Sources: Horseman and Shirey, 1974; and PSE&G, 1999.

Table D1-28: Windowpane Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.41	0	0	0.00000154
Larvae	6.99	0	0	0.00165
Juvenile	2.98	0	0	0.00223
Age 1+	0.420	0	0	0.0325
Age 2+	0.420	1.6	0.25	0.122
Age 3+	0.420	1.6	0.61	0.265
Age 4+	0.420	1.6	1.0	0.433
Age 5+	0.420	1.6	1.0	0.603
Age 6+	0.420	1.6	1.0	0.761
Age 7+	0.420	1.6	1.0	0.899
Age 8+	0.420	1.6	1.0	1.02
Age 9+	0.420	1.6	1.0	1.11
Age 10+	0.420	1.6	1.0	1.19

Sources: Hendrickson, 2000; PG&E National Energy Group, 2001; USGen New England, 2001; and Froese and Pauly, 2003.

Table D1-29: Winter Flounder Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.00000115
Larvae	4.37	0	0	0.0138
Juvenile	2.38	0	0	0.0330
Age 1+	1.10	0.24	0.01	0.208
Age 2+	0.924	0.24	0.29	0.562
Age 3+	0.200	0.24	0.80	0.997
Age 4+	0.200	0.24	0.92	1.42
Age 5+	0.200	0.24	0.83	1.78
Age 6+	0.200	0.24	0.89	2.07
Age 7+	0.200	0.24	0.89	2.29
Age 8+	0.200	0.24	0.89	2.45
Age 9+	0.200	0.24	0.89	2.57
Age 10+	0.200	0.24	0.89	2.65
Age 11+	0.200	0.24	0.89	2.71
Age 12+	0.200	0.24	0.89	2.75
Age 13+	0.200	0.24	0.89	2.78
Age 14+	0.200	0.24	0.89	2.80
Age 15+	0.200	0.24	0.89	2.82
Age 16+	0.200	0.24	0.89	2.83

Sources: Able and Fahay, 1998; Colarusso, 2000; Nitschke et al., 2000; and PG&E National Energy Group, 2001.

Table D1-30: Other Commercial Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.5	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes American butterfish, American eel, brown bullhead, channel catfish, conger eel, gizzard shad, harvestfish, silver hake, white catfish, and yellow perch.

Sources: Durbin et al., 1983; Able and Fahay, 1998; and PSE&G, 1999.

Table D1-31: Other Recreational Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.5	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes black drum, black sea bass, bluefish, northern puffer, northern searobin, orange filefish, oyster toadfish, sea lamprey, spotted hake, and spotted seatrout.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table D1-32: Other Recreational and Commercial Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Yolksac larvae	2.85	0	0	0.000000728
Post-yolksac larvae	2.85	0	0	0.00000335
Juvenile 1	1.43	0	0	0.000746
Juvenile 2	1.43	0	0	0.0472
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.5	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes species designated as other commercial from Salem.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table D1-33: Other Forage Species Life History Parameters 1[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Yolksac larvae	1.57	0	0	0.0000000441
Post-yolksac larvae 1	2.11	0	0	0.0000000929
Post-yolksac larvae 2	4.02	0	0	0.00000461
Juvenile 1	0.0822	0	0	0.0000495
Juvenile 2	0.0861	0	0	0.000199
Juvenile 3	0.129	0	0	0.000532
Juvenile 4	0.994	0	0	0.001161
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] Includes species designated as other forage from Salem.

Sources: Derickson and Price, 1973; and PSE&G, 1999.

Table D1-34: Other Forage Species Life History Parameters 2[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Larvae	7.70	0	0	0.00000158
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] Includes Atlantic herring, Atlantic needlefish, Atlantic silverside, banded killifish, blackcheek tonguefish, bluegill, chain pickerel, fourspine stickleback, golden shiner, inland silverside, inshore lizardfish, lined seahorse, mississippi silvery minnow, mud minnow, mummichog, northern pipefish, northern stargazer, pumpkinseed, sheepshead minnow, skilletfish, spottail shiner, spotted codling, striped anchovy, striped blenny, striped killifish, threespine stickleback, and other organisms not identified to species.

Sources: Derickson and Price, 1973; and PSE&G, 1999.

Table D1-35: Other Forage Species Life History Parameters 3[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Yolksac larvae	1.57	0	0	0.0000000441
Post-yolksac larvae	6.10	0	0	0.00000662
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] Includes inland silverside, river herring, and silversides not identified to species.

Sources: Derickson and Price, 1973; and PSE&G, 1999.

Appendix D2: Reductions in I&E in the Mid-Atlantic Region Under Five Other Options Evaluated for the Proposed Section 316(b) Phase III Regulation

Table D2-1: Estimated Reductions in I&E in the Mid-Atlantic Region Under Five Other Options Evaluated for the Proposed Section 316(b) Regulation

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
20 MGD All	13,600,000	610,000
2	13,600,000	610,000
3	13,400,000	606,000
4	13,600,000	610,000
All Phase III Facilities	13,700,000	615,000

Appendix D3: Commercial Fishing Benefits for Five Other Options Evaluated for Phase III Existing Facilities in the Mid-Atlantic Region

Section D3-2 in Chapter D3 displays the results of the commercial fishing benefits analysis for the 50 MGD option, the 200 MGD option, and the 100 MGD option. To facilitate comparisons among the options, this appendix displays results for the following additional options: All Potentially Regulated Phase III Existing Facilities option (All Phase III Facilities); the 20 MGD option (20 MGD All); Option 2; Option 3; and Option 4.

Table D3-1: Annualized Commercial Fishing Benefits Attributable to the All Phase III Facilities Option at Facilities in the Mid-Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$45,600	$79,600	$125,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$18,200	$31,800	$50,100
Expected reduction due to rule	75%	56%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$31,400
3% discount rate			$25,500
7% discount rate			$19,600

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table D3-2: Annualized Commercial Fishing Benefits Attributable to the 20 MGD All Option at Facilities in the Mid-Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$45,600	$79,600	$125,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$18,200	$31,800	$50,100
Expected reduction due to rule	74%	55%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$31,100
3% discount rate			$25,300
7% discount rate			$19,400

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table D3-3: Annualized Commercial Fishing Benefits Attributable to Option 2 at Facilities in the Mid-Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$45,600	$79,600	$125,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$18,200	$31,800	$50,100
Expected reduction due to rule	74%	55%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$31,100
3% discount rate			$25,300
7% discount rate			$19,400

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table D3-4: Annualized Commercial Fishing Benefits Attributable to Option 3 at Facilities in the Mid-Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$45,600	$79,600	$125,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$18,200	$31,800	$50,100
Expected reduction due to rule	74%	55%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$30,900
3% discount rate			$25,100
7% discount rate			$19,200

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table D3-5: Annualized Commercial Fishing Benefits Attributable to Option 4 at Facilities in the Mid-Atlantic Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss - gross revenue			
Undiscounted	$45,600	$79,600	$125,000
Producer surplus lost - low	$0	$0	$0
Producer surplus lost - high (gross revenue * 0.4)			
Undiscounted	$18,200	$31,800	$50,100
Expected reduction due to rule	74%	55%	
Benefits attributable to rule - low	$0	$0	$0
Benefits attributable to rule - high			
Undiscounted			$31,100
3% discount rate			$25,300
7% discount rate			$19,400

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Appendix D4: Recreational Use Benefits of Other Policy Options

Introduction

Chapter D4 presents EPA's estimates of the recreational benefits of the three proposed options for the section 316(b) rule for Phase III facilities, for electric generators and manufacturers in the Mid-Atlantic region. This appendix supplements Chapter D4 by presenting estimates of the recreational fishing benefits of five other options that EPA evaluated for the purpose of comparison:

- Option 3,
- Option 4,
- Option 2,
- Option 1, and
- Option 6.

Appendix Contents

Recreational fishing benefits presented in this chapter were estimated using the benefit transfer approach discussed in Chapter D4 and in Chapter A5, "Recreational Fishing Benefits Methodology."

D4-1 Recreational Fishing Benefits of the Other Evaluated Options

D4-1.1 Estimated Reductions in Recreational Fishing Losses under the Other Evaluated Options

Table D4-1 presents EPA's estimates of the annual reduction in baseline (i.e., current) recreational fishing losses from impingement and entrainment (I&E) in the Mid-Atlantic region under the other evaluated options.

Table D4-1: Reductions in Recreational Fishing Losses from I&E under the Other Evaluated Options in the Mid-Atlantic Region

Species[a]	Annual Reduction in Recreational Losses (# of fish)[b]				
	Option 3	Option 4	Option 2	Option 1	Option 6
Striped bass	1,630	1,652	1,652	1,652	1,666
Weakfish	3,406	3,444	3,444	3,444	3,474
Total (small game)	**5,036**	**5,096**	**5,096**	**5,096**	**5,140**
Summer flounder	322	322	322	322	325
Winter flounder	177	179	179	179	181
Total (flatfish)	**499**	**501**	**501**	**501**	**506**
Atlantic croaker	25,762	26,152	26,152	26,152	26,378
Spot	100,509	101,671	101,671	101,671	102,550
White perch	537	541	541	541	545
Total (other saltwater)	**126,808**	**128,365**	**128,365**	**128,365**	**129,475**
Total (unidentified)	**26,783**	**27,152**	**27,152**	**27,152**	**27,387**
Total (all species)	***159,127***	***161,115***	***161,115***	***161,115***	***162,508***

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The ‘other saltwater’ group includes bottomfish and other miscellaneous species. The ‘unidentified’ group includes fish lost indirectly through trophic transfer.

[b] In the Mid-Atlantic region, the set of facilities with technology requirements under Option 1 is the same as under Option 4 and Option 2. Thus, reductions in recreational losses under these options are also identical.

Source: U.S. EPA analysis for this report.

D4-1.2 Recreational Fishing Benefits of the Other Evaluated Options

Tables D4-2 throuh D4-4 present EPA's estimates of the annualized recreational benefits of the other evaluated options in the Mid-Atlantic region.

In the Mid-Atlantic region, all potentially regulated facilities that would install new technology under Option 4, Option 2, and Option 1 have design intake flows greater than 20 MGD. Because the requirements under these four options are identical for this class of facilities, the I&E reductions and benefits resulting from these four options are also identical. Thus, the benefits estimates presented in Table D4-3 apply to all four options.

Table D4-2: Recreational Fishing Benefits of Option 3 in the Mid-Atlantic Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Small game	5.0	$2.74	$6.87	$16.94	$13.8	$34.6	$85.3
Flatfish	0.5	$3.28	$6.91	$14.71	$1.6	$3.5	$7.3
Other saltwater	126.8	$1.79	$3.73	$7.83	$226.4	$473.0	$993.0
Unidentified	26.8	$1.83	$3.86	$8.20	$48.9	$103.4	$219.6
Total (undiscounted)	**159.1**				**$290.7**	**$614.4**	**$1,305.3**
Total (evaluated at 3%)	**159.1**				**$236.3**	**$499.4**	**$1,061.1**
Total (evaluated at 7%)	**159.1**				**$181.4**	**$383.3**	**$814.4**

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[b] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

Table D4-3: Recreational Fishing Benefits of Option 4, Option 2, and Option 1, in the Mid-Atlantic Region (2003$)[a]

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	5.1	$2.74	$6.87	$16.94	$13.9	$35.0	$86.4
Flatfish	0.5	$3.28	$6.91	$14.71	$1.6	$3.5	$7.4
Other saltwater	128.4	$1.79	$3.73	$7.83	$229.1	$478.8	$1,005.2
Unidentified	27.2	$1.83	$3.86	$8.20	$49.6	$104.8	$222.6
Total (undiscounted)	**161.1**				**$294.3**	**$622.1**	**$1,321.6**
Total (evaluated at 3%)	**161.1**				**$239.2**	**$505.7**	**$1,074.3**
Total (evaluated at 7%)	**161.1**				**$183.6**	**$388.1**	**$824.6**

[a] In the Mid-Atlantic region, the set of facilities with technology requirements under Option 4 is the same as under Option 2 and Option 1. Thus, reductions in recreational losses under these options are also identical.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

Table D4-4: Recreational Fishing Benefits of Option 6 in the Mid-Atlantic Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Small game	5.1	$2.74	$6.87	$16.94	$14.1	$35.3	$87.1
Flatfish	0.5	$3.28	$6.91	$14.71	$1.7	$3.5	$7.4
Other saltwater	129.5	$1.79	$3.73	$7.83	$231.1	$482.9	$1,013.9
Unidentified	27.4	$1.83	$3.86	$8.20	$50.0	$105.7	$224.5
Total (undiscounted)	**162.5**				**$296.9**	**$627.4**	**$1,333.0**
Total (evaluated at 3%)	**162.5**				**$241.2**	**$509.8**	**$1,083.0**
Total (evaluated at 7%)	**162.5**				**$185.0**	**$391.0**	**$830.8**

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[b] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

D4-2 Comparison of Recreational Fishing Benefits by Option

Table D4-5 compares the recreational fishing benefits of the five other evaluated options. The table shows that annual recreational fishing benefits are very similar under all of the options.

Table D4-5: Annual Recreational Benefits of the Other Evaluated Options in the Mid-Atlantic Region

Policy Option[a]	Annual Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands; 2003$)[b]		
		Low	Mean	High
Option 3	159.1	$290.7	$614.4	$1,305.3
Option 4	161.1	$294.3	$622.1	$1,321.6
Option 2	161.1	$294.3	$622.1	$1,321.6
Option 1	161.1	$294.3	$622.1	$1,321.6
Option 6	162.5	$296.9	$627.4	$1,333.0

[a] In the Mid-Atlantic region, the set of facilities with technology requirements under Option 4 is the same as under Option 2 and Option 1. Thus, reductions in recreational losses under these options are also identical.
[b] These benefit estimates were calculated using the meta-analysis approach discussed in Chapter A5 and Chapter D4. EPA did not use the RUM approach from the Phase II analysis to analyze the other evaluated options.

Source: U.S. EPA analysis for this report.

Part E: Gulf of Mexico

Chapter E1: Background

Introduction

Chapter Contents

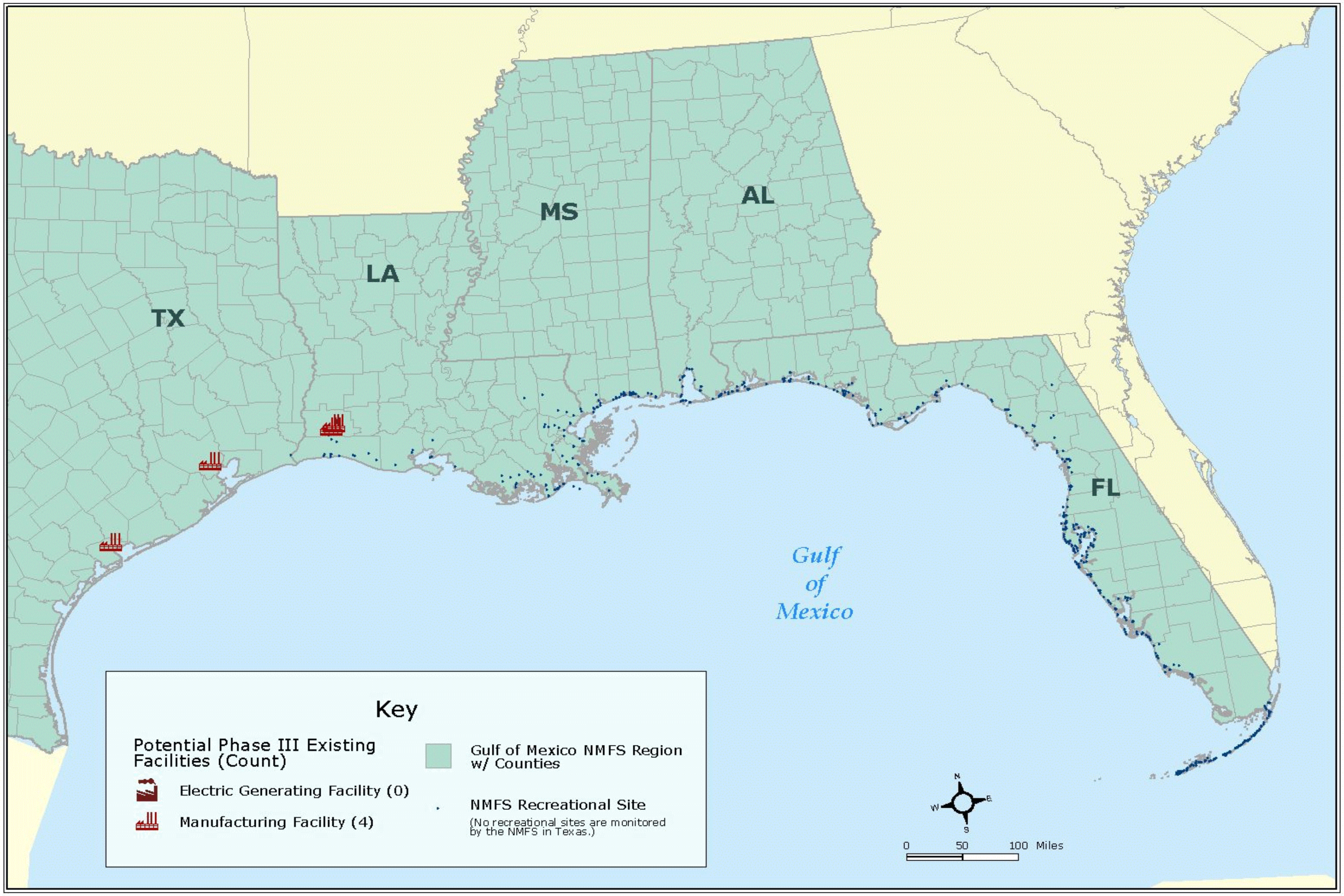
This chapter presents an overview of the potential Phase III existing facilities in the Gulf of Mexico study region and summarizes their key cooling water and compliance characteristics. For further discussion of the technical and compliance characteristics of potential Phase III existing facilities, refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* and the *Technical Development Document for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a,b).

E1-1 Facility Characteristics

The Gulf of Mexico Regional Study includes four sample facilities that are potentially subject to the proposed standards for Phase III existing facilities. All four facilities are manufacturing facilities. Industry-wide, these four sample facilities represent 11 manufacturing facilities.[1] Figure E1-1 presents a map of these facilities.

[1] EPA applied sample weights to the survey respondents to account for non-sampled facilities and facilities that did not respond to the survey. For more information on EPA's 2000 Section 316(b) Industry Survey, please refer to the Information Collection Request (U.S. EPA, 2000).

Figure E1-1: Potential Existing Phase III Facilities in the Gulf of Mexico Regional Study



Source: U.S. EPA analysis for this report.

Table E1-1 summarizes key technical and compliance characteristics for all potentially regulated Phase III existing facilities in the Gulf of Mexico study region and for the three proposed regulatory options considered by EPA for this proposal (the “50 MGD for All Waterbodies” option, the “200 MGD for All Waterbodies” option, and the “100 MGD for Certain Waterbodies” option). Facilities with a design intake flow below the three applicability thresholds would be subject to permitting based on best professional judgment and are excluded from EPA’s analyses.[2] Therefore, a different number of facilities is affected under each option.

Table E1-1 shows that 11 Phase III existing facilities in the Gulf of Mexico study region would potentially be subject to the national requirements. Under the “50 MGD for All Waterbodies” option, the most inclusive of the three proposed options, seven facilities would be subject to the national requirements for Phase III existing facilities. Under the less inclusive “200 MGD for All Waterbodies” option, two facilities would be subject to the national requirements. Seven facilities would also be subject to the national requirements under the “100 MGD for Certain Waterbodies” option. No facility in the Gulf of Mexico study region has a recirculating system in the baseline. Data on design intake flow for the Gulf of Mexico study facilities have been withheld due to data confidentiality reasons.

Table E1-1: Technical and Compliance Characteristics of Existing Phase III Facilities (Sample-Weighted)

	All Potentially Regulated Facilities	**Proposed Options**		
		50 MGD All	**200 MGD All**	**100 MGD CWB**
Total Number of Facilities (Sample-Weighted)	**11**	**7**	**2**	**7**
Number of Facilities with Recirculating System in Baseline	**-**	**-**	**-**	**-**
Design Intake Flow (MGD)	**w[a]**	**w[a]**	**w[a]**	**w[a]**
Number of Facilities by Compliance Response				
New larger intake structure with fine mesh and fish H&R	7	7	2	7
Passive fine mesh screens	4	-	-	-
Compliance Cost at 3%[b]	$14.50	$9.07	$3.83	$9.07
Compliance Cost at 7%[b]	$17.01	$10.21	$4.38	$10.21

[a] Data withheld because of confidentiality reasons.
[b] Annualized pre-tax compliance cost (2003$, millions)

Source: U.S. EPA, 2000; U.S. EPA analysis for this report.

[2] Also excluded are facilities that are estimated to be baseline closures. For additional information on EPA’s baseline closure analyses, please refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a).

Chapter E2: Evaluation of Impingement and Entrainment in the Gulf of Mexico

Chapter Contents

Background: Gulf of Mexico Marine Fisheries

Important marine fisheries of the Gulf of Mexico include both migratory pelagic species and reef fishes. Coastal pelagic fishes include king mackerel, Spanish mackerel, cero, dolphinfish, and cobia. These species range from the northeastern U.S. through the Gulf of Mexico and Caribbean Sea, and as far south as Brazil (NMFS, 1999a). They are managed under the Coastal Migratory Pelagic Resources Fishery Management Plan and regulations of the South Atlantic and Gulf of Mexico Fishery Management Councils, which are implemented by the National Marine Fisheries Service. King and Spanish mackerel make up nearly 95% of harvested coastal pelagic species, and are managed as two separate groups, the Gulf group and the Atlantic group (NMFS, 1999a). Most of the commercial catch of Spanish mackerel is landed in Florida. Up to 40% of the Gulf stock is also recreationally fished. Dolphinfish and cobia are also important recreational species, but the status of these stocks is uncertain (NMFS, 1999a).

Reef fishes include over 100 species ranging from North Carolina through the Gulf of Mexico and the Caribbean Sea that are important for commercial and recreational anglers (NMFS, 1999a). Many reef fisheries are closely associated with other managed reef animals, including spiny lobster and stone crab. In the Gulf of Mexico, reef fisheries include snapper and grouper species as well as grunts, amberjacks, and seabasses. Although landings of individual species aren't large, collectively reef fisheries have significant landings and value (NMFS, 1999a). However, stock status of many of these species remains unknown. Red snapper, the most important Gulf reef fish, is considered overutilized, in part because it is caught incidentally by the shrimp fishery (NMFS, 1999a).

E2-1 I&E Species/Species Groups Evaluated

Table E2-1 provides a list of species/species groups that were evaluated in EPA's analysis of impingement and entrainment (I&E) in the Gulf region.

Table E2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in the Gulf of Mexico

Species/Species Group	Recreational	Commercial	Forage
Atlantic croaker	X	X	
Bay anchovy			X
Black drum	X	X	
Blue crab		X	
Chain pipefish			X
Gobies			X

Table E2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in the Gulf of Mexico

Species/Species Group	Recreational	Commercial	Forage
Gulf killifish			X
Hogchoker			X
Leatherjacket		X	
Mackerel	X	X	
Menhaden		X	
Other (commercial)		X	
Other (forage)			X
Other (recreational)	X		
Pinfish	X		
Pink shrimp		X	
Red drum	X		
Scaled sardine			X
Sea basses	X	X	
Searobin	X		
Sheepshead	X	X	
Silver perch	X		
Spot	X	X	
Spotted seatrout	X		
Stone crab		X	
Striped mullet	X	X	
Tidewater silverside			X

The life history data used in EPA's analysis and associated data sources are provided in Appendix E1 of this report.

E2-2 I&E Data Evaluated

Table E2-2 lists the facility I&E data evaluated by EPA to estimate current I&E rates for the region. Because EPA found no I&E data for Phase III facilities in this region, EPA developed I&E estimates for these facilities by extrapolation of I&E estimates of Phase II facilities. See Chapter A1 of Part A for a discussion of extrapolation methods.

Table E2-2: Phase II Facility I&E Data Evaluated for the Gulf of Mexico Analysis

Facilities	Years of Data
Big Bend (FL)	1976-1979
Crystal River (FL)	1984
P H Robinson (TX)	1978
Webster (TX)	1978

E2-3 EPA's Estimate of Current I&E at Phase III Facilities in the Gulf Region Expressed as Age-1 Equivalents and Foregone Yield

Table E2-3 provides EPA's estimate of the annual age-1 equivalents and foregone fishery yield resulting from the impingement of aquatic species at facilities located in the Gulf region. Table E2-4 displays this information for entrainment. Note that in these tables, "total yield" includes direct losses of harvested species and the yield of harvested species that is lost due to losses of forage species. As discussed in Chapter A1 of Part A of the section 316(b) Phase III Regional Benefits Assessment, the conversion of forage to yield contributes only a very small fraction to total yield.

Table E2-3: Estimated Current Annual Impingement at Phase III Facilities in the Gulf Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Atlantic croaker	455,000	93,900
Bay anchovy	481,000	na
Black drum	3,630	16,300
Blue crab	1,400,000	17,300
Chain pipefish	11,500	na
Gobies	1,680	na
Gulf killifish	5,170	na
Hogchoker	16,400	na
Leatherjacket	35,600	4,460
Mackerel	2,360	326
Menhaden	531,000	105,000
Other (commercial)	62,300	12,300
Other (forage)	37,600	na
Other (recreational)	14,200	2,800
Pinfish	4,970	211
Pink shrimp	2,320,000	21,800
Red drum	22,800	102,000
Scaled sardine	20,900	na
Sea basses	208	45
Searobin	227,000	9,380
Sheepshead	122	<1
Silver perch	57,600	7
Spot	108,000	12,100
Spotted seatrout	175,000	157,000
Stone crab	47,500	34,700
Striped mullet	70,200	33,400
Tidewater silverside	26,600	na
Trophic transfer[a]	na	43

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table E2-4: Estimated Current Annual Entrainment at Phase III Facilities in the Gulf Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Atlantic croaker	212	44
Bay anchovy	1,630,000	na
Black drum	265,000	1,190,000
Blue crab	1,290,000	15,900
Chain pipefish	4,500	na
Gobies	181,000	na
Hogchoker	3,640	na
Leatherjacket	2,130	267
Menhaden	6,490	1,280
Other (commercial)	4,340	857
Other (forage)	1,170,000	na
Other (recreational)	7,870	1,550
Pinfish	136,000	5,760
Pink shrimp	869,000	8,170
Red drum	1,830	8,250
Scaled sardine	75,900	na
Searobin	46,200	1,910
Sheepshead	4,400	15
Silver perch	599,000	70
Spot	11,300	1,270
Spotted seatrout	8,500	7,610
Stone crab	52,500	38,400
Striped mullet	166,000	78,800
Tidewater silverside	41,600	na
Trophic transfer[a]	na	2,100

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

E2-4 Reductions in I&E at Phase III Facilities in the Gulf of Mexico Region Under Three Alternative Options

Table E2-5 presents estimated reductions in I&E under the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD for Certain Waterbodies" option. Reductions under all other options are presented in Appendix E2.

Table E2-5: Estimated Reductions in I&E Under Three Alternative Options

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
50 MGD All Option	8,380,000	1,250,000
200 MGD All Option	4,580,000	682,000
100 MGD Option	8,380,000	1,250,000

E2-5 Assumptions Used in Calculating Recreational and Commercial Losses

The lost yield estimates presented in Tables E2-3 and E2-4 are expressed as total pounds and include losses to both commercial and recreational catch. To estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table E2-6 presents the percentage impacts assumed for each species/species group. Commercial and recreational fishing benefits are presented in Chapters E3 and E4.

Table E2-6: Percentage of Total Impacts Occurring to the Commercial and Recreational Fisheries and Commercial Value per Pound for Species Impinged and Entrained at Gulf of Mexico Facilities

Species/Species Group	Percent Impact to Recreational Fishery[a,b]	Percent Impact to Commercial Fishery[a,b]
Atlantic croaker	88.2%	11.8%
Black drum	93.0%	7.0%
Blue crab	0.0%	100.0%
Leatherjacket	0.0%	100.0%
Mackerel	73.5%	26.5%
Menhaden	0.0%	100.0%
Other (commercial)	0.0%	100.0%
Other (recreational)	100.0%	0.0%
Pinfish	100.0%	0.0%
Pink shrimp	0.0%	100.0%
Red drum	100.0%	0.0%
Sea basses	86.0%	14.0%
Searobin	100.0%	0.0%
Sheepshead	67.0%	33.0%
Silver perch	100.0%	0.0%
Spot	23.9%	76.1%
Spotted seatrout	100.0%	0.0%
Stone crab	0.0%	100.0%
Striped mullet	10.1%	89.9%
Trophic transfer[d]	50.0%	50.0%

[a] Based on landings from 1993-2001 in Alabama, Florida (west coast), Louisiana, and Mississippi. Recreational landings data for Texas are not collected by NMFS.
[b] Calculated using recreational landings data from NMFS (2003b, http://www.st.nmfs.gov/recreational/queries/catch/snapshot.html) and commercial landings data from NMFS (2003a, http://www.st.nmfs.gov/commercial/landings/annual_landings.html).
[c] Calculated using commercial landings data from NMFS (2003a).
[d] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

See Chapter E3 for results of the commercial fishing benefits analysis and Chapter E4 for recreational fishing results. As discussed in Chapter A8, benefits were discounted to account for 1) the time to achieve compliance once the rule goes into effect in 2007, and 2) the time it takes for fish spared from I&E to reach a harvestable age.

Chapter E3: Commercial Fishing Valuation

Introduction

This chapter presents the results of the commercial fishing benefits analysis for the Gulf of Mexico region. Section E3-1 details the estimated losses under current, or baseline, conditions. Section E3-2 presents expected benefits under three alternative options. Chapter A4 details the methods used in this analysis.

Chapter Contents

E3-1 Baseline Losses

Table E3-1 provides EPA's estimate of the value of gross revenues lost in commercial fisheries resulting from the impingement of aquatic species at facilities in the Gulf of Mexico region. Table E3-2 displays this information for entrainment. Total annualized revenue losses are approximately $357,000 (undiscounted).

Table E3-1: Annualized Commercial Fishing Gross Revenues Lost due to Impingement at Facilities in the Gulf of Mexico Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
Atlantic croaker	11,100	$0.24	$2,670
Black drum	1,150	$0.68	$788
Blue crab	17,300	$0.67	$11,600
Leatherjacket	4,460	$1.10	$4,920
Mackerels	86	$0.47	$40
Menhaden	105,000	$0.06	$5,810
Other (species are only commercially fished, not recreationally)	12,300	$0.58	$7,160
Pink shrimp	21,800	$2.42	$52,800
Sea basses	6	$0.55	$4
Spot	9,230	$0.28	$2,590
Stone crab	34,700	$1.50	$52,000
Striped mullet	30,000	$0.69	$20,700
Trophic transfer[b]	22	$0.47	$10

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table E3-2: Annualized Commercial Fishing Gross Revenues Lost due to Entrainment at Facilities in the Gulf of Mexico Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
Black drum	84,100	$0.68	$57,500
Blue crab	15,900	$0.67	$10,600
Leatherjacket	267	$1.10	$294
Menhaden	1,280	$0.06	$71
Other (species are only commercially fished, not recreationally)	857	$0.58	$498
Pink shrimp	8,170	$2.42	$19,800
Sheepshead	5	$0.33	$2
Spot	965	$0.28	$270
Stone crab	38,400	$1.50	$57,600
Striped mullet	70,900	$0.69	$48,900
Trophic transfer[b]	1,050	$0.47	$494

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

E3-2 Expected Benefits Under Three Alternative Options

As described in Chapter A4, EPA estimates that 0 to 40% of the gross revenue losses represent surplus losses to producers, assuming no change in prices or fishing costs. The 0% estimate, of course, results in loss estimates of $0. The 40% estimates, as presented in Tables E3-3, E3-4, and E3-5, total approximately $143,000 (undiscounted).

The expected reductions in impingement and entrainment (I&E) attributable to changes at facilities required by the “50 MGD for All Waterbodies” option (50 MGD option) are 76% for impingement and 57% for entrainment, for the “200 MGD for All Waterbodies” option (200 MGD option) are 41% for impingement and 31% for entrainment, and for the “100 MGD for Certain Waterbodies” option (100 MGD option) are 76% for impingement and 57% for entrainment. Total annualized benefits are estimated by applying these estimated reductions to the annual producer surplus loss. As presented in Tables E3-3, E3-4, and E3-5, this results in total annualized benefits of up to approximately $78,100 for the 50 MGD option, $42,700 for the 200 MGD option, and $78,100 for the 100 MGD option, assuming a 3% discount rate.

Table E3-3: Annualized Commercial Fishing Benefits Attributable to the 50 MGD Option at Facilities in the Gulf of Mexico Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$161,000	$196,000	$357,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$64,500	$78,400	$143,000
Expected reduction due to rule	76%	57%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$93,300
3% discount rate			$78,100
7% discount rate			$62,200

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table E3-4: Annualized Commercial Fishing Benefits Attributable to the 200 MGD Option at Facilities in the Gulf of Mexico Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$161,000	$196,000	$357,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$64,500	$78,400	$143,000
Expected reduction due to rule	41%	31%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$51,000
3% discount rate			$42,700
7% discount rate			$34,000

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table E3-5: Annualized Commercial Fishing Benefits Attributable to the 100 MGD Option at Facilities in the Gulf of Mexico Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$161,000	$196,000	$357,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$64,500	$78,400	$143,000
Expected reduction due to rule	76%	57%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$93,300
3% discount rate			$78,100
7% discount rate			$62,200

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Chapter E4: Recreational Use Benefits

Introduction

This chapter presents the results of the recreational fishing benefits analysis for the Gulf of Mexico region. The chapter presents EPA's estimates of baseline (i.e., current) annual recreational fishery losses from impingement and entrainment (I&E) at potentially regulated facilities in the Gulf of Mexico region and annual reduction in these losses under the three proposed regulatory options for Phase III existing facilities:[1]

- the "50 MGD for All Waterbodies" option,
- the "200 MGD for All Waterbodies" option, and
- the "100 MGD for Certain Waterbodies" option.

The chapter then presents the estimated welfare gain to Gulf of Mexico anglers from eliminating baseline recreational fishing losses from I&E and the expected benefits under the three proposed options.

EPA estimated the recreational benefits of reducing and eliminating I&E losses using a benefit transfer methodology based on a meta-analysis of the marginal value of catching different species of fish. This meta-analysis is discussed in detail in Chapter A5, "Recreational Fishing Benefits Methodology." To validate these results, this chapter also presents the results of a random utility model (RUM) analysis for the Gulf of Mexico region. A detailed discussion of the RUM analysis for the Gulf of Mexico region can be found in Chapter F4 of the final Phase II Regional Studies report (U.S. EPA, 2004).

EPA considered a wide range of policy options in developing this regulation. Results of the recreational fishing benefits analysis for five other options evaluated by EPA are presented in Appendix E4.

Chapter Contents

[1] See the introduction to this report for a description of the three proposed options.

E4-1 Benefit Transfer Approach Based on Meta-Analysis

EPA estimated the recreational welfare gain from the reduction in annual I&E losses expected under the policy options, and the welfare gain from eliminating I&E at potentially regulated facilities, using a benefit transfer approach. As discussed in Chapter A5, the Agency used the meta-analysis regression equation to estimate the marginal recreational value per additional fish caught by anglers, for different species in different regions. Since I&E at potentially regulated facilities affects a variety of species, EPA assigned each species with I&E losses to one of the general species groups used in the meta-analysis. The Agency then calculated the economic value of reducing or eliminating baseline I&E losses, for each species group, by multiplying the value per fish for that species group by the number of fish in the group that are lost in the baseline or saved under the policy options.[2]

In general, the fit between the species with I&E losses and the species groups in the meta-analysis was good. However, EPA's estimates of baseline I&E losses and reductions in I&E under the policy options included losses of 'unidentified' species. The 'unidentified' group includes fish lost indirectly through trophic transfer, as well as species for which no species information was available.[3] Rather than using the meta-analysis regression to try to predict the value per fish for an "unidentified" species, EPA assumed that per-fish values for these species can be approximated by the weighted average value per fish for all species affected by I&E in the Gulf of Mexico region.[4]

E4-1.1 Estimated Reductions in Recreational Fishery Losses under the Proposed Regulation

Table E4-1 presents EPA's estimates of baseline (i.e., current) annual recreational I&E losses at potentially regulated facilities, and annual reductions in these losses under each of the proposed options, in the Gulf of Mexico region. The table shows that total baseline losses to recreational fisheries are 270.6 thousand fish per year. In comparison, the "50 MGD for All Waterbodies"and "100 MGD for Certain Waterbodies" options prevent losses of 183.1 thousand fish per year, and the "200 MGD for All Waterbodies" option prevents losses of 100.0 thousand fish per year. Of all the affected species, black drum and spotted seatrout have the highest losses in the baseline and the highest prevented losses under the proposed options.

[2] Note that the estimates of I&E presented in this chapter include only the fraction of impinged and entrained recreational fish that would otherwise be caught by anglers. The total amount of I&E of recreational species is actually much higher.

[3] In addition to recreational fish that are lost because they are impinged or entrained, some recreational fish are lost because the forage fish that they feed on are impinged or entrained, and thus removed from the food chain. These trophic transfer losses of recreational species are included in EPA's estimates of total I&E losses. However, since it is difficult to predict which recreational species would be affected by losses of forage fish, these losses are classified as 'unidentified' recreational species. Also included in the 'unidentified' group are losses of fish that were reported by facilities without information about their exact species.

[4] EPA used the estimated level of baseline recreational losses for each species group as a weighting factor.

Table E4-1: Baseline Recreational Fishing Losses from I&E at Potentially Regulated Phase III Facilities and Reductions in Recreational Losses under the Proposed Regulatory Options in the Gulf of Mexico Region

Species[a]	Baseline Annual Recreational Fishing Losses (# of fish)	Annual Reductions in Recreational Fishing Losses (# of fish)		
		50 MGD All	200 MGD All	100 MGD CWB
Mackerels	336	254	139	254
Red drum	6,869	5,104	2,789	5,104
Spotted seatrout	66,981	50,133	27,392	50,133
Total (small game)	**74,186**	**55,492**	**30,320**	**55,492**
Atlantic croaker	49,288	37,318	20,390	37,318
Black drum	69,758	39,796	21,744	39,796
Pinfish	32,936	18,926	10,341	18,926
Sea bass	32	24	13	24
Searobin	24,860	18,030	9,851	18,030
Sheepshead	6	3	2	3
Silver perch	179	105	57	105
Spot	7,737	5,720	3,126	5,720
Striped mullet	3,931	2,454	1,341	2,454
Total (other saltwater)	**188,728**	**122,377**	**66,864**	**122,377**
Total (unidentified)	**7,731**	**5,205**	**2,844**	**5,205**
Total (all species)	***270,645***	***183,074***	***100,028***	***183,074***

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The 'other saltwater' group includes bottomfish and other miscellaneous species. The 'unidentified' group includes fish lost indirectly through trophic transfer.

Source: U.S. EPA analysis for this report.

E4-1.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table E4-2 shows the results of EPA's analysis of the welfare gain to recreational anglers from eliminating baseline recreational fishery losses at potentially regulated facilities in the Gulf of Mexico region. The table presents baseline annual recreational I&E losses, the estimated value per fish, and the monetized annual welfare gain from eliminating recreational losses, for each species group. Total baseline recreational fishing losses for the Gulf of Mexico region are 0.27 million fish per year. The undiscounted annual welfare gain to Gulf of Mexico anglers from eliminating these losses is $0.97 million (2003$), with lower and upper bounds of $0.43 million and $2.17 million. Evaluated at 3% and 7%, the mean annualized welfare gain of eliminating these losses is $0.94 million and $0.90 million, respectively. The majority of monetized recreational losses from I&E under baseline conditions are attributable to losses of spotted seatrout and black drum.

Table E4-2: Recreational Fishing Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the Gulf of Mexico Region (2003$)

Species Group	Baseline Annual Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Benefits from Eliminating Recreational Fishing Losses (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	74.2	$2.30	$5.32	$12.20	$170.6	$394.7	$904.8
Other saltwater	188.7	$1.32	$2.88	$6.38	$249.2	$544.0	$1,203.9
Unidentified	7.7	$1.60	$3.57	$8.02	$12.3	$27.6	$62.0
Total (undiscounted)	**270.6**				**$432.2**	**$966.4**	**$2,170.7**
Total (evaluated at 3%)[c]	**270.6**				**$419.2**	**$937.3**	**$2,105.5**
Total (evaluated at 7%)[c]	**270.6**				**$403.7**	**$902.6**	**$2,027.5**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying baseline losses by the estimated value per fish.
[d] Annualized values represent the total welfare gain over the time frame of the analysis from eliminating recreational losses, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

E4-1.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table E4-3 shows the results of EPA's analysis of the recreational benefits of the "50 MGD for All Waterbodies" option for the Gulf of Mexico region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 0.18 million fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.67 million (2003$), with lower and upper bounds of $0.30 million and $1.50 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.57 million and $0.48 million, respectively. The majority of benefits result from reduced losses of spotted seatrout and black drum.

Table E4-3: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the Gulf of Mexico Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Small game	55.5	$2.30	$5.32	$12.20	$127.6	$295.3	$676.8
Other saltwater	122.4	$1.32	$2.88	$6.38	$161.6	$352.8	$780.6
Unidentified	5.2	$1.60	$3.57	$8.02	$8.3	$18.6	$41.7
Total (undiscounted)	**183.1**				**$297.6**	**$666.6**	**$1,499.2**
Total (evaluated at 3%)[c]	**183.1**				**$249.0**	**$557.8**	**$1,254.3**
Total (evaluated at 7%)[c]	**183.1**				**$198.2**	**$443.9**	**$998.4**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.

[b] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.

[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

E4-1.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

Table E4-3 shows the results of EPA's analysis of the recreational benefits of the "200 MGD for All Waterbodies" option for the Gulf of Mexico region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 0.10 million fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.36 million (2003$), with lower and upper bounds of $0.16 million and $0.82 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.30 million and $0.24 million, respectively. The majority of benefits result from reduced losses of spotted seatrout and black drum.

Table E4-3: Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option in the Gulf of Mexico Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	30.3	$2.30	$5.32	$12.20	$69.7	$161.3	$369.8
Other saltwater	66.9	$1.32	$2.88	$6.38	$88.3	$192.7	$426.5
Unidentified	2.8	$1.60	$3.57	$8.02	$4.5	$10.2	$22.8
Total (undiscounted)	**100.0**				**$162.6**	**$364.2**	**$819.1**
Total (evaluated at 3%)[c]	**100.0**				**$136.0**	**$304.7**	**$685.3**
Total (evaluated at 7%)[c]	**100.0**				**$108.3**	**$242.6**	**$545.5**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

E4-1.5 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

All potentially regulated facilities in the Gulf of Mexico region that would have to install new technology under the "50 MGD for All Waterbodies" option and "100 MGD for Certain Waterbodies" option have design intake flows that are greater than 100 MGD and are located on coastal waterbodies or great lakes. Because the requirements under the 50 MGD option and the 100 MGD option are identical for this class of facilities, the estimated I&E reductions and recreational fishing benefits from these two options are identical. Thus, the estimated recreational fishing benefits presented in Table E4-3 also apply to the "100 MGD for Certain Waterbodies" option. The table shows that this option reduces recreational losses by 0.18 million fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.67 million (2003$), with lower and upper bounds of $0.30 million and $1.50 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.57 million and $0.48 million, respectively. The majority of benefits result from reduced losses of spotted seatrout and black drum.

E4-2 RUM Approach

To validate the results of the benefit transfer approach, EPA applied the RUM model presented in Chapter F4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004) to the baseline losses and reductions in losses at potentially regulated Phase III existing facilities. This section presents the results of the recreational fishing benefits analysis for the Gulf of Mexico region based on the Phase II RUM approach.

E4-2.1 RUM Methodology: Gulf of Mexico Region

EPA's methodology for evaluating the change in welfare resulting from a change in recreational losses from I&E consists of four basic steps: (1) calculating the change in historical catch rates under a given policy scenario, (2) estimating the per-trip welfare gain to anglers based on the Phase II RUM model, (3) estimating the number of fishing trips taken by anglers, and (4) combining fishing participation data with the estimated per-trip welfare gain to calculate the total annual welfare gain. These steps are briefly described in the following sections. For a more detailed discussion of the RUM methodology, see Chapters A11 and F4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004).

E4-2.1.1 Estimating Changes in the Quality of Fishing Sites

The first step in EPA's analysis was to combine estimates of recreational I&E losses at potentially regulated facilities with state-level recreational fishery landings data to estimate the percentage change in historical catch rates under each policy option. Because most species considered in this analysis (e.g., black drum, seatrout, sea bass) are found throughout Gulf of Mexico waters, EPA made the assumption that changes in I&E will result in uniform changes in catch rates across all marine fishing sites in this region.[5] Although no landings data was available for the state of Texas, EPA assumed that catch rates for Texas anglers are similar to catch rates for other anglers in the region.[6] Thus, EPA used five-year National Marine Fisheries Service (NMFS) recreational landings data (1997 through 2001) for state waters to calculate the average statewide landings per year for all species groups for western Florida, Alabama, Mississippi, and Louisiana.[7] EPA then divided baseline recreational I&E losses for those four states by total recreational landings to calculate the percentage change in historical catch rates from completely eliminating recreational fishing losses from I&E.[8] Similarly, the Agency also estimated the percentage changes to historic catch rates that would result under each policy option.

E4-2.1.2 Estimating Per-Trip Benefits from Reducing I&E

EPA's second step was to use the recreational behavior model described in Chapter F4 of the Phase II Regional Studies document to estimate an angler's per-trip welfare gain from changes in the historical catch rates in the Gulf of Mexico region. The Agency estimated welfare gains to recreational anglers under four scenarios: eliminating baseline recreational fishing losses from I&E at potentially regulated facilities, and reducing recreational fishing losses from I&E by implementing the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, or the "100 MGD for Certain Waterbodies" option. EPA assumed that the welfare gain per fishing trip is independent of the number of days fished per trip and therefore equivalent for both single-

[5] Fish lost to I&E are most often very small fish that are too small to catch. Because of the migratory nature of most affected species, by the time these fish have grown to catchable size, they may have traveled some distance from the facility where I&E occurs. Without collecting extensive data on migratory patterns of all affected fish, it is not possible to evaluate whether catch rates will change uniformly or in some other pattern. Thus, EPA assumed that catch rates will change uniformly across the entire region.

[6] EPA obtained landings data for Texas from the Texas Parks and Wildlife Department, Marine Sport-Harvest Monitoring Program, but found that landings data for the shore mode were not available, and data for private/rental and charter boat modes were very limited (e.g., landings data for the bottomfish group included only three species, whereas NMFS data for other Gulf states included 20 species in this group) (TPWD, 2003).

[7] State waters include sounds, inlets, tidal portions of rivers, bays, estuaries, and other areas of salt or brackish water, plus ocean waters to three nautical miles from shore (NMFS, 2003a).

[8] Because EPA did not have landings data for Texas, the Agency excluded I&E for Texas from this calculation. EPA estimated I&E losses for West Florida, Alabama, Mississippi, and Louisiana by applying an adjustment factor of 0.517 to the I&E losses estimated for all five states in the Gulf of Mexico region. This adjustment factor reflects the fact that Texas facilities account for 48.3% of cooling water intake system (CWIS) flow in the region.

and multiple-day trips. Thus, a multiple-day trip is valued the same as a single-day trip.[9] EPA estimated separate per-day welfare gains for different categories of anglers, based on their target species and fishing mode.[10]

E4-2.1.3 Estimating Angler Participation

The third step in EPA's analysis was to estimate baseline and post-regulatory fishing participation, measured by the total number of fishing trips taken by Gulf of Mexico anglers.[11] Because the policy options for Phase III facilities are expected to result in relatively small improvements in fishing quality, EPA assumed that increases in recreational fishing participation under the policy options will be negligible. Thus, to estimate both baseline and post-regulatory participation, EPA used the total number of fishing trips taken by Gulf of Mexico anglers in 2002. The total number of trips to the Gulf of Mexico fishing sites was calculated from data provided by NMFS for western Florida, Alabama, Mississippi, and Louisiana, and by U.S. Department of the Interior (U.S. DOI, 2002) for Texas. To estimate the proportion of recreational fishing trips taken by no-target anglers and by anglers targeting each species of concern, EPA used the Marine Recreational Fisheries Statistics Survey (MRFSS) sample. The Agency then applied those percentages to the total number of fishing trips taken by Gulf of Mexico anglers to calculate the number of anglers.

E4-2.1.4 Estimating Total Benefits from Eliminating or Reducing I&E

The final step in EPA's analysis was to calculate the total benefits of the policy options. To calculate total benefits for each subcategory of anglers targeting a particular species with a particular fishing mode, EPA multiplied the per-trip welfare gain for an angler with that particular species/fishing mode combination by the total number of fishing trips taken by all anglers with that species/fishing mode combination. EPA then summed benefits for all subcategories of anglers to calculate the total welfare change in the Gulf of Mexico region. Finally, as discussed in Chapter A8, EPA discounted and annualized the benefits estimates, using both 3% and 7% discount rates.

E4-2.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table E4-5 presents the baseline level of recreational landings at potentially regulated facilities and the estimated change in catch rates that would result from eliminating recreational fishing losses from I&E in the Gulf region. The table shows that I&E has the largest effect on catch rates for bottomfish, which would increase by 0.29% if I&E were eliminated.

[9] See section F4-5.1 of the 316(b) Phase II document for limitations and uncertainties associated with this assumption.

[10] EPA used the per-day values for private/rental boat anglers to estimate welfare gains for charter boat anglers.

[11] See Chapter F4 of the 316(b) Phase II document for a detailed description of the angler participation estimates in the Gulf of Mexico.

Table E4-5: Estimated Changes in Historical Catch Rates from Eliminating I&E at Potentially Regulated Phase III Facilities in the Gulf of Mexico Region[a]

	Annual Recreational Landings (thousands of fish)[b]		Baseline Annual Recreational Fishing Losses (thousands of fish)[c]		Percent Increase in Recreational Catch from Eliminating I&E (based on four states)
Species Group	**Entire Region[d]**	**Four States[e]**	**Entire Region[d]**	**Four States[e,f]**	
Bottomfish	n/a	33,608.8	191.44	99.00	0.29%
Seatrout	n/a	27,823.0	69.25	35.82	0.13%
Small game	n/a	15,004.4	8.43	4.36	0.03%
Snapper/Grouper	n/a	17,132.5	1.44	0.74	0.00%[g]
Flatfish	n/a	1,077.2	0.09	0.05	0.00%[g]
No target	n/a	104,065.0[h]	270.65	139.97	0.13%

[a] Because no recreational landings data were available for Texas, EPA calculated the impact of eliminating I&E in the four other states in the Gulf of Mexico region, and then used the percentage change in recreational catch in those four states as an estimate of the percentage change in recreational catch across the entire region.
[b] Total recreational landings are calculated as a five-year average (1997-2001) for state waters. No landings data were available for Texas.
[c] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[d] Includes all five states in the Gulf of Mexico region (western Florida, Alabama, Mississippi, Louisiana, and Texas).
[e] Includes western Florida, Alabama, Mississippi, and Louisiana; does not include Texas.
[f] I&E losses for four states were estimated from I&E losses for the entire Gulf of Mexico region, based on intake flow. The four states account for 51.7% of intake flow in the region; thus, EPA assumed these states also account for 51.7% of losses.
[g] Denotes a positive value less than 0.005%.
[h] Annual recreational landings for the ‘no target’ group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table E4-6 presents the per-trip welfare gain for anglers targeting different species, the number of fishing trips taken by anglers targeting those species, and the total annual welfare gain from eliminating baseline I&E. The table shows that the total undiscounted value of baseline losses in the Gulf of Mexico region is $0.66 million (2003$), and the annualized value of those losses is $0.64 million and $0.62 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for ‘no-target’ species and seatrout. The table shows that eliminating baseline recreational fishing losses from I&E would result in per-trip welfare gains of eight cents or less per angler.

Table E4-6: Recreational Fishing Benefits from Eliminating I&E at Potentially Regulated Phase III Facilities in the Gulf of Mexico Region (2003$)

Species Group	Per-Trip Welfare Gain: Boat Anglers	Per-Trip Welfare Gain: Shore Anglers	Number of Fishing Trips in the Five Gulf States (thousands)[a]	Annualized Total Benefits (thousands)[b]
Bottomfish	$0.08	$0.02	590	$25.0
Seatrout	$0.05	$0.06	3,901	$197.1
Small game	$0.01	$0.00[c]	6,816	$47.2
Snapper/Grouper	$0.00[c]	$0.00[c]	1,773	$2.6
Flatfish	$0.00[c]	$0.00[c]	228	$0.1
No target	$0.03	$0.02	14,912	$389.8
Total, All Species (undiscounted)			**28,548**	**$661.8**
Total, All Species (discounted at 3%)			**28,548**	**$642.0**
Total, All Species (discounted at 7%)			**28,548**	**$618.2**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.

Source: U.S. EPA analysis for this report.

E4-2.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table E4-9 presents the estimated change in historical catch rates that would result from reductions in I&E under the "50 MGD for All Waterbodies" option. In the Gulf of Mexico, catch rates for anglers targeting bottomfish would increase the most under this option, by 0.2%.

Table E4-7: Estimated Changes in Historical Catch Rates under the "50 MGD for All Waterbodies" Option in the Gulf of Mexico Region[a]

Species Group	Annual Recreational Landings (thousands of fish)[b]		Annual Reduction in Recreational Fishing Losses (thousands of fish)[c]		Percent Increase in Recreational Catch from Reducing I&E (based on four states)
	Entire Region[d]	Four States[e]	Entire Region[d]	Four States[e,f]	
Bottomfish	n/a	33,608.8	124.2	67.9	0.20%
Seatrout	n/a	27,823.0	51.7	28.2	0.10%
Small game	n/a	15,004.4	6.2	3.4	0.02%
Snapper/Grouper	n/a	17,132.5	1.0	0.5	0.00%[h]
Flatfish	n/a	1,077.2	0.1	0.0[g]	0.00%[h]
No target	n/a	104,065.0[i]	183.1	100.0	0.10%

[a] Because no recreational landings data were available for Texas, EPA calculated the impact of reducing I&E in the four other states in the Gulf of Mexico region, and then used the percentage change in recreational catch in those four states as an estimate of the percentage change in recreational catch across the entire region.
[b] Total recreational landings are calculated as a five-year average (1997-2001) for state waters. No landings data were available for Texas.
[c] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[d] Includes all five states in the Gulf of Mexico region (western Florida, Alabama, Mississippi, Louisiana, and Texas).
[e] Includes western Florida, Alabama, Mississippi, and Louisiana; does not include Texas.
[f] The annual reduction in recreational losses for four states was estimated from the annual reduction for the entire region, based on intake flow at in-scope Phase III facilities. Under this option, the four states account for 54.6% of intake flow at Phase III facilities in the region; thus, EPA assumed these states also account for 54.6% of losses.
[g] Denotes a positive value less than 50 fish.
[h] Denotes a positive value less than 0.005%.
[i] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table E4-8 presents the recreational benefits of the "50 MGD for All Waterbodies" option for the Gulf of Mexico region. The table shows that the total undiscounted benefits of this option are $0.49 million (2003$), and the annualized value of those benefits is $0.41 million and $0.33 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for 'no-target' species and seatrout. The table shows that this option would result in per-trip welfare gains of six cents or less per angler.

Table E4-8: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the Gulf of Mexico Region (2003$)

Species Group	Per-Trip Welfare Gain		Number of Fishing Trips in the Five Gulf States (thousands)[a]	Annualized Total Benefits (thousands)[b]
	Boat Anglers	Shore Anglers		
Bottomfish	$0.06	$0.01	590	$17.1
Seatrout	$0.04	$0.05	3,901	$154.3
Small game	$0.01	$0.00[c]	6,816	$37.4
Snapper/Grouper	$0.00[c]	$0.00[c]	1,773	$2.0
Flatfish	$0.00[c]	$0.00[c]	228	$0.1
No target	$0.02	$0.02	14,912	$277.2
Total, All Species (undiscounted)			**28,548**	**$488.1**
Total, All Species (discounted at 3%)			**28,548**	**$408.4**
Total, All Species (discounted at 7%)			**28,548**	**$325.1**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.

Source: U.S. EPA analysis for this report.

E4-2.3 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

Table E4-9 presents the estimated change in historical catch rates that would result from reductions in I&E under the "200 MGD for All Waterbodies" option. In the Gulf of Mexico region, catch rates for anglers targeting bottomfish would increase the most under this option, by 0.2%.

Table E4-9: Estimated Changes in Historical Catch Rates from Reducing I&E under the "200 MGD for All Waterbodies" Option in the Gulf of Mexico Region[a]

Species Group	Annual Recreational Landings (thousands of fish)[b]		Annual Reduction in Recreational Fishing Losses (thousands of fish)[c]		Percent Increase in Recreational Catch from Reducing I&E (based on four states)
	Entire Region[d]	Four States[e]	Entire Region[d]	Four States[e,f]	
Bottomfish	n/a	33,608.8	67.9	67.9	0.20%
Seatrout	n/a	27,823.0	28.2	28.2	0.10%
Small game	n/a	15,004.4	3.4	3.4	0.02%
Snapper/Grouper	n/a	17,132.5	0.5	0.5	0.00%[h]
Flatfish	n/a	1,077.2	0.0[g]	0.0[g]	0.00%[h]
No target	n/a	104,065.0[i]	100.0	100.0	0.10%

[a] Because no recreational landings data were available for Texas, EPA calculated the impact of reducing I&E in the four other states in the Gulf of Mexico region, and then used the percentage change in recreational catch in those four states as an estimate of the percentage change in recreational catch across the entire region.
[b] Total recreational landings are calculated as a five-year average (1997-2001) for state waters. No landings data were available for Texas.
[c] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[d] Includes all five states in the Gulf of Mexico region (western Florida, Alabama, Mississippi, Louisiana, and Texas).
[e] Includes western Florida, Alabama, Mississippi, and Louisiana; does not include Texas.
[f] Since all Phase III facilities with intake flows greater than 200 MGD are located in these four states, the annual reduction in recreational losses for four states is the same as the reduction for five states.
[g] Denotes a positive value less than 50 fish.
[h] Denotes a positive value less than 0.005%.
[i] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: NMFS, 2002e; and U.S. EPA analysis for this report.

Table E4-10 presents the recreational benefits of the "200 MGD for All Waterbodies" option for the Gulf of Mexico region. The table shows that the total undiscounted benefits of this option are $0.36 million (2003$), and the annualized value of those benefits is $0.30 million and $0.24 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for 'no-target' species and seatrout. The table shows that this option would result in per-trip welfare gains of six cents or less per angler.

Table E4-10: Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option in the Gulf of Mexico Region (2003$)

	Per-Trip Welfare Gain			
Species Group	**Boat Anglers**	**Shore Anglers**	**Number of Fishing Trips in the Four Gulf States (thousands)[a,b]**	**Annualized Total Benefits (thousands)[d]**
Bottomfish	$0.06	$0.01	434	$12.6
Flatfish	$0.04	$0.05	168	$0.1
Seatrout	$0.01	$0.00[c]	2,871	$113.6
Small game	$0.00[c]	$0.00[c]	5,016	$27.5
Snapper/Grouper	$0.00[c]	$0.00[c]	1,305	$1.5
No target	$0.02	$0.02	10,974	$204.0
Total, All Species (undiscounted)			**21,010**	**$359.2**
Total, All Species (discounted at 3%)			**21,010**	**$300.6**
Total, All Species (discounted at 7%)			**21,010**	**$239.2**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Since none of the facilities in TX has a design intake flow greater than 200 MGD, EPA assumed that recreational anglers of this state will not benefit from the I&E reduction. The total number of fishing trips for the four other Gulf states is calculated.
[c] Denotes a positive value less than $0.005.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

E4-2.4 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

In the Gulf of Mexico region, all Phase III facilities that would have to install new technology under the "50 MGD for All Waterbodies" option and "100 MGD for Certain Waterbodies" option have design intake flows that are greater than 100 MGD. Because the requirements under the "50 MGD for All Waterbodies" option and the "100 MGD for Certain Waterbodies" option are identical for this class of facilities, the estimated I&E reductions and recreational fishing benefits from these two options are identical. Thus, the estimated recreational fishing benefits presented in Table E4-8 also apply to "100 MGD for Certain Waterbodies".

E4-3 Validation of Benefit Transfer Results Based on RUM Results

Table E4-11 compares the undiscounted results of the benefit transfer based on the meta-analysis with the results of the RUM analysis. The table shows that under both models, the welfare gain under the "50 MGD for All Waterbodies" option and the "100 MGD for Certain Waterbodies" option is higher than the welfare gain under the "200 MGD for All Waterbodies" option. In general, the RUM results fall within the range of values estimated based on the meta-model. That the values from the two independent analyses are relatively close corroborates the use of meta-analysis in estimating the value of incremental recreational fishing improvements resulting from the section 316(b) Phase III proposed regulation.

Table E4-11: Recreational Fishing Benefits in the Gulf of Mexico Region Calculated from Meta-Analysis Approach and RUM Approach

Policy Option	Estimated Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands, 2003$)			
		Based on Meta-Analysis			Based on RUM
		Low	Mean	High	
Eliminating baseline recreational fishing losses from I&E	270.6	$432.2	$966.4	$2,170.7	$661.8
50 MGD All	183.1	$297.6	$666.6	$1,499.2	$488.1
200 MGD All	100.0	$162.6	$364.2	$819.1	$359.2
100 MGD CWB[a]	183.1	$297.6	$666.6	$1,499.2	$488.1

[a] Because all Phase III facilities that would have to install new technology under the "50 MGD for All Waterbodies" option and "100 MGD for Certain Waterbodies" option have design intake flows that are greater than 100 MGD, recreational fishing benefits resulting from these two options are identical.

Source: U.S. EPA analysis for this report.

E4-4 Limitations and Uncertainty

E4-4.1 Limitations and Uncertainty: Meta-Analysis

The results of the benefit transfer based on the meta-analysis results represent EPA's best estimate of the recreational benefits of the proposed options. Nonetheless, there are a number of limitations and uncertainties inherent in these estimates. General limitations pertaining to the development of the meta-analysis model, the use of the model to estimate per-fish values, and the validity of the benefit transfer are discussed in section A5-3.3e and section A5-5.3 of Chapter A5.

E4-4.2 Limitations and Uncertainty: RUM Approach

The results of the benefit transfer based on the RUM analysis results serve to confirm that EPA's estimates of the recreational benefits of the proposed options are reasonable. However, there are a number of limitations and uncertainties inherent in these estimates. Some general limitations pertaining to the RUM model are discussed in Chapter A11 of the 316(b) Phase II document. Some additional region-specific limitations are discussed in Chapter F4 of the 316(b) Phase II document.

Although the estimated total welfare gain to the Gulf of Mexico recreational anglers based on the regional RUM model is likely to be accurate, the estimated average per-trip welfare gain presented in Tables E4-6, E4-8 and E4-10 must be used and understood in the context of the regional model developed by EPA for the Phase II analysis. The regional RUM model assumes uniform changes in catch rates at all sites across the region. Given that there are only eleven potentially regulated facilities in the Gulf of Mexico region and the total intake flow associated with these facilities is relatively small, catch rate improvements are more likely to occur locally rather than regionally. These local improvements in catch rates and the associated average per-trip welfare gain are likely to be greater than those presented in the tables in section E4-2. However, the number of anglers benefitting from these improvements would be smaller, and so the resulting aggregate benefits are likely to be similar.

Appendix E1: Life History Parameter Values Used to Evaluate I&E in the Gulf of Mexico Region

The tables in this appendix are those life history parameter values used by EPA to calculate age-1 equivalents and fishery yield from impingement and entrainment (I&E) data for the Gulf of Mexico region. Because of differences in the number of life stages represented in the loss data, there are cases where more than one life stage sequence was needed for a given species or species group. Alternative parameter sets were developed for this purpose and are indicated with a number following the species or species group name (i.e., Anchovies 1, Anchovies 2).

Table E1-1: Atlantic Croaker Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.817	0	0	0.0000000128
Larvae	8.10	0	0	0.000000145
Juvenile	3.38	0	0	0.0000624
Age 1+	1.09	0.30	0.50	0.220
Age 2+	0.300	0.30	1.0	0.672
Age 3+	0.300	0.30	1.0	1.24
Age 4+	0.300	0.30	1.0	1.88
Age 5+	0.300	0.30	1.0	2.43
Age 6+	0.300	0.30	1.0	3.26
Age 7+	0.300	0.30	1.0	3.26
Age 8+	0.300	0.30	1.0	3.26

Source: PSE&G, 1999.

Table E1-2: Anchovies Parameters 1[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.94	0	0	0.0000000186
Prolarvae	1.57	0	0	0.0000000441
Post larvae	6.12	0	0	0.00000235
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] Includes bay anchovy, striped anchovy, and other anchovies not identified to species.

Sources: Derickson and Price, 1973; Leak and Houde, 1987; PSE&G, 1999; and NMFS, 2003a.

Table E1-3: Anchovies Parameters 2[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.94	0	0	0.0000000186
Larvae	7.70	0	0	0.00000158
Juvenile 1	0.0822	0	0	0.0000495
Juvenile 2	0.0861	0	0	0.000199
Juvenile 3	0.129	0	0	0.000532
Juvenile 4	0.994	0	0	0.00114
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] Includes bay anchovy.

Sources: Derickson and Price, 1973; Leak and Houde, 1987; PSE&G, 1999; and NMFS, 2003a.

Table E1-4: Black Drum Life History Parameters 1				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Egg	2.27	0	0	0.000000842
Prolarvae	3.06	0	0	0.000000926
Postlarvae	3.06	0	0	0.0000176
Juvenile	1.15	0.15	0.50	0.0327
Age 1+	0.0977	0.15	1.0	0.671
Age 2+	0.0977	0.15	1.0	1.70
Age 3+	0.0977	0.15	1.0	3.21
Age 4+	0.0977	0.15	1.0	5.15
Age 5+	0.0977	0.15	1.0	7.43
Age 6+	0.0977	0.15	1.0	9.93
Age 7+	0.0977	0.15	1.0	12.6
Age 8+	0.0977	0.15	1.0	15.3
Age 9+	0.0977	0.15	1.0	18.0
Age 10+	0.0977	0.15	1.0	20.7
Age 11+	0.0977	0.15	1.0	23.3
Age 12+	0.0977	0.15	1.0	25.7
Age 13+	0.0977	0.15	1.0	28.1
Age 14+	0.0977	0.15	1.0	30.2
Age 15+	0.0977	0.15	1.0	32.3
Age 16+	0.0977	0.15	1.0	34.1
Age 17+	0.0977	0.15	1.0	35.8
Age 18+	0.0977	0.15	1.0	37.4
Age 19+	0.0977	0.15	1.0	38.8
Age 20+	0.0977	0.15	1.0	40.1
Age 21+	0.0977	0.15	1.0	41.3
Age 22+	0.0977	0.15	1.0	42.4
Age 23+	0.0977	0.15	1.0	43.3
Age 24+	0.0977	0.15	1.0	44.2
Age 25+	0.0977	0.15	1.0	45.0
Age 26+	0.0977	0.15	1.0	45.7
Age 27+	0.0977	0.15	1.0	46.3
Age 28+	0.0977	0.15	1.0	46.8
Age 29+	0.0977	0.15	1.0	47.3
Age 30+	0.0977	0.15	1.0	47.8
Age 31+	0.0977	0.15	1.0	48.2
Age 32+	0.0977	0.15	1.0	48.5
Age 33+	0.0977	0.15	1.0	48.8
Age 34+	0.0977	0.15	1.0	49.1
Age 35+	0.0977	0.15	1.0	49.4
Age 36+	0.0977	0.15	1.0	49.6

Table E1-4: Black Drum Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Age 37+	0.0977	0.15	1.0	49.8
Age 38+	0.0977	0.15	1.0	50.0
Age 39+	0.0977	0.15	1.0	50.1
Age 40+	0.0977	0.15	1.0	50.3

Sources: Sutter et al., 1986; Scott and Scott, 1988; Murphy and Taylor, 1989; Leard et al., 1993; Bartell and Campbell, 2000; Froese and Pauly, 2001; and personal communication with Michael D. Murphy, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, January 23, 2002.

Table E1-5: Black Drum Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Egg	2.27	0	0	0.000000842
Larvae	6.13	0	0	0.00000453
Juvenile	1.15	0.15	0.50	0.0327
Age 1+	0.0977	0.15	1.0	0.671
Age 2+	0.0977	0.15	1.0	1.70
Age 3+	0.0977	0.15	1.0	3.21
Age 4+	0.0977	0.15	1.0	5.15
Age 5+	0.0977	0.15	1.0	7.43
Age 6+	0.0977	0.15	1.0	9.93
Age 7+	0.0977	0.15	1.0	12.6
Age 8+	0.0977	0.15	1.0	15.3
Age 9+	0.0977	0.15	1.0	18.0
Age 10+	0.0977	0.15	1.0	20.7
Age 11+	0.0977	0.15	1.0	23.3
Age 12+	0.0977	0.15	1.0	25.7
Age 13+	0.0977	0.15	1.0	28.1
Age 14+	0.0977	0.15	1.0	30.2
Age 15+	0.0977	0.15	1.0	32.3
Age 16+	0.0977	0.15	1.0	34.1
Age 17+	0.0977	0.15	1.0	35.8
Age 18+	0.0977	0.15	1.0	37.4
Age 19+	0.0977	0.15	1.0	38.8
Age 20+	0.0977	0.15	1.0	40.1
Age 21+	0.0977	0.15	1.0	41.3
Age 22+	0.0977	0.15	1.0	42.4
Age 23+	0.0977	0.15	1.0	43.3
Age 24+	0.0977	0.15	1.0	44.2
Age 25+	0.0977	0.15	1.0	45.0

Table E1-5: Black Drum Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Age 26+	0.0977	0.15	1.0	45.7
Age 27+	0.0977	0.15	1.0	46.3
Age 28+	0.0977	0.15	1.0	46.8
Age 29+	0.0977	0.15	1.0	47.3
Age 30+	0.0977	0.15	1.0	47.8
Age 31+	0.0977	0.15	1.0	48.2
Age 32+	0.0977	0.15	1.0	48.5
Age 33+	0.0977	0.15	1.0	48.8
Age 34+	0.0977	0.15	1.0	49.1
Age 35+	0.0977	0.15	1.0	49.4
Age 36+	0.0977	0.15	1.0	49.6
Age 37+	0.0977	0.15	1.0	49.8
Age 38+	0.0977	0.15	1.0	50.0
Age 39+	0.0977	0.15	1.0	50.1
Age 40+	0.0977	0.15	1.0	50.3

Sources: Sutter et al., 1986; Scott and Scott, 1988; Murphy and Taylor, 1989; Leard et al., 1993; Able and Fahay, 1998; Bartell and Campbell, 2000; Froese and Pauly, 2001; and personal communication with Michael D. Murphy, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, January 23, 2002.

Table E1-6: Blue Crab Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Zoeae	13.8	0	0	0.000000211
Megalops	1.30	0	0	0.00000291
Juvenile	1.73	0.48	0.50	0.00000293
Age 1+	1.00	1.0	1.0	0.00719
Age 2+	1.00	1.0	1.0	0.113
Age 3+	1.00	1.0	1.0	0.326

Sources: Hartman, 1993; PSE&G, 1999; and Murphy et al., 2000.

Table E1-7: Commercial Shrimp Life History Parameters 1[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	3.22	0	0	0.0000000253
Prolarvae	1.70	0	0	0.00000274
Postlarvae	1.70	0	0	0.0000268
Juvenile	0.140	0.14	1.0	0.0473
Age 1+	0.140	0.14	1.0	0.0770

[a] Includes pink shrimp, brown shrimp, white shrimp, and other commercial shrimp not identified to species.

Sources: Costello and Allen, 1970; Stone & Webster Engineering Corporation, 1980; Bielsa et al., 1983; and TBNEP, 1992.

Table E1-8: Commercial Shrimp Life History Parameters 2[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	3.22	0	0	0.0000000253
Larvae	3.40	0	0	0.00000274
Juvenile	0.140	0.14	1.0	0.0473
Age 1+	0.140	0.14	1.0	0.0770

[a] Includes pink shrimp.

Sources: Costello and Allen, 1970; Stone & Webster Engineering Corporation, 1980; Bielsa et al., 1983; and TBNEP, 1992.

Table E1-9: Goby Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.288	0	0	0.00000200
Larvae	4.09	0	0	0.00000219
Juvenile	2.30	0	0	0.00049
Age 1+	2.55	0	0	0.00205

[a] Includes clown goby, code goby, frillfin goby, green goby, naked goby, sharptail goby, skilletfish, violet goby, and other goby species not identified to species.

Sources: PSE&G, 1999; Froese and Pauly, 2003; and NMFS, 2003a.

Table E1-10: Hogchoker Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.24	0	0	0.000000487
Larvae	6.73	0	0	0.00110
Juvenile	0.916	0	0	0.00207
Age 1+	0.250	0	0	0.0113
Age 2+	0.250	0	0	0.0313
Age 3+	0.250	0	0	0.0610
Age 4+	0.250	0	0	0.0976
Age 5+	0.250	0	0	0.138
Age 6+	0.250	0	0	0.178

Sources: New England Power Company and Marine Research Inc., 1995; Able and Fahay, 1998; PG&E National Energy Group, 2001; and NMFS, 2003a.

Table E1-11: Jack/Pompano Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.817	0	0	0.00000115
Larvae	8.61	0	0	0.00000127
Juvenile	0.916	0	0	0.0222
Age 1+	0.340	0.25	0.50	0.168
Age 2+	0.340	0.25	1.0	0.460
Age 3+	0.340	0.25	1.0	0.511
Age 4+	0.340	0.25	1.0	0.565

[a] Includes Atlantic bumper, Atlantic moonfish, bluntnose jack, crevalle jack, leatherjacket, lookdown, and permit.

Sources: PSE&G, 1999; Florida Fish and Wildlife Conservation Commission, 2001; Overholtz, 2002b; and Froese and Pauly, 2003.

Table E1-12: Killifish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.0000180
Larvae	3.00	0	0	0.0000182
Juvenile	0.916	0	0	0.000157
Age 1+	0.777	0	0	0.0121
Age 2+	0.777	0	0	0.0327
Age 3+	0.777	0	0	0.0551
Age 4+	0.777	0	0	0.0778
Age 5+	0.777	0	0	0.0967
Age 6+	0.777	0	0	0.113
Age 7+	0.777	0	0	0.158

[a] Includes gulf killifish, longnose killifish, bayou killifish, and other killifish species not identified to species.

Sources: Carlander, 1969; Stone & Webster Engineering Corporation, 1977; Meredith and Lotrich, 1979; Able and Fahay, 1998; and NMFS, 2003a.

Table E1-13: Mackerel Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.39	0	0	0.00000176
Larvae	10.6	0	0	0.00000193
Juvenile	0.916	0	0	0.0000368
Age 1+	0.520	0	0	0.309
Age 2+	0.370	0.25	0.50	0.510
Age 3+	0.370	0.25	1.0	0.639
Age 4+	0.370	0.25	1.0	0.752
Age 5+	0.370	0.25	1.0	0.825
Age 6+	0.370	0.25	1.0	0.918
Age 7+	0.370	0.25	1.0	1.02
Age 8+	0.370	0.25	1.0	1.10
Age 9+	0.370	0.25	1.0	1.13
Age 10+	0.370	0.25	1.0	1.15
Age 11+	0.370	0.25	1.0	1.22
Age 12+	0.370	0.25	1.0	1.22
Age 13+	0.370	0.25	1.0	1.22
Age 14+	0.370	0.25	1.0	1.22

[a] Includes Spanish mackerel.

Sources: Scott and Scott, 1988; Overholtz et al., 1991; Studholme et al., 1999; Entergy Nuclear Generation Company, 2000; and Froese and Pauly, 2001, 2003.

Table E1-14: Menhaden Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000203
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.8	0.50	0.356
Age 3+	0.450	0.8	1.0	0.679
Age 4+	0.450	0.8	1.0	0.974
Age 5+	0.450	0.8	1.0	1.21
Age 6+	0.450	0.8	1.0	1.38

[a] Includes Alabama shad, Atlantic thread herring, finescale menhaden, gizzard shad, gulf menhaden, skipjack herring, yellowfin menhaden, and other closely related herrings not identified to species.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; Entergy Nuclear Generation Company, 2000; ASMFC, 2001b; and Froese and Pauly, 2001.

Table E1-15: Pinfish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000107
Larvae	7.39	0	0	0.0000238
Juvenile	1.91	0	0	0.00669
Age 1+	0.340	0.34	0.50	0.0791
Age 2+	0.340	0.34	1.0	0.218

[a] Includes pinfish, spottail pinfish, and other porgies not identified to species.

Sources: Muncy, 1984; Nelson, 1998; and Froese and Pauly, 2001.

Table E1-16: Pipefish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000000842
Larvae	2.40	0	0	0.0000122
Juvenile	0.916	0	0	0.00785
Age 1+	0.750	0	0	0.0195
Age 2+	0.750	0	0	0.0384
Age 3+	0.750	0	0	0.0658
Age 4+	0.750	0	0	0.103
Age 5+	0.750	0	0	0.151

[a] Includes chain pipefish, dusky pipefish, gulf pipefish, and other pipefish not identified to species.

Sources: Stone & Webster Engineering Corporation, 1977; Scott and Scott, 1988; Able and Fahay, 1998; Froese and Pauly, 2001, 2003; and NMFS, 2003a.

Table E1-17: Red Drum Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Egg	2.27	0	0	0.000000842
Prolarvae	3.06	0	0	0.000000926
Postlarvae	3.06	0	0	0.0000176
Juvenile	1.15	0.15	0.50	0.0327
Age 1+	0.0977	0.15	1.0	0.671
Age 2+	0.0977	0.15	1.0	1.70
Age 3+	0.0977	0.15	1.0	3.21
Age 4+	0.0977	0.15	1.0	5.15
Age 5+	0.0977	0.15	1.0	7.43
Age 6+	0.0977	0.15	1.0	9.93
Age 7+	0.0977	0.15	1.0	12.6
Age 8+	0.0977	0.15	1.0	15.3
Age 9+	0.0977	0.15	1.0	18.0
Age 10+	0.0977	0.15	1.0	20.7
Age 11+	0.0977	0.15	1.0	23.3
Age 12+	0.0977	0.15	1.0	25.7
Age 13+	0.0977	0.15	1.0	28.1
Age 14+	0.0977	0.15	1.0	30.2
Age 15+	0.0977	0.15	1.0	32.3
Age 16+	0.0977	0.15	1.0	34.1
Age 17+	0.0977	0.15	1.0	35.8
Age 18+	0.0977	0.15	1.0	37.4

Table E1-17: Red Drum Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Age 19+	0.0977	0.15	1.0	38.8
Age 20+	0.0977	0.15	1.0	40.1
Age 21+	0.0977	0.15	1.0	41.3
Age 22+	0.0977	0.15	1.0	42.4
Age 23+	0.0977	0.15	1.0	43.3
Age 24+	0.0977	0.15	1.0	44.2
Age 25+	0.0977	0.15	1.0	45.0
Age 26+	0.0977	0.15	1.0	45.7
Age 27+	0.0977	0.15	1.0	46.3
Age 28+	0.0977	0.15	1.0	46.8
Age 29+	0.0977	0.15	1.0	47.3
Age 30+	0.0977	0.15	1.0	47.8
Age 31+	0.0977	0.15	1.0	48.2
Age 32+	0.0977	0.15	1.0	48.5
Age 33+	0.0977	0.15	1.0	48.8
Age 34+	0.0977	0.15	1.0	49.1
Age 35+	0.0977	0.15	1.0	49.4
Age 36+	0.0977	0.15	1.0	49.6
Age 37+	0.0977	0.15	1.0	49.8
Age 38+	0.0977	0.15	1.0	50.0
Age 39+	0.0977	0.15	1.0	50.1
Age 40+	0.0977	0.15	1.0	50.3

Sources: Sutter et al., 1986; Scott and Scott, 1988; Murphy and Taylor, 1989; Leard et al., 1993; Bartell and Campbell, 2000; Froese and Pauly, 2001; and personal communication with Michael D. Murphy, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, January 23, 2002.

Table E1-18: Scaled Sardine Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.12	0	0	0.00000533
Prolarvae	0.560	0	0	0.00000586
Postlarvae	6.53	0	0	0.0000247
Juvenile	0.916	0	0	0.000483
Age 1+	1.02	0	0	0.275

[a] Includes Brazilian sardinella, scaled sardine, threadfin shad, and other clupeids not identified to species.

Sources: Houde et al., 1974; Stone & Webster Engineering Corporation, 1980; Pierce et al., 2001; Froese and Pauly, 2003; and NMFS, 2003a.

Table E1-19: Sea Bass Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Egg	0.288	0	0	0.00000101
Larvae	6.00	0	0	0.00000111
Juvenile	0.190	0	0	0.000581
Age 1+	0.190	0	0	0.0313
Age 2+	0.190	0	0	0.0625
Age 3+	0.190	0	0	0.125
Age 4+	0.190	0	0	0.312
Age 5+	0.190	0.26	0.50	0.531
Age 6+	0.190	0.26	1.0	0.813
Age 7+	0.287	0.26	1.0	1.13
Age 8+	0.287	0.26	1.0	1.50
Age 9+	0.287	0.26	1.0	1.88
Age 10+	0.287	0.26	1.0	2.19

[a] Includes black sea bass.

Sources: Cailliet, 2000; California Department of Fish and Game, 2000b; Leet et al., 2001; and Froese and Pauly, 2002.

Table E1-20: Searobin Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000132
Larvae	3.66	0	0	0.00000145
Juvenile	0.916	0	0	0.000341
Age 1+	0.420	0.10	0.50	0.0602
Age 2+	0.420	0.10	1.0	0.176
Age 3+	0.420	0.10	1.0	0.267
Age 4+	0.420	0.10	1.0	0.386
Age 5+	0.420	0.10	1.0	0.537
Age 6+	0.420	0.10	1.0	0.721
Age 7+	0.420	0.10	1.0	0.944
Age 8+	0.420	0.10	1.0	1.21

[a] Includes bighead searobin, leopard searobin, and other searobins not identified to species.

Sources: Saila et al., 1997; Virginia Tech, 1998; and Froese and Pauly, 2001, 2003.

Table E1-21: Sheepshead Seabream Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000000591
Larvae	7.39	0	0	0.0000241
Juvenile	1.91	0	0	0.00167
Age 1+	1.98	0	0	0.981
Age 2+	1.98	0	0	1.22
Age 3+	1.98	0.45	0.50	1.56
Age 4+	1.98	0.45	1.0	2.33
Age 5+	1.98	0.45	1.0	2.43
Age 6+	1.98	0.45	1.0	2.45
Age 7+	1.98	0.45	1.0	2.47
Age 8+	1.98	0.45	1.0	2.49
Age 9+	1.98	0.45	1.0	2.51
Age 10+	1.98	0.45	1.0	2.53
Age 11+	1.98	0.45	1.0	2.55
Age 12+	1.98	0.45	1.0	2.57
Age 13+	1.98	0.45	1.0	2.59
Age 14+	1.98	0.45	1.0	2.61
Age 15+	1.98	0.45	1.0	2.63
Age 16+	1.98	0.45	1.0	2.65

Sources: Pattillo et al., 1997; Nelson, 1998; Murphy and MacDonald, 2000; Murphy et al., 2000; Froese and Pauly, 2002; and personal communication with Michael D. Murphy, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, January 23, 2002.

Table E1-22: Silver Perch Life History Parameters 1[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.75	0	0	0.000000527
Prolarvae	2.10	0	0	0.000000580
Postlarvae	3.27	0	0	0.0000379
Juvenile	1.71	0	0	0.0445
Age 1+	3.84	0	0	0.273
Age 2+	3.84	0.10	0.50	4.15
Age 3+	3.84	0.10	1.0	0.607

[a] Includes banded drum, silver perch, silver seatrout, southern kingfish, and star drum.

Sources: Able and Fahay, 1998; PSE&G, 1999; Florida Fish and Wildlife Conservation Commission, 2001; Froese and Pauly, 2001, 2003; and personal communication with Michael D. Murphy, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, January 23, 2002.

Table E1-23: Silver Perch Life History Parameters 2[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.75	0	0	0.000000527
Larvae	5.37	0	0	0.00000771
Juvenile	1.71	0	0	0.0445
Age 1+	3.84	0	0	0.273
Age 2+	3.84	0.10	0.50	0.415
Age 3+	3.84	0.10	1.0	0.607

[a] Includes silver perch, northern kingfish, and southern kingfish.

Sources: Able and Fahay, 1998; PSE&G, 1999; Florida Fish and Wildlife Conservation Commission, 2001; Froese and Pauly, 2001, 2003; and personal communication with Michael D. Murphy, Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, January 23, 2002.

Table E1-24: Silverside Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000000487
Prolarvae	1.45	0	0	0.000000554
Postlarvae	1.45	0	0	0.00000554
Juvenile	0.916	0	0	0.0000292
Age 1+	2.10	0	0	0.0119
Age 2+	2.10	0	0	0.0224

[a] Includes California grunion, inland silverside, rough silverside, tidewater silverside, and other silversides not identified to the species.

Sources: Hildebrand, 1922; Garwood, 1968; Stone & Webster Engineering Corporation, 1977, 1980; Scott and Scott, 1988; Froese and Pauly, 2001; and NMFS, 2003a.

Table E1-25: Spot Life History Parameters 1

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.825	0	0	0.000000131
Prolarvae	3.30	0	0	0.000000154
Postlarvae	4.12	0	0	0.000000854
Juvenile	2.57	0	0	0.000121
Age 1+	0.463	0.4	1.0	0.0791
Age 2+	0.400	0.4	1.0	0.299
Age 3+	0.400	0.4	1.0	0.507
Age 4+	0.400	0.4	1.0	0.648
Age 5+	0.400	0.4	1.0	0.732
Age 6+	0.400	0.4	1.0	0.779
Age 7+	0.400	0.4	1.0	0.779
Age 8+	0.400	0.4	1.0	0.779
Age 9+	0.400	0.4	1.0	0.779
Age 10+	0.400	0.4	1.0	0.779
Age 11+	0.400	0.4	1.0	0.779
Age 12+	0.400	0.4	1.0	0.779
Age 13+	0.400	0.4	1.0	0.779
Age 14+	0.400	0.4	1.0	0.779
Age 15+	0.400	0.4	1.0	0.779

Sources: Warlen et al., 1980; and PSE&G, 1984, 1999.

Table E1-26: Spot Life History Parameters 2

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.825	0	0	0.000000131
Larvae	7.42	0	0	0.000000504
Juvenile	2.57	0	0	0.000121
Age 1+	0.463	0.4	1.0	0.0791
Age 2+	0.400	0.4	1.0	0.299
Age 3+	0.400	0.4	1.0	0.507
Age 4+	0.400	0.4	1.0	0.648
Age 5+	0.400	0.4	1.0	0.732
Age 6+	0.400	0.4	1.0	0.779
Age 7+	0.400	0.4	1.0	0.779
Age 8+	0.400	0.4	1.0	0.779
Age 9+	0.400	0.4	1.0	0.779
Age 10+	0.400	0.4	1.0	0.779
Age 11+	0.400	0.4	1.0	0.779
Age 12+	0.400	0.4	1.0	0.779
Age 13+	0.400	0.4	1.0	0.779
Age 14+	0.400	0.4	1.0	0.779
Age 15+	0.400	0.4	1.0	0.779

Sources: Warlen et al., 1980; and PSE&G, 1984, 1999.

Table E1-27: Spotted Seatrout Life History Parameters 1[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000000842
Prolarvae	1.50	0	0	0.000000926
Postlarvae	6.92	0	0	0.00000568
Juvenile	0.272	0.27	0.50	0.571
Age 1+	0.272	0.27	1.0	0.914
Age 2+	0.272	0.27	1.0	1.55
Age 3+	0.272	0.27	1.0	2.50
Age 4+	0.272	0.27	1.0	3.15
Age 5+	0.272	0.27	1.0	3.54
Age 6+	0.272	0.27	1.0	4.41
Age 7+	0.272	0.27	1.0	4.97
Age 8+	0.272	0.27	1.0	4.99

[a] Includes sand seatrout, sand weakfish, spotted seatrout, and other drums not identified to species.

Sources: Stone & Webster Engineering Corporation, 1980; Johnson and Seaman, 1986; Sutter et al., 1986; and Murphy and Taylor, 1994.

Table E1-28: Spotted Seatrout Life History Parameters 2[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.000000842
Larvae	8.42	0	0	0.000000926
Juvenile	0.272	0.27	0.50	0.571
Age 1+	0.272	0.27	1.0	0.914
Age 2+	0.272	0.27	1.0	1.55
Age 3+	0.272	0.27	1.0	2.50
Age 4+	0.272	0.27	1.0	3.15
Age 5+	0.272	0.27	1.0	3.54
Age 6+	0.272	0.27	1.0	4.41
Age 7+	0.272	0.27	1.0	4.97
Age 8+	0.272	0.27	1.0	4.99

[a] Includes sand seatrout and spotted seatrout.

Sources: Stone & Webster Engineering Corporation, 1980; Johnson and Seaman, 1986; Sutter et al., 1986; and Murphy and Taylor, 1994.

Table E1-29: Stone Crab Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Stage 1	1.97	0	0	0.000000101
Stage 2	1.97	0	0	0.000000417
Stage 3	1.97	0	0	0.00000109
Stage 4	1.97	0	0	0.00000226
Stage 5	1.97	0	0	0.00000405
Megalops	1.97	0	0	0.00000662
Juvenile	1.97	0	0	0.0000182
Age 1+	0.939	0.75	0.50	1.02
Age 2+	0.939	0.75	1.0	3.63
Age 3+	0.939	0.75	1.0	7.12
Age 4+	0.939	0.75	1.0	10.0

Sources: Bert et al., 1978; Sullivan, 1979; Lindberg and Marshall, 1984; Van den Avyle and Fowler, 1984; and Ehrhardt et al., 1990.

Table E1-30: Striped Mullet Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.000000537
Larvae	4.61	0	0	0.0000110
Juvenile	0.916	0	0	0.131
Age 1+	0.230	0.30	0.50	0.187
Age 2+	0.230	0.30	1.0	0.379
Age 3+	0.230	0.30	1.0	0.774
Age 4+	0.230	0.30	1.0	1.58
Age 5+	0.230	0.30	1.0	3.21
Age 6+	0.230	0.30	1.0	6.53

Sources: Collins, 1985; Wang, 1986; PSE&G, 1999; and Froese and Pauly, 2003.

Table E1-31: Other Commercial Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes Atlantic cutlassfish, black bullhead, cobia, grey snapper, gulf butterfish, ladyfish, largehead hairtail, mojarra spp, silver jenny, spotfin mojarra, tripletail, and yellow bullhead.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table E1-32: Other Recreational Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] See Table E1-34 for a list of species.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; and ASMFC, 2001b.

Table E1-33: Other Forage Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Larvae	7.70	0	0	0.00000158
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] See Table E1-35 for a list of species.

Sources: Derickson and Price, 1973; and PSE&G, 1999.

Table E1-34: Other Recreational Species[a]

Atlantic sharpnose shark	Bonnethead	Hardhead sea catfish	Smooth butterfly ray
Atlantic stingray	Channel catfish	Least puffer	Smooth puffer
Bandtail puffer	Dwarf sandperch	Pigfish	Southern flounder
Belted sandfish	Gafftopsail catfish	Rock sea bass	Southern puffer
Blackear bass	Gag grouper	Sand perch	Tomtate
Bluefish	Gulf toadfish	Sea catfish	

[a] Includes other organisms not identified to species.

Table E1-35: Other Forage Species[a]

Atlantic midshipman	Dwarf seahorse	Jawfish	Seahorse
Atlantic needlefish	Fat sleeper	Lined seahorse	Sheepshead minnow
Atlantic spadefish	Feather blenny	Live sharksucker	Snakefish
Atlantic threadfin	Florida blenny	Longear sunfish	Southern codling
Barbfish	Freckled blenny	Mottled jawfish	Southern hake
Bay whiff	Fringed filefish	Needlefish	Southern stargazer
Blackcheek tonguefish	Fringed flounder	Orange filefish	Spotted whiff
Blackwing flyingfish	Golden shiner	Planehead filefish	Striped blenny
Bluegill	Green sunfish	Polka dot batfish	Striped burrfish
Bridle cardinalfish	Gulf of Mexico ocellated flounder	Redfin needlefish	Warmouth
Carp	Halfbeak	Roughback batfish	Yellowhead jawfish
Common halfbeak	Harvestfish	Sailfin molly	
Diamond lizardfish	Inshore lizardfish	Scrawled cowfish	

[a] Includes other organisms not identified to species.

Appendix E2: Reductions in I&E in the Gulf of Mexico Region Under Five Other Options Evaluated for the Proposed Section 316(b) Phase III Regulation

Table E2-1: Estimated Reductions in I&E in the Gulf of Mexico Region Under Five Other Options Evaluated for the Proposed Section 316(b) Regulation

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
20 MGD All	8,860,000	1,320,000
2	8,860,000	1,320,000
3	8,865,000	1,270,000
4	8,860,000	1,320,000
All Phase III Facilities	8,860,000	1,320,000

Appendix E3: Commercial Fishing Benefits for Five Other Options Evaluated for Phase III Existing Facilities in the Gulf of Mexico Region

Section E3-2 in Chapter E3 displays the results of the commercial fishing benefits analysis for the 50 MGD option, the 200 MGD option, and the 100 MGD option. To facilitate comparisons among the options, this appendix displays results for the following additional options: All Potentially Regulated Phase III Existing Facilities option (All Phase III Facilities); the 20 MGD option (20 MGD All); Option 2; Option 3; and Option 4.

Table E3-1: Annualized Commercial Fishing Benefits Attributable to the All Phase III Facilities Option at Facilities in the Gulf of Mexico Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$161,000	$196,000	$357,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$64,500	$78,400	$143,000
Expected reduction due to rule	80%	60%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$98,600
3% discount rate			$82,500
7% discount rate			$65,700

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table E3-2: Annualized Commercial Fishing Benefits Attributable to the 20 MGD All Option at Facilities in the Gulf of Mexico Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$161,000	$196,000	$357,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$64,500	$78,400	$143,000
Expected reduction due to rule	80%	60%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$98,600
3% discount rate			$82,500
7% discount rate			$65,700

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table E3-3: Annualized Commercial Fishing Benefits Attributable to Option 2 at Facilities in the Gulf of Mexico Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$161,000	$196,000	$357,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$64,500	$78,400	$143,000
Expected reduction due to rule	80%	60%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$98,600
3% discount rate			$82,500
7% discount rate			$65,700

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table E3-4: Annualized Commercial Fishing Benefits Attributable to Option 3 at Facilities in the Gulf of Mexico Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$161,000	$196,000	$357,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$64,500	$78,400	$143,000
Expected reduction due to rule	80%	57%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$96,100
3% discount rate			$80,400
7% discount rate			$64,000

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table E3-5: Annualized Commercial Fishing Benefits Attributable to Option 4 at Facilities in the Gulf of Mexico Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$161,000	$196,000	$357,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$64,500	$78,400	$143,000
Expected reduction due to rule	80%	60%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$98,600
3% discount rate			$82,500
7% discount rate			$65,700

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Appendix E4: Recreational Use Benefits of Other Policy Options

Introduction

Chapter E4 presents EPA's estimates of the recreational benefits of the three proposed options for the section 316(b) rule for Phase III facilities, for electric generators and manufacturers in the Gulf of Mexico region. This appendix supplements Chapter E4 by presenting estimates of the recreational fishing benefits of five other options that EPA evaluated for the purposes of comparison:

- Option 3,
- Option 4,
- Option 2,
- Option 1, and
- Option 6.

Appendix Contents

Recreational fishing benefits presented in this chapter were estimated using the benefit transfer approach discussed in Chapter E4 and in Chapter A5, "Recreational Fishing Benefits Methodology."

E4-1 Recreational Fishing Benefits of the Other Evaluated Options

E4-1.1 Estimated Reductions in Recreational Fishing Losses under the Other Evaluated Options

Table E4-1 presents EPA's estimates of the annual reduction in baseline (i.e., current) recreational fishing losses from impingement and entrainment (I&E) in the Gulf of Mexico region under the other evaluated options.

Table E4-1: Reductions in Recreational Fishing Losses from I&E under the Other Evaluated Options in the Gulf of Mexico Region

Species[a]	Annual Reduction in Recreational Losses (# of fish)[b]				
	Option 3	**Option 4**	**Option 2**	**Option 1**	**Option 6**
Mackerels	269	269	269	269	269
Red drum	5,376	5,393	5,393	5,393	5,393
Spotted seatrout	52,865	52,965	52,965	52,965	52,965
Total (small game)	**58,510**	**58,626**	**58,626**	**58,626**	**58,626**
Atlantic croaker	39,425	39,426	39,426	39,426	39,426
Black drum	39,836	42,043	42,043	42,043	42,043
Pinfish	18,975	19,995	19,995	19,995	19,995
Sea bass	26	26	26	26	26
Searobin	18,914	19,049	19,049	19,049	19,049
Sheepshead	3	4	4	4	4
Silver perch	106	111	111	111	111
Spot	6,020	6,043	6,043	6,043	6,043
Striped mullet	2,504	2,592	2,592	2,592	2,592
Total (other saltwater)	**125,809**	**129,289**	**129,289**	**129,289**	**129,289**
Total (unidentified)	**5,389**	**5,499**	**5,499**	**5,499**	**5,499**
Total (all species)	***189,709***	***193,414***	***193,414***	***193,414***	***193,414***

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The 'other saltwater' group includes bottomfish and other miscellaneous species. The 'unidentified' group includes fish lost indirectly through trophic transfer.

[b] In the Gulf of Mexico region, the set of facilities with technology requirements under Option 1 is the same as under Option 4, Option 2, and Option 6. Thus, reductions in recreational losses under these options are also identical.

Source: U.S. EPA analysis for this report.

E4-1.2 Recreational Fishing Benefits of the Other Evaluated Options

Tables E4-2 and E4-3 present EPA's estimates of the annualized recreational benefits of the other evaluated options in the Gulf of Mexico region.

In the Gulf of Mexico region, all potentially regulated facilities that would install new technology under Option 4, Option 2, Option 1, or Option 6 have design intake flows greater than 20 MGD. Because the requirements under these four options are identical for this class of facilities, the I&E reductions and benefits resulting from these four options are also identical. Thus, the benefits estimates presented in Table E4-3 apply to all four options.

Table E4-2: Recreational Fishing Benefits of Option 3 in the Gulf of Mexico Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Small game	58.5	$2.30	$5.32	$12.20	$134.6	$311.3	$713.6
Other saltwater	125.8	$1.32	$2.88	$6.38	$166.1	$362.6	$802.5
Unidentified	5.4	$1.60	$3.57	$8.02	$8.6	$19.2	$43.2
Total (undiscounted)	**189.7**				**$309.3**	**$693.2**	**$1,559.3**
Total (evaluated at 3%)	**189.7**				**$258.8**	**$580.0**	**$1,304.7**
Total (evaluated at 7%)	**189.7**				**$206.0**	**$461.7**	**$1,038.5**

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[b] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

Table E4-3: Recreational Fishing Benefits of Option 4, Option 2, Option 1, or Option 6, in the Gulf of Mexico Region (2003$)[a]

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game	58.6	$2.30	$5.32	$12.20	$134.8	$311.9	$715.0
Other saltwater	129.3	$1.32	$2.88	$6.38	$170.7	$372.7	$824.7
Unidentified	5.5	$1.60	$3.57	$8.02	$8.8	$19.6	$44.1
Total (undiscounted)	**193.4**				**$314.4**	**$704.3**	**$1,583.8**
Total (evaluated at 3%)	**193.4**				**$263.0**	**$589.3**	**$1,325.2**
Total (evaluated at 7%)	**193.4**				**$209.4**	**$469.0**	**$1,054.8**

[a] In the Gulf of Mexico region, the set of facilities with technology requirements under Option 4 is the same as under Option 2, Option 1, and Option 6. Thus, reductions in recreational losses under these options are also identical.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

E4-2 Comparison of Recreational Fishing Benefits by Option

Table E4-4 compares the recreational fishing benefits of the five other evaluated options. The table shows that the annual recreational fishing benefits of Option 3 are slightly lower than the annual recreational fishing benefits of the other options.

Table E4-4: Annual Recreational Benefits of the Other Evaluated Options in the Gulf of Mexico Region

Policy Option[a]	Annual Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands; 2003$)[b]		
		Low	Mean	High
Option 3	189.7	$309.3	$693.2	$1,559.3
Option 4	193.4	$314.4	$704.3	$1,583.8
Option 2	193.4	$314.4	$704.3	$1,583.8
Option 1	193.4	$314.4	$704.3	$1,583.8
Option 6	193.4	$314.4	$704.3	$1,583.8

[a] In the Gulf of Mexico region, the set of facilities with technology requirements under Option 4 is the same as under Option 2, Option 1, and Option 6. Thus, reductions in recreational losses under these options are also identical.

[b] These benefit estimates were calculated using the meta-analysis approach discussed in Chapter A5 and Chapter E4. EPA did not use the RUM approach from the Phase II analysis to analyze the other evaluated options.

Source: U.S. EPA analysis for this report.

Part F: The Great Lakes

Chapter F1: Background

Introduction

Chapter Contents

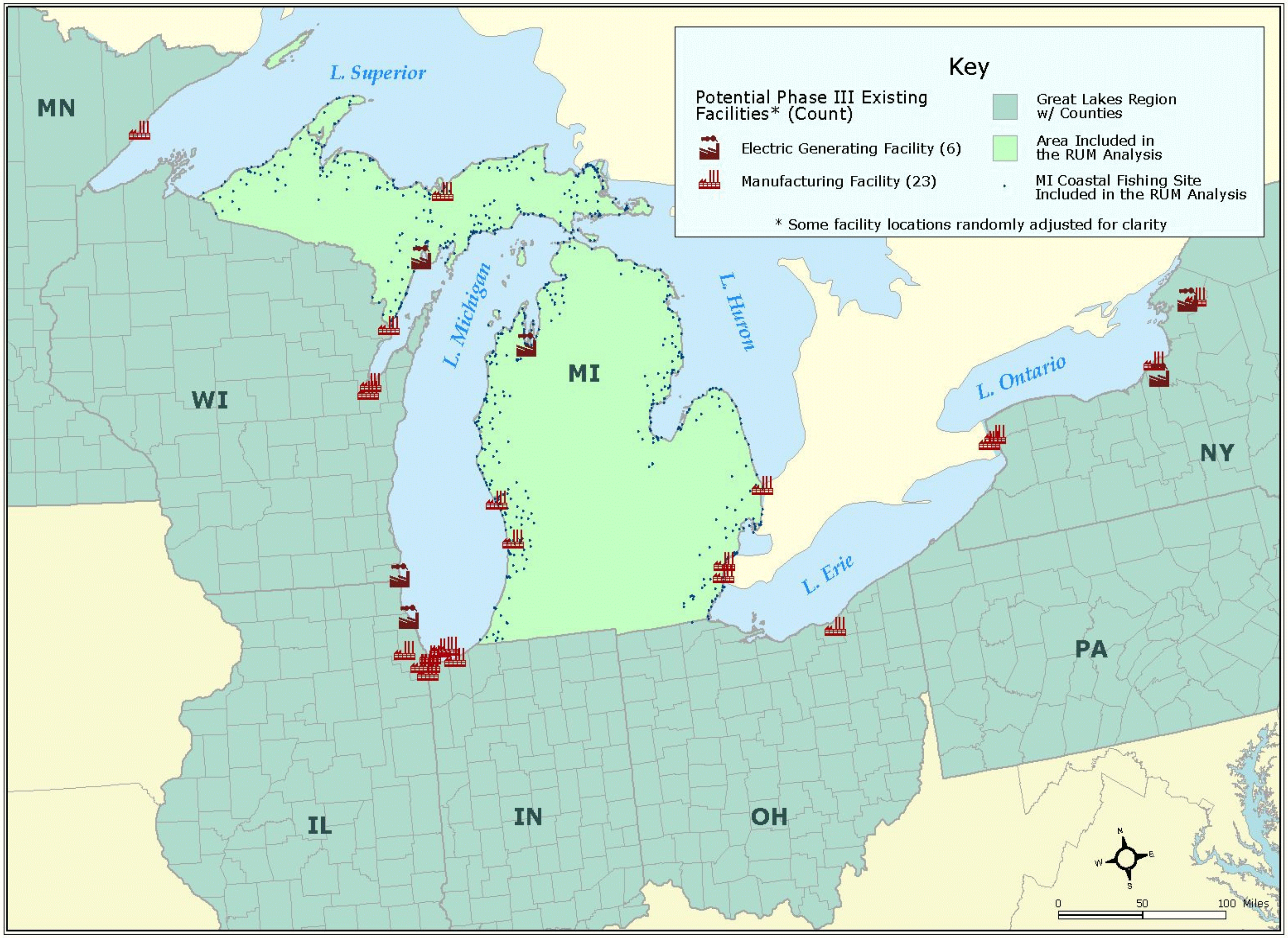
This chapter presents an overview of the potential Phase III existing facilities in the Great Lakes study region and summarizes their key cooling water and compliance characteristics. For further discussion of the technical and compliance characteristics of potential Phase III existing facilities, refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* and the *Technical Development Document for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a,b).

F1-1 Facility Characteristics

The Great Lakes Regional Study includes 29 sample facilities that are potentially subject to the proposed standards for Phase III existing facilities. Twenty three of them are manufacturing facilities and six are electric generators. Industry-wide, these 29 sample facilities represent 68 facilities.[1] Figure F1-1 presents a map of these facilities.

[1] EPA applied sample weights to the survey respondents to account for non-sampled facilities and facilities that did not respond to the survey. For more information on EPA's 2000 Section 316(b) Industry Survey, please refer to the Information Collection Request (U.S. EPA, 2000).

Figure F1-1: Potential Existing Phase III Facilities in the Great Lakes Regional Study



Source: U.S. EPA analysis for this report.

Table F1-1 summarizes key technical and compliance characteristics for all potentially regulated Phase III existing facilities in the Great Lakes study region and for the three proposed regulatory options considered by EPA for this proposal (the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD for Certain Waterbodies" option). Facilities with a design intake flow below the three applicability thresholds would be subject to permitting based on best professional judgment and are excluded from EPA's analyses.[2] Therefore, a different number of facilities is affected under each option.

Table F1-1 shows that 68 Phase III existing facilities in the Great Lakes study region would potentially be subject to the national requirements. Under the "50 MGD for All Waterbodies" option, the most inclusive of the three proposed options, 23 facilities would be subject to the national requirements for Phase III existing facilities. Under the less inclusive "200 MGD for All Waterbodies" option, five facilities would be subject to the national requirement, and under the "100 MGD for Certain Waterbodies" option, eight facilities would be subject to the national requirements. One facility in the Great Lakes study region has a recirculating system in the baseline.

Table F1-1: Technical and Compliance Characteristics of Existing Phase III Facilities (Sample-Weighted)

	All Potentially Regulated Facilities	Proposed Options		
		50 MGD All	200 MGD All	100 MGD CWB
Total Number of Facilities (Sample-Weighted)	**68**	**23**	**5**	**8**
Number of Facilities with Recirculating System In Baseline	**1**	**-**	**-**	**-**
Design Intake Flow (MGD)	**2,693**	**2,294**	**w[b]**	**1,841**
Number of Facilities by Compliance Response				
Fish H&R	8	5	-	-
Fine mesh traveling screens with fish H&R	8	3	2	3
Velocity cap	6	-	-	-
New larger intake structure with fine mesh and fish H&R	6	-	-	-
Double-entry, single-exit with fine mesh and fish H&R	4	-	-	-
Passive fine mesh screens	29	11	3	3
None	7	4	-	1
Compliance Cost at 3%[a]	$28.62	$10.08	$4.05	$4.47
Compliance Cost at 7%[a]	$30.87	$10.20	$3.68	$4.10

[a] Annualized pre-tax compliance cost (2003$, millions)
[b] Data withheld because of confidentiality reasons.

Source: U.S. EPA, 2000; U.S. EPA analysis for this report.

[2] Also excluded are facilities that are estimated to be baseline closures. For additional information on EPA's baseline closure analyses, please refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a).

Chapter F2: Evaluation of Impingement and Entrainment in the Great Lakes Region

Background: The Great Lakes Fisheries

Chapter Contents

Great Lakes fisheries are among the most important in the world, providing $4 billion in landings and recreation for some 5 million recreational anglers (Great Lakes Fishery Commission, 2003). Historically, the top predators in the Great Lakes included lake trout (*Salvelinus namaycush*), sturgeon (*Acipenser fulvescens*), lake whitefish (*Coregonus clupeaformis*), northern pike (*Esox lucius*), walleye (*Sander vitreus*), and muskellunge (*Esox masquinongy*). Today, as a result of numerous stressors such as habitat destruction, damming, and the introduction of sea lamprey and other exotic species, dominant species are primarily non-native salmon sustained by hatcheries. Not all introductions have been harmful, however. For example, alewife was introduced to provide forage for sport fish (Jude et al., 1987). Losses of alewife (*Alosa pseudoharengus*), emerald shiner (*Notropis atherinoides*), and other forage species to impingement and entrainment (I&E) at Great Lakes facilities are sometimes substantial. Impinged and entrained species of commercial and/or recreational importance include yellow perch (*Perca flavescens*), white bass (*Morone chrysops*), gizzard shad (*Dorosoma cepedianum*), and walleye.

F2-1 I&E Species/Species Groups Evaluated

Table F2-1 provides a list of species/species groups that were evaluated in EPA's analysis of I&E in the Great Lakes.

Table F2-1: Species/Species Group Evaluated by EPA that are Subject to I&E in the Great Lakes Region

Species/Species Group	Recreational	Commercial	Forage
Alewife			X
Black bullhead		X	
Black crappie	X		
Bluegill	X		
Bluntnose minnow			X
Brown bullhead		X	
Bullhead species		X	
Burbot			X
Carp			X
Channel catfish	X	X	

Table F2-1: Species/Species Group Evaluated by EPA that are Subject to I&E in the Great Lakes Region

Species/Species Group	Recreational	Commercial	Forage
Chinook salmon			X
Crappie	X		
Darter species	X		
Emerald shiner			X
Freshwater drum		X	
Gizzard shad			X
Golden redhorse			X
Herring			X
Logperch			X
Muskellunge	X		
Other (forage)			X
Other (recreational)	X		
Rainbow smelt	X	X	
Salmon	X		
Sculpin species	X	X	
Shiner species			X
Smallmouth bass	X		
Smelt	X	X	
Spotted sucker			X
Sucker species			X
Sunfish	X		
Threespine stickleback			X
Walleye	X		
White bass	X	X	
White perch			X
Whitefish	X	X	
Yellow perch	X	X	

The life history data used in EPA’s analysis and associated data sources are provided in Appendix F1 of this report.

F2-2 I&E Data Evaluated

Table F2-2 lists the facility I&E data evaluated by EPA to estimate current I&E rates for the region. Data for both Phase II and Phase III facilities were used as a basis for extrapolation of I&E rates to Phase III facilities without I&E data. Chapter A1 of Part A presents the extrapolation methods.

Table F2-2: Facility I&E Data Evaluated for the Great Lakes Region

Phase III Facilities	Phase	Years of Data
Bailly Generating Station	II	1975
DC Cook Nuclear Power Plant	II	1975-1982
D.H. Mitchell Station	II	1975
Fort Drum HTW Cogenerational Facility	III	1993
J.P. Pulliam Power Plant	II	1975
J.R. Whiting Power Plant	II	1978-1991
Monroe Power Plant	II	1974-1985
Pleasant Prairie Power Plant	III	1980
Port Washington Power Plant	II	1975-1980
Silver Bay Power Plant	III	1981
U.S. Steel Corporation Gary Works	III	1977

F2-3 EPA's Estimate of Current I&E at Phase III Facilities in the Great Lakes Region Expressed as Age-1 Equivalents and Foregone Yield

Table F2-3 provides EPA's estimate of the annual age-1 equivalents and foregone fishery yield resulting from the impingement of aquatic species at facilities located in the Great Lakes region. Table F2-4 displays this information for entrainment. Note that in these tables, "total yield" includes direct losses of harvested species and the yield of harvested species that is lost due to losses of forage species. As discussed in Chapter A1 of Part A of the section 316(b) Phase III Regional Benefits Assessment, the conversion of forage to yield contributes only a very small fraction to total yield.

Table F2-3: Estimated Current Annual Impingement at Phase III Facilities in the Great Lakes Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Alewife	25,200	na
Black bullhead	20,700	1,640
Black crappie	107	18
Bluegill	46	<1
Bluntnose minnow	115	na
Brown bullhead	249	21
Bullhead species	300	24
Burbot	842	na
Carp	2,770	na

Table F2-3: Estimated Current Annual Impingement at Phase III Facilities in the Great Lakes Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Channel catfish	1,920	399
Chinook salmon	467	na
Crappie	236	40
Darter species	658	na
Emerald shiner	4,270,000	na
Freshwater drum	62,500	15,100
Gizzard shad	23,200,000	na
Golden redhorse	7	na
Log perch	22,600	na
Muskellunge	7	28
Other (forage)	6,440	na
Other (recreational)	1,370	270
Rainbow smelt	79,200	294
Salmon	241	1,020
Sculpin species	43	2
Shiner species	3,290,000	na
Smallmouth bass	325	13
Smelts	48,400	1,200
Spotted sucker	<1	na
Sucker species	551	na
Sunfish	4,730	3
Threespine stickleback	1,450	na
Trophic transfer[a]	na	303,000
Walleye	6,580	5,870
White bass	246,000	75,400
White perch	222,000	na
Whitefish	4,890	4,380
Yellow perch	263,000	3,660

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table F2-4: Estimated Current Annual Entrainment at Phase III Facilities in the Great Lakes Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Alewife	966	na
Black bullhead	477	38
Bluegill	37	<1
Bluntnose minnow	5,070	na
Burbot	454	na
Carp	292,000	na
Channel catfish	28,600	5,930
Crappie	4,740	799
Darter species	8	na
Emerald shiner	69,600	na
Freshwater drum	20,700	4,990
Gizzard shad	1,120,000	na
Herring	8,200	na
Logperch	29,200	na
Other (forage)	159,000	na
Other (recreational)	46	9
Rainbow smelt	23,600	88
Salmon	216	911
Sculpin species	2,270	90
Shiner	77,800	na
Smallmouth bass	14,800	600
Smelts	1,360	34
Sucker species	6,380	na
Sunfish	393,000	284
Threespine stickleback	357	na
Trophic transfer[a]	na	19,900
Walleye	3,150	2,810
White bass	122,000	37,300
Whitefish	19	17
Yellow perch	187,000	2,600

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

F2-4 Reductions in I&E at Phase III Facilities in the Great Lakes Region Under Three Alternative Options

Table F2-5 presents estimated reductions in I&E under the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD for Certain Waterbodies" option. Reductions under all other options are presented in Appendix F2.

Table F2-5: Estimated Reductions in I&E Under Three Alternative Options

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
50 MGD All Option	11,600,000	169,000
200 MGD All Option	7,710,000	116,000
100 MGD Option	8,740,000	130,000

F2-5 Assumptions Used in Calculating Recreational and Commercial Losses

In order to estimate the economic value of these losses, total yield was partitioned between commercial and recreational fisheries based on the landings in each fishery. Table F2-6 presents the percentage impacts for each species/species group. Commercial and recreational fishing benefits are presented in Chapters F3 and F4.

Table F2-6: Percentage of Total Impacts Occurring to the Commercial and Recreational Fisheries and Commercial Value per Pound for Species Impinged and Entrained at Great Lakes Facilities

Species/Species Group	Percent Impact to Recreational Fishery[a,b]	Percent Impact to Commercial Fishery[a,b]
Black bullhead	0.0%	100.0%
Black crappie	100.0%	0.0%
Bluegill	100.0%	0.0%
Brown bullhead	0.0%	100.0%
Bullhead species	0.0%	100.0%
Channel catfish	50.0%	50.0%
Crappie	100.0%	0.0%
Darter species	100.0%	0.0%
Freshwater drum	0.0%	100.0%
Muskellunge	100.0%	0.0%
Other (recreational)	100.0%	0.0%
Rainbow smelt	50.0%	50.0%
Salmon	100.0%	0.0%
Sculpin species	85.0%	15.0%
Smallmouth bass	100.0%	0.0%
Smelts	6.2%	93.8%
Sunfish	100.0%	0.0%
Trophic transfer[c]	50.0%	50.0%
Walleye	100.0%	0.0%

Table F2-6: Percentage of Total Impacts Occurring to the Commercial and Recreational Fisheries and Commercial Value per Pound for Species Impinged and Entrained at Great Lakes Facilities

Species/Species Group	Percent Impact to Recreational Fishery[a,b]	Percent Impact to Commercial Fishery[a,b]
White bass	50.0%	50.0%
Whitefish	50.0%	50.0%
Yellow perch	50.0%	50.0%

[a] Based on opinion of local experts and comments received at proposal. EPA collected recreational landings data by species from State fisheries experts. However, this data was limited to a few broad species groups and was not sufficient to calculate more accurate values.
[b] Calculated using 1993-2001 commercial landings data from NMFS (2003a, http://www.st.nmfs.gov/commercial/landings/annual_landings.html).
[c] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

See Chapter F3 for results of the commercial fishing benefits analysis and Chapter F4 for recreational fishing results. As discussed in Chapter A8, benefits were discounted to account for 1) the time to achieve compliance once the rule goes into effect in 2007, and 2) the time it takes for fish spared from I&E to reach a harvestable age.

Chapter F3: Commercial Fishing Valuation

Introduction

This chapter presents the results of the commercial fishing benefits analysis for the Great Lakes region. Section F3-1 details the estimated losses under current, or baseline, conditions. Section F3-2 presents the expected benefits under three alternative options. Chapter A4 details the methods used in this analysis.

Chapter Contents

F3-1 Baseline Losses

Table F3-1 provides EPA's estimate of the value of gross revenues lost in commercial fisheries resulting from the impingement of aquatic species at facilities in the Great Lakes region. Table F3-2 displays this information for entrainment. Total annualized revenue losses are approximately $180,000 (undiscounted).

Table F3-1: Annualized Commercial Fishing Gross Revenues Lost due to Impingement at Facilities in the Great Lakes Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
Black bullhead	1,640	$0.51	$833
Brown bullhead	21	$0.51	$10
Bullhead species	24	$0.51	$12
Channel catfish	199	$0.51	$101
Freshwater drum	15,100	$0.14	$2,180
Rainbow smelt	147	$0.62	$91
Smelts	1,130	$0.27	$309
Trophic transfer[b]	152,000	$0.72	$109,000
White bass	37,700	$0.87	$32,800
Whitefish	2,190	$0.86	$1,880
Yellow perch	1,830	$2.17	$3,970

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table F3-2: Annualized Commercial Fishing Gross Revenues Lost due to Entrainment at Facilities in the Great Lakes Region

Species[a]	Estimated Pounds of Harvest Lost	Commercial Value per Pound (2003$)	Estimated Value of Harvest Lost (2003$) Undiscounted
Black bullhead	38	$0.51	$19
Channel catfish	2,960	$0.51	$1,510
Freshwater drum	4,990	$0.14	$723
Rainbow smelt	44	$0.62	$27
Sculpins	14	$2.61	$35
Smelts	32	$0.27	$9
Trophic transfer[b]	9,960	$0.72	$7,180
White bass	18,700	$0.87	$16,200
Whitefish	8	$0.86	$7
Yellow perch	1,300	$2.17	$2,820

[a] Species included are only those that have baseline losses greater than $1.
[b] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

F3-2 Expected Benefits Under Three Alternative Options

As described in Chapter A4, EPA estimates that 0 to 40% of the gross revenue losses represent surplus losses to producers, assuming no change in prices or fishing costs. The 0% estimate, of course, results in loss estimates of $0. The 40% estimates, as presented in Tables F3-3, F3-4, and F3-5, total approximately $72,000 (undiscounted).

The expected reductions in impingement and entrainment (I&E) attributable to changes at facilities required by the “50 MGD for All Waterbodies” option (50 MGD option) are 33% for impingement and 43% for entrainment, for the “200 MGD for All Waterbodies” option (200 MGD option) are 21% for impingement and 38% for entrainment, and for the “100 MGD for Certain Waterbodies” option (100 MGD option) are 24% for impingement and 40% for entrainment. Total annualized benefits are estimated by applying these estimated reductions to the annual producer surplus loss. As presented in Tables F3-3, F3-4, and F3-5, this results in total annualized benefits of up to approximately $20,500 for the 50 MGD option, $13,900 for the 200 MGD option, and $15,700 for the 100 MGD option, assuming a 3% discount rate.

Table F3-3: Annualized Commercial Fishing Benefits Attributable to the 50 MGD Option at Facilities in the Great Lakes Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$152,000	$28,600	$180,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$60,600	$11,400	$72,000
Expected reduction due to rule	33%	43%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$24,900
3% discount rate			$20,500
7% discount rate			$15,900

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table F3-4: Annualized Commercial Fishing Benefits Attributable to the 200 MGD Option at Facilities in the Great Lakes Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$152,000	$28,600	$180,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$60,600	$11,400	$72,000
Expected reduction due to rule	21%	38%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$17,100
3% discount rate			$13,900
7% discount rate			$10,700

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table F3-5: Annualized Commercial Fishing Benefits Attributable to the 100 MGD Option at Facilities in the Great Lakes Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$152,000	$28,600	$180,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$60,600	$11,400	$72,000
Expected reduction due to rule	24%	40%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$19,200
3% discount rate			$15,700
7% discount rate			$12,100

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Chapter F4: Recreational Use Benefits

Introduction

This chapter presents the results of the recreational fishing benefits analysis for the Great Lakes region. The chapter presents EPA's estimates of baseline (i.e., current) annual recreational fishery losses from impingement and entrainment (I&E) at potentially regulated facilities in the Great Lakes region and annual reduction in these losses under the three proposed regulatory options for Phase III existing facilities:[1]

- the "50 MGD for All Waterbodies" option,
- the "200 MGD for All Waterbodies" option, and
- the "100 MGD for Certain Waterbodies" option.

The chapter then presents the estimated welfare gain to Great Lakes anglers from eliminating baseline recreational fishing losses from I&E and the expected benefits under the three proposed options.

EPA estimated the recreational benefits of reducing and eliminating I&E losses using a benefit transfer methodology based on a meta-analysis of the marginal value of catching different species of fish. This meta-analysis is discussed in detail in Chapter A5, "Recreational Fishing Benefits Methodology." To validate these results, this chapter also presents the results of a random utility model (RUM) analysis for the Great Lakes region. A detailed discussion of the RUM analysis for the Great Lakes region can be found in Chapter G4 of the final Phase II Regional Studies report (U.S. EPA, 2004).[2]

EPA considered a wide range of policy options in developing this regulation. Results of the

Chapter Contents

[1] See the introduction to this report for a description of the three proposed options.

[2] The Phase II Great Lakes RUM model was refined for the Phase III analysis as follows: (1) it estimates separate values for yellow perch and bass and (2) includes site amenity effects in the site choice model (Besedin et al., 2004).

recreational fishing benefits analysis for five other options evaluated by EPA are presented in Appendix F4.

F4-1 Benefit Transfer Approach Based on Meta-Analysis

EPA estimated the recreational welfare gain from the reduction in annual I&E losses expected under the policy options, and the welfare gain from eliminating I&E at potentially regulated facilities, using a benefit transfer approach. As discussed in Chapter A5, the Agency used the meta-analysis regression equation to estimate the marginal recreational value per additional fish caught by anglers, for different species in different regions. Since I&E at potentially regulated facilities affects a variety of species, EPA assigned each species with I&E losses to one of the general species groups used in the meta-analysis. The Agency then calculated the economic value of reducing or eliminating baseline I&E losses, for each species group, by multiplying the value per fish for that species group by the number of fish in the group that are lost in the baseline or saved under the policy options.[3]

In general, the fit between the species with I&E losses and the species groups in the meta-analysis was good. However, EPA's estimates of baseline I&E losses and reductions in I&E under the policy options included losses of 'unidentified' species. The 'unidentified' group includes fish lost indirectly through trophic transfer, as well as species for which no species information was available.[4] Rather than using the meta-analysis regression to try to predict the value per fish for an "unidentified" species, EPA assumed that per-fish values for these species can be approximated by the weighted average value per fish for all species affected by I&E in the Great Lakes region.[5]

F4-1.1 Estimated Reductions in Recreational Fishery Losses under the Proposed Regulation

Table F4-1 presents EPA's estimates of baseline (i.e., current) annual recreational I&E losses at potentially regulated facilities and annual reductions in these losses under each of the proposed options, in the Great Lakes region. The table shows that total baseline losses to recreational fisheries are 263.5 thousand fish per year. In comparison, the "50 MGD for All Waterbodies" option prevents losses of 92.2 thousand fish per year, the "200 MGD for All Waterbodies" option prevents losses of 64.2 thousand fish per year, and the "100 MGD for Certain Waterbodies" option prevents losses of 71.9 thousand fish per year. Of all the affected species, white bass and yellow perch have the highest losses in the baseline and the highest prevented losses under the proposed options.

[3] Note that the estimates of I&E presented in this chapter include only the fraction of impinged and entrained recreational fish that would otherwise be caught by anglers. The total amount of I&E of recreational species is actually much higher.

[4] In addition to recreational fish that are lost because they are impinged or entrained, some recreational fish are lost because the forage fish that they feed on are impinged or entrained, and thus removed from the food chain. These trophic transfer losses of recreational species are included in EPA's estimates of total I&E losses. However, since it is difficult to predict which recreational species would be affected by losses of forage fish, these losses are classified as 'unidentified' recreational species. Also included in the 'unidentified' group are losses of fish that were reported by facilities without information about their exact species.

[5] EPA used the estimated level of baseline recreational losses for each species group as a weighting factor.

Table F4-1: Baseline Recreational Fishing Losses from I&E at Potentially Regulated Phase III Facilities and Reductions in Recreational Losses under the Proposed Regulatory Options in the Great Lakes Region

Species[a]	Baseline Annual Recreational Fishing Losses (# of fish)	Annual Reductions in Recreational Fishing Losses (# of fish)		
		50 MGD All	200 MGD All	100 MGD CWB
Salmon	87	33	25	28
Total (salmon)	**87**	**33**	**25**	**28**
Northern pike	1	0[b]	0[b]	0[b]
Walleye	2,761	1,003	731	808
Total (walleye/pike)	**2,762**	**1,003**	**731**	**809**
Smallmouth bass	735	317	273	290
White bass	60,701	22,097	16,144	17,840
Total (bass)	**61,436**	**22,414**	**16,416**	**18,130**
Black crappie	27	9	6	7
Bluegill	16	6	4	5
Channel catfish	2,556	1,091	931	991
Crappie	1,273	545	467	496
Rainbow smelt	1,370	484	342	381
Sculpin	588	254	218	232
Smelts	161	54	35	40
Sunfish	4,627	2,001	1,724	1,830
Yellow perch	24,855	9,266	6,950	7,629
Total (panfish)	**35,473**	**13,710**	**10,678**	**11,611**
Whitefish	1,499	495	319	365
Total (trout)	**1,499**	**495**	**319**	**365**
Total (unidentified)	**162,272**	**54,523**	**36,051**	**40,919**
Total (all species)	***263,529***	***92,178***	***64,221***	***71,861***

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The 'unidentified' group includes fish lost indirectly through trophic transfer.
[b] Denotes a positive value less than 0.5 fish.

Source: U.S. EPA analysis for this report.

F4-1.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table F4-2 shows the results of EPA's analysis of the welfare gain to recreational anglers from eliminating baseline recreational fishery losses at potentially regulated facilities in the Great Lakes region. The table presents baseline annual recreational I&E losses, the estimated value per fish, and the monetized annual welfare gain from eliminating recreational losses, for each species group. Total baseline recreational fishing losses for the Great Lakes region are 0.26 million fish per year. The undiscounted annual welfare gain to the Great Lakes anglers from eliminating these losses is $1.11 million (2003$), with lower and upper bounds of $0.55 million and $2.17 million. Evaluated at 3% and 7%, the mean annualized welfare gain of eliminating these losses is $1.08 million and $1.04 million, respectively. The majority of monetized recreational losses from I&E under baseline conditions are attributable to losses of species in the bass and panfish group, primarily white bass and yellow perch.

Table F4-2: Recreational Fishing Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the Great Lakes Region (2003$)

Species Group	Baseline Annual Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Benefits from Eliminating Recreational Fishing Losses (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Salmon	0.1	$6.53	$11.19	$19.39	$0.6	$1.0	$1.7
Trout	1.5	$1.23	$7.99	$9.53	$1.8	$12.0	$14.3
Walleye/Pike	2.8	$2.37	$4.58	$8.92	$6.5	$12.7	$24.6
Bass	61.4	$3.00	$5.90	$11.66	$184.2	$362.7	$716.6
Panfish	35.5	$0.52	$1.06	$2.21	$18.5	$37.8	$78.4
Unidentified	162.3	$2.09	$4.21	$8.25	$339.2	$682.8	$1,339.1
Total (undiscounted)	**263.5**				**$550.9**	**$1,108.9**	**$2,174.7**
Total (evaluated at 3%)	**263.5**				**$534.3**	**$1,075.6**	**$2,109.4**
Total (evaluated at 7%)	**263.5**				**$514.5**	**$1,035.8**	**$2,031.3**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying baseline losses by the estimated value per fish.
[d] Annualized values represent the total welfare gain over the time frame of the analysis from eliminating recreational losses, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.

Source: U.S. EPA analysis for this report.

F4-1.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table F4-3 shows the results of EPA's analysis of the recreational benefits of the "50 MGD for All Waterbodies" option for the Great Lakes region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 92.2 thousand fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.39 million (2003$), with lower and upper bounds of $0.19 million and $0.76 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.32 million and $0.25 million, respectively. The majority of benefits result from reduced losses of species in the bass and panfish group, primarily white bass and yellow perch.

Table F4-3: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the Great Lakes Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Salmon	0.0[e]	$6.53	$11.19	$19.39	$0.2	$0.4	$0.6
Trout	0.5	$1.23	$7.99	$9.53	$0.6	$4.0	$4.7
Walleye/Pike	1.0	$2.37	$4.58	$8.92	$2.4	$4.6	$8.9
Bass	22.4	$3.00	$5.90	$11.66	$67.2	$132.3	$261.4
Panfish	13.7	$0.52	$1.06	$2.21	$7.1	$14.6	$30.3
Unidentified	54.5	$2.09	$4.21	$8.25	$114.0	$229.4	$449.9
Total (undiscounted)	**92.2**				**$191.5**	**$385.3**	**$756.0**
Total (evaluated at 3%)	**92.2**				**$157.3**	**$316.4**	**$620.8**
Total (evaluated at 7%)	**92.2**				**$122.4**	**$246.2**	**$483.0**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] Denotes a positive value less than 50 fish.

Source: U.S. EPA analysis for this report.

F4-1.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

Table F4-4 shows the results of EPA's analysis of the recreational benefits of the "200 MGD for All Waterbodies" option for the Great Lakes region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 64.2 thousand fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.27 million (2003$), with lower and upper bounds of $0.13 million and $0.52 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.22 million and $0.17 million, respectively. The majority of benefits result from reduced losses of species in the bass and panfish group, primarily white bass and yellow perch.

Table F4-4: Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option in the Great Lakes Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Salmon	0.0[e]	$6.53	$11.19	$19.39	$0.2	$0.3	$0.5
Trout	0.3	$1.23	$7.99	$9.53	$0.4	$2.5	$3.0
Walleye/Pike	0.7	$2.37	$4.58	$8.92	$1.7	$3.3	$6.5
Bass	16.4	$3.00	$5.90	$11.66	$49.2	$96.9	$191.5
Panfish	10.7	$0.52	$1.06	$2.21	$5.6	$11.4	$23.6
Unidentified	36.1	$2.09	$4.21	$8.25	$75.4	$151.7	$297.5
Total (undiscounted)	**64.2**				**$132.4**	**$266.2**	**$522.6**
Total (evaluated at 3%)	**64.2**				**$107.6**	**$216.3**	**$424.7**
Total (evaluated at 7%)	**64.2**				**$82.6**	**$166.0**	**$325.9**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] Denotes a positive value less than 50 fish.

Source: U.S. EPA analysis for this report.

F4-1.5 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

Table F4-5 shows the results of EPA's analysis of the recreational benefits of the "100 MGD for Certain Waterbodies" option for the Great Lakes region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 0.072 million fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.30 million (2003$), with lower and upper bounds of $0.15 million and $0.59 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.24 million and $0.19 million, respectively. The majority of benefits result from reduced losses of species in the bass and panfish group, primarily white bass and yellow perch.

Table F4-5: Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option in the Great Lakes Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Salmon	0.0[e]	$6.53	$11.19	$19.39	$0.2	$0.3	$0.5
Trout	0.4	$1.23	$7.99	$9.53	$0.4	$2.9	$3.5
Walleye/Pike	0.8	$2.37	$4.58	$8.92	$1.9	$3.7	$7.2
Bass	18.1	$3.00	$5.90	$11.66	$54.4	$107.0	$211.5
Panfish	11.6	$0.52	$1.06	$2.21	$6.0	$12.4	$25.7
Unidentified	40.9	$2.09	$4.21	$8.25	$85.5	$172.2	$337.7
Total (undiscounted)	**71.9**				**$148.5**	**$298.5**	**$586.0**
Total (evaluated at 3%)	**71.9**				**$121.1**	**$243.4**	**$477.9**
Total (evaluated at 7%)	**71.9**				**$93.4**	**$187.7**	**$368.5**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] Denotes a positive value less than 50 fish.

Source: U.S. EPA analysis for this report.

F4-2 RUM Approach

To validate the results of the benefit transfer approach, EPA applied the approach presented in Chapter G4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004) to the baseline losses and reductions in losses at potentially regulated Phase III existing facilities.[6] This section presents the results of the recreational fishing benefits analysis for the Great Lakes region based on the Phase II RUM approach.

F4-2.1 RUM Methodology: Great Lakes Region

EPA's methodology for evaluating the change in welfare resulting from a change in recreational losses from I&E consists of four basic steps: (1) calculating the change in historical catch rates under a given policy scenario, (2) estimating the per-trip welfare gain to anglers based on the Phase II RUM model, (3) estimating the number of fishing trips taken by anglers, and (4) combining fishing participation data with the estimated per-trip welfare gain to calculate the total annual welfare gain. These steps are briefly described in the following sections. For a more

[6] EPA notes that the Great Lakes RUM model presented in Chapter G4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004) was refined for the Phase III analysis as follows: (1) it estimates separate values for yellow perch and bass and (2) includes site amenity effects in the site choice model (Besedin et al., 2004).

detailed discussion of the RUM methodology, see Chapters A11 and G4 of the *Regional Studies for the Final Section 316(b) Phase II Existing Facilities Rule* (U.S. EPA, 2004).

F4-2.1.1 Estimating Changes in the Quality of Fishing Sites

The first step in EPA's analysis was to combine estimates of recreational I&E losses at potentially regulated facilities with state-level recreational fishery landings data to estimate the percentage change in historical catch rates under each policy option. EPA obtained recreational landings data from each state in the Great Lakes region: New York, Pennsylvania, Ohio, Michigan, Illinois, Indiana, Wisconsin, and Minnesota. Some states reported both the number of fish harvested and the total number of fish caught, which includes fish caught and released, but EPA used the total number of fish caught to measure total landings. For states that only reported fish harvested, EPA adjusted harvest figures upward, using adjustment factors based on the average proportion of catch to harvest in Indiana, Pennsylvania, and Michigan, the three states that reported both values. The adjustment factors ranged from 1.09 for walleye to 9.28 for bass. Because most species considered in this analysis (e.g., perch, white bass) are found throughout Great Lakes waters, EPA made the assumption that changes in I&E will result in uniform changes in catch rates across all marine fishing sites in this region.[7] Thus, EPA then divided baseline recreational I&E losses by total recreational landings to calculate the percentage change in historical catch rates from completely eliminating recreational fishing losses from I&E. Similarly, the Agency also estimated the percentage changes to historic catch rates that would result under each policy option.

F4-2.1.2 Estimating Per-Trip Benefits from Reducing I&E

EPA's second step was to use the recreational behavior model described in Chapter F4 of the Phase II Regional Studies document to estimate an angler's per-trip welfare gain from changes in the historical catch rates in the Great Lakes region. The Agency estimated welfare gains to recreational anglers under four scenarios: eliminating baseline recreational fishing losses from I&E at potentially regulated facilities, and reducing recreational fishing losses from I&E by implementing the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, or the "100 MGD for Certain Waterbodies" option. EPA assumed that the welfare gain per fishing trip is independent of the number of days fished per trip and therefore equivalent for both single- and multiple-day trips. Thus, a multiple-day trip is valued the same as a single-day trip.[8] EPA estimated separate per-day welfare gains for different categories of anglers, based on their target species and fishing mode.[9]

---

[7] This assumption may not hold across lakes, as some lakes (e.g., Lakes Michigan and Erie) have more facilities, and therefore are likely to have greater benefits from reduced I&E. However, data were not sufficient to estimate welfare changes by lake, so EPA assumed that catch rates will change uniformly across the entire region.

[8] See section G4-5.2 of Chapter G4 of the 316(b) Phase II document for limitations and uncertainties associated with this assumption.

[9] EPA used the per-day values for private/rental boat anglers to estimate welfare gains for charter boat anglers.

F4-2.1.3 Estimating Angler Participation

The third step in EPA's analysis was to estimate baseline and post-regulatory fishing participation, measured by the total number of fishing trips taken by Great Lakes anglers.[10] Because the policy options for Phase III facilities are expected to result in relatively small improvements in fishing quality, EPA assumed that increases in recreational fishing participation under the policy options will be negligible. Thus, to estimate both baseline and post-regulatory participation, EPA used adjusted estimates of the total number of fishing trips taken by anglers targeting different species, taken from the *2001 Survey of Fishing, Hunting, and Wildlife-Related Recreation* (U.S. DOI, 2002).[11]

F4-2.1.4 Estimating Total Benefits from Eliminating or Reducing I&E

The final step in EPA's analysis was to calculate the total benefits of the policy options. To calculate total benefits for each subcategory of anglers targeting a particular species with a particular fishing mode, EPA multiplied the per-trip welfare gain for an angler with that particular species/fishing mode combination by the total number of fishing trips taken by all anglers with that species/fishing mode combination. EPA then summed benefits for all subcategories of anglers to calculate the total welfare change in the Great Lakes region. Finally, as discussed in Chapter A8, EPA discounted and annualized the benefits estimates, using both 3% and 7% discount rates.

F4-2.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table F4-6 presents the baseline level of recreational landings at potentially regulated facilities and the estimated change in catch rates that would result from eliminating recreational fishing losses from I&E in the Great Lakes. The table shows that I&E has the largest effect on catch rates for bass, which would increase by 2% if I&E were eliminated.

---

[10] See Chapter G4 of the section 316(b) Phase II Case Study document for a detailed description of the angler participation estimates in the Great Lakes.

[11] Some anglers surveyed by U.S. FWS reported targeting more than one species per day. To avoid double-counting trips for these anglers, EPA adjusted the total number of trips anglers spent targeting each species downward, based on the proportion of all trips (including trips spent by anglers targeting multiple species) that were spent targeting that species.

Table F4-6: Estimated Changes in Historical Catch Rates from Eliminating I&E at Potentially Regulated Phase III Facilities in the Great Lakes Region[d]

Species Group	Annual Recreational Landings (thousands of fish)	Baseline Annual Recreational Fishing Losses (thousands of fish)[a]	Percent Increase in Recreational Catch from Eliminating I&E
Bass	3,048.4	61.4	2.02%
Perch	10,808.3	24.9	0.23%
Walleye/Pike	1,693.9	2.8	0.16%
Salmon/Trout	1,905.2	0.1	0.00%[b]
No target	28,885.8[c]	174.4	0.60%

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[b] Denotes a positive value less than 0.005%.
[c] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.
[d] In this table, recreational fishing losses include only the fraction of impinged and entrained recreational fish that would otherwise be caught by anglers.

Sources: MDNR, 2002; and U.S. EPA analysis for this report.

Table F4-7 presents the per-trip welfare gain for anglers targeting different species, the number of fishing trips taken by anglers targeting those species, and the total annual welfare gain from eliminating baseline I&E. The table shows that the total undiscounted value of baseline losses in the Great Lakes region is $1.43 million (2003$), and the annualized value of those losses is $1.39 million and $1.33 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bass. The table shows that eliminating baseline recreational fishing losses from I&E would result in per-trip welfare gains of less than thirty cents per angler.

Table F4-7: Recreational Fishing Benefits from Eliminating I&E at Potentially Regulated Phase III Facilities in the Great Lakes Region (2003$)

Species Group	Per-Trip Welfare Gain	Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
Bass	$0.28	3,944	$1,095.5
Perch	$0.04	4,095	$148.3
Walleye/Pike	$0.03	4,296	$118.4
Salmon/Trout	$0.00[c]	8,468	$7.6
No target	$0.03	2,336	$58.1
Total, All Species (undiscounted)		**23,138**	**$1,427.9**
Total, All Species (discounted at 3%)		**23,138**	**$1,385.0**
Total, All Species (discounted at 7%)		**23,138**	**$1,333.7**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.

Source: U.S. EPA analysis for this report.

F4-2.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table F4-8 presents the estimated change in historical catch rates that would result from reductions in I&E under the "50 MGD for All Waterbodies" option. In the Great Lakes region, catch rates for anglers targeting bass would increase the most under this option, by 0.74%.

Table F4-8: Estimated Changes in Historical Catch Rates from Reducing I&E under the "50 MGD for All Waterbodies" Option in the Great Lakes Region

Species Group	Annual Recreational Landings (thousands of fish)	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Percent Increase in Recreational Catch from Reducing I&E
Bass	3,048.4	22.4	0.74%
Perch	10,808.3	9.3	0.09%
Walleye/Pike	1,693.9	1.0	0.06%
Salmon/Trout	1,905.2	0.0[b]	0.00%[c]
No target	28,885.8[d]	59.5	0.20%

[a] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[b] Denotes a positive value less than 50 fish.
[c] Denotes a positive value less than 0.005%.
[d] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: MDNR, 2002; and U.S. EPA analysis for this report.

Table F4-9 presents the recreational benefits of the "50 MGD for All Waterbodies" option for the Great Lakes region. The table shows that the total undiscounted benefits of this option are $0.52 million (2003$), and the annualized value of those benefits is $0.43 million and $0.33 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bass. The table shows that this option would result in per-trip welfare gains of ten cents or less per angler.

Table F4-9: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the Great Lakes Region (2003$)

Species Group	Per-Trip Welfare Gain	Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
Bass	$0.10	3,944	$400.6
Perch	$0.01	4,095	$55.3
Walleye/Pike	$0.01	4,296	$43.0
Salmon/Trout	$0.00[c]	8,468	$2.9
No target	$0.01	2,336	$19.8
Total, All Species (undiscounted)		**23,138**	**$521.6**
Total, All Species (discounted at 3%)		**23,138**	**$428.3**
Total, All Species (discounted at 7%)		**23,138**	**$333.3**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.

Source: U.S. EPA analysis for this report.

F4-2.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

Table F4-10 presents the estimated change in historical catch rates that would result from reductions in I&E under the "200 MGD for All Waterbodies" option. In the Great Lakes region, catch rates for anglers with targeting bass would increase the most under this option, by 0.01%.

Table F4-10: Estimated Changes in Historical Catch Rates from Reducing I&E under the "200 MGD for All Waterbodies" Option in the Great Lakes Region

Species Group	Annual Recreational Landings (thousands of fish)	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Percent Increase in Recreational Catch from Reducing I&E
Bass	3,048.4	16.4	0.01%
Perch	10,808.3	7.0	0.00%[c]
Walleye/Pike	1,693.9	0.7	0.00%[c]
Salmon/Trout	1,905.2	0.0[b]	0.00%[c]
No target	28,885.8[d]	40.1	0.00%[c]

[a] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[b] Denotes a positive value less than 50 fish.
[c] Denotes a positive value less than 0.005%.
[d] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: MDNR, 2002; and U.S. EPA analysis for this report.

Table F4-11 presents the recreational benefits of the "200 MGD for All Waterbodies" option for the Great Lakes region. The table shows that the total undiscounted benefits of this option are $0.38 million (2003$), and the annualized value of those benefits is $0.31 million and $0.24 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bass. The table shows that this option would result in per-trip welfare gains of seven cents or less per angler.

Table F4-11: Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option in the Great Lakes Region (2003$)

Species Group	Per-Trip Welfare Gain	Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
Bass	$0.07	3,944	$293.5
Perch	$0.01	4,095	$41.5
Walleye/Pike	$0.01	4,296	$31.3
Salmon/Trout	$0.00[c]	8,468	$2.2
No target	$0.01	2,336	$13.4
Total, All Species (undiscounted)		**23,138**	**$381.9**
Total, All Species (discounted at 3%)		**23,138**	**$310.4**
Total, All Species (discounted at 7%)		**23,138**	**$238.2**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.

Source: U.S. EPA analysis for this report.

F4-2.4 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

Table F4-12 presents the estimated change in historical catch rates that would result from reductions in I&E under the "100 MGD for Certain Waterbodies" option. In the Great Lakes region, catch rates for anglers targeting bass would increase the most under this option, by 0.01%.

Table F4-12: Estimated Changes in Historical Catch Rates from Reducing I&E under the "100 MGD for Certain Waterbodies" Option in the Great Lakes Region

Species Group	Annual Recreational Landings (thousands of fish)	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Percent Increase in Recreational Catch from Reducing I&E
Bass	3,048.4	18.1	0.01%
Perch	10,808.3	7.6	0.00%[c]
Walleye/Pike	1,693.9	0.8	0.00%[c]
Salmon/Trout	1,905.2	0.0[b]	0.00%[c]
No target	28,885.8[d]	45.3	0.00%[b]

[a] Reductions in recreational losses include only the portion of recreational fish that are saved from impingement and entrainment that are then caught by anglers. Losses of species that were not identified were distributed to the species groups in the same proportions found in the MRFSS landings data.
[b] Denotes a positive value less than 50 fish.
[c] Denotes a positive value less than 0.005%.
[d] Annual recreational landings for the 'no target' group were calculated as a sum of landings for all species groups.

Sources: MDNR, 2002; and U.S. EPA analysis for this report.

Table F4-13 presents the recreational benefits of the "100 MGD for Certain Waterbodies" option for the Great Lakes region. The table shows that the total undiscounted benefits of this option are $0.42 million (2003$), and the annualized value of those benefits is $0.34 million and $0.27 million, evaluated at 3% and 7%, respectively. The majority of benefits in this region are attributable to changes in catch rates for bass. The table shows that this option would result in per-trip welfare gains of eight cents or less per angler.

Table F4-13: Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option in the Great Lakes Region (2003$)

Species Group	Per-Trip Welfare Gain	Number of Fishing Trips (thousands)[a]	Annualized Total Benefits (thousands)[b]
Bass	$0.08	3,944	$324.1
Perch	$0.01	4,095	$45.6
Walleye/Pike	$0.01	4,296	$34.7
Salmon/Trout	$0.00[c]	8,468	$2.4
No target	$0.01	2,336	$15.1
Total, All Species (undiscounted)		**23,138**	**$421.8**
Total, All Species (discounted at 3%)[c]		**23,138**	**$344.0**
Total, All Species (discounted at 7%)[c]		**23,138**	**$265.2**

[a] The number of fishing trips for all species is not equal to the sum of those listed; the total includes fishing trips for the 'big game' species group.
[b] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[c] Denotes a positive value less than $0.005.

Source: U.S. EPA analysis for this report.

F4-3 Validation of Benefit Transfer Results Based on RUM Results

Table F4-14 compares the undiscounted results of the benefit transfer based on the meta-analysis with the results of the RUM analysis. In general, the RUM-based results are fall within the upper range of values estimated based on the meta-model. However, in absolute terms, the values from the two independent analyses are relatively close, corroborating the use of meta-analysis in estimating the value of incremental recreational fishing improvements resulting from the section 316(b) regulation for Phase III facilities. The table shows that under both models, the welfare gain under the "50 MGD for All Waterbodies" option is higher than the welfare gain under the "200 MGD for All Waterbodies" option and the "100 MGD for Certain Waterbodies" option.

Table F4-14: Recreational Fishing Benefits in the Great Lakes Region Calculated from Meta-Analysis Approach and RUM Approach

Policy Option	Estimated Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands, 2003$)			
		Based on Meta-Analysis			
		Low	Mean	High	Based on RUM
Eliminating baseline recreational fishing losses from I&E	263.5	$550.9	$1,108.9	$2,174.7	$1,428
50 MGD All	92.2	$191.5	$385.3	$756.0	$522
200 MGD All	64.2	$132.4	$266.2	$522.6	$382
100 MGD CWB	71.9	$148.5	$298.5	$586.0	$422

Source: U.S. EPA analysis for this report.

F4-4 Limitations and Uncertainty

F4-4.1 Limitations and Uncertainty: Meta-Analysis

The results of the benefit transfer based on the meta-analysis results represent EPA's best estimate of the recreational benefits of the proposed options. Nonetheless, there are a number of limitations and uncertainties inherent in these estimates. General limitations pertaining to the development of the meta-analysis model, the use of the model to estimate per-fish values, and the validity of the benefit transfer are discussed in section A5-3.3e and section A5-5.3 of Chapter A5. In addition to these general concerns about the analysis, there are other limitations and uncertainties that are specific to the Great Lakes region.

The main limitation of using the meta-analysis to calculate recreational benefits for the Great Lakes region is that EPA was unable to locate any studies that evaluated WTP for some Great Lakes species such as rainbow smelt and sculpin. However, the Agency believes that the per-fish values for these species can be approximated by the per-fish values for panfish.

F4-4.2 Limitations and Uncertainty: RUM Approach

The results of the benefit transfer based on the RUM analysis results serve to confirm that EPA's estimates of the recreational benefits of the proposed options are reasonable. However, there are a number of limitations and uncertainties inherent in these estimates. Some general limitations pertaining to the RUM model are discussed in Chapter A11 of the 316(b) Phase II document. Some additional region-specific limitations are discussed in Chapter G4 of the 316(b) Phase II document.

Although the estimated total welfare gain to the Great Lakes recreational anglers based on the regional RUM model is likely to be accurate, the estimated average per-trip welfare gain presented in Tables F4-7, F4-9, F4-11, and F4-13 must be used and understood in the context of the regional model developed by EPA for the Phase II analysis (or Besedin et al, 2004). The regional RUM model assumes uniform changes in catch rates at all sites across the region. Given that there are only 80 potentially regulated facilities in the Great Lakes region, which includes a large amount of aquatic habitat, catch rate improvements are more likely to occur locally rather than regionally. These local improvements in catch rates and the associated average per-trip welfare gain are likely to be greater than those presented in the tables in section F4-2. However, the number of anglers benefitting from these improvements would be smaller, and so the resulting aggregate benefits are likely to be similar.

Appendix F1: Life History Parameter Values Used to Evaluate I&E in the Great Lakes Region

The tables in this appendix summarize the life history parameter values used by EPA to calculate age-1 equivalents and fishery yield from impingement and entrainment (I&E) data for the Great Lakes region.

Table F1-1: Alewife Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	11.5	0	0	0.00000128
Larvae	5.50	0	0	0.00000141
Juvenile	6.21	0	0	0.00478
Age 1+	0.500	0	0	0.0160
Age 2+	0.500	0	0	0.0505
Age 3+	0.500	0	0	0.0764
Age 4+	0.500	0	0	0.0941
Age 5+	0.500	0	0	0.108
Age 6+	0.500	0	0	0.130
Age 7+	0.500	0	0	0.149

Sources: Spigarelli et al., 1981; PG&E National Energy Group, 2001; Froese and Pauly, 2003; and NMFS, 2003a.

Table F1-2: Bass Species (*Micropterus* sp.) Life History Parameters[a]				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	1.90	0	0	0.00000731
Larvae	2.70	0	0	0.0000198
Juvenile	0.446	0	0	0.0169
Age 1+	0.860	0	0	0.202
Age 2+	1.17	0.32	0.50	0.518
Age 3+	0.755	0.21	1.0	0.733
Age 4+	1.05	0.29	1.0	1.04
Age 5+	0.867	0.24	1.0	1.44
Age 6+	0.867	0.24	1.0	2.24
Age 7+	0.867	0.24	1.0	2.56
Age 8+	0.867	0.24	1.0	2.92
Age 9+	0.867	0.24	1.0	3.30

[a] Includes largemouth bass, smallmouth bass, and other sunfish not identified to species level.

Sources: Scott and Crossman, 1973; Carlander, 1977; Wang, 1986; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-3: Black Bullhead Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	1.90	0	0	0.0000312
Larvae	4.61	0	0	0.000186
Juvenile	1.39	0	0	0.00132
Age 1+	0.446	0	0	0.0362
Age 2+	0.223	0.22	0.50	0.0797
Age 3+	0.223	0.22	1.0	0.137
Age 4+	0.223	0.22	1.0	0.233
Age 5+	0.223	0.22	1.0	0.402
Age 6+	0.223	0.22	1.0	0.679
Age 7+	0.223	0.22	1.0	0.753
Age 8+	0.223	0.22	1.0	0.815
Age 9+	0.223	0.22	1.0	0.823

Sources: Carlander, 1969; Scott and Crossman, 1973; Geo-Marine, Inc., 1978; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-4: Black Crappie Life History Parameter

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.80	0	0	0.000000929
Larvae	0.498	0	0	0.00000857
Juvenile	2.93	0	0	0.0120
Age 1+	0.292	0	0	0.128
Age 2+	0.292	0.29	0.50	0.193
Age 3+	0.292	0.29	1.0	0.427
Age 4+	0.292	0.29	1.0	0.651
Age 5+	0.292	0.29	1.0	0.888
Age 6+	0.292	0.29	1.0	0.925
Age 7+	0.292	0.29	1.0	0.972
Age 8+	0.292	0.29	1.0	1.08
Age 9+	0.292	0.29	1.0	1.26

Sources: Carlander, 1977; Wang, 1986; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-5: Bluegill Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.73	0	0	0.00000130
Larvae	0.576	0	0	0.00000156
Juvenile	4.62	0	0	0.00795
Age 1+	0.390	0	0	0.00992
Age 2+	0.151	0	0	0.0320
Age 3+	0.735	0.74	0.50	0.0594
Age 4+	0.735	0.74	1.0	0.104
Age 5+	0.735	0.74	1.0	0.189
Age 6+	0.735	0.74	1.0	0.193
Age 7+	0.735	0.74	1.0	0.209
Age 8+	0.735	0.74	1.0	0.352
Age 9+	0.735	0.74	1.0	0.393

Sources: Carlander, 1977; Wang, 1986; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-6: Brown Bullhead Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000115
Larvae	4.61	0	0	0.0000192
Juvenile	1.39	0	0	0.00246
Age 1+	0.446	0	0	0.0898
Age 2+	0.223	0.22	0.50	0.172
Age 3+	0.223	0.22	1.0	0.278
Age 4+	0.223	0.22	1.0	0.330
Age 5+	0.223	0.22	1.0	0.570
Age 6+	0.223	0.22	1.0	0.582

Sources: Carlander, 1969; Geo-Marine, Inc., 1978; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-7: Bullhead Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.0000312
Larvae	4.61	0	0	0.000186
Juvenile	1.39	0	0	0.00132
Age 1+	0.446	0	0	0.0362
Age 2+	0.223	0.22	0.50	0.0797
Age 3+	0.223	0.22	1.0	0.137
Age 4+	0.223	0.22	1.0	0.233
Age 5+	0.223	0.22	1.0	0.402
Age 6+	0.223	0.22	1.0	0.679
Age 7+	0.223	0.22	1.0	0.753
Age 8+	0.223	0.22	1.0	0.815
Age 9+	0.223	0.22	1.0	0.823

[a] Includes black bullhead, stonecat, tadpole madtom, yellow bullhead, and other bullheads not identified to species level.

Sources: Carlander, 1969; Scott and Crossman, 1973; Geo-Marine, Inc., 1978; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-8: Burbot Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000154
Larvae	7.13	0	0	0.00000160
Juvenile	0.916	0	0	0.0154
Age 1+	0.562	0	0	0.129
Age 2+	0.562	0	0	0.513
Age 3+	0.562	0	0	0.842
Age 4+	0.562	0	0	1.23
Age 5+	0.562	0	0	1.99
Age 6+	0.562	0	0	2.68
Age 7+	0.562	0	0	2.97
Age 8+	0.562	0	0	3.35
Age 9+	0.562	0	0	3.57
Age 10+	0.562	0	0	4.09

Sources: Schram et al., 1998; Scott and Crossman, 1998; Snyder, 1998; and NMFS, 2003a.

Table F1-9: Carp Life History Parameters[a]				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	1.90	0	0	0.00000673
Larvae	4.61	0	0	0.0000118
Juvenile	1.39	0	0	0.0225
Age 1+	0.130	0	0	0.790
Age 2+	0.130	0	0	1.21
Age 3+	0.130	0	0	1.81
Age 4+	0.130	0	0	5.13
Age 5+	0.130	0	0	5.52
Age 6+	0.130	0	0	5.82
Age 7+	0.130	0	0	6.76
Age 8+	0.130	0	0	8.17
Age 9+	0.130	0	0	8.55
Age 10+	0.130	0	0	8.94
Age 11+	0.130	0	0	9.76
Age 12+	0.130	0	0	10.2
Age 13+	0.130	0	0	10.6
Age 14+	0.130	0	0	11.1
Age 15+	0.130	0	0	11.5
Age 16+	0.130	0	0	12.0
Age 17+	0.130	0	0	12.5

[a] Includes bowfin, carp, goldfish, and other similar carps not identified to species level.

Sources: Carlander, 1969; Geo-Marine, Inc., 1978; Wang, 1986; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-10: Carp/Minnow Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000115
Larvae	2.06	0	0	0.000375
Juvenile	2.06	0	0	0.00208
Age 1+	1.00	0	0	0.00585
Age 2+	1.00	0	0	0.0121
Age 3+	1.00	0	0	0.0171

[a] Includes bluntnose minnow, fathead minnow, hornyhead chub, lake chub, longnose dace, and other similar minnows not identified to species level.

Sources: Carlander, 1969; Froese and Pauly, 2001; NMFS, 2003a; and Ohio Department of Natural Resources, 2003.

Table F1-11: Crappie Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.80	0	0	0.000000929
Larvae	0.498	0	0	0.00000857
Juvenile	2.93	0	0	0.0120
Age 1+	0.292	0	0	0.128
Age 2+	0.292	0.29	0.50	0.193
Age 3+	0.292	0.29	1.0	0.427
Age 4+	0.292	0.29	1.0	0.651
Age 5+	0.292	0.29	1.0	0.888
Age 6+	0.292	0.29	1.0	0.925
Age 7+	0.292	0.29	1.0	0.972
Age 8+	0.292	0.29	1.0	1.08
Age 9+	0.292	0.29	1.0	1.26

[a] Includes white crappie and other crappies not identified to the species level.

Sources: Carlander, 1977; Wang, 1986; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-12: Freshwater Catfish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.0000539
Larvae	4.61	0	0	0.0000563
Juvenile	1.39	0	0	0.0204
Age 1+	0.410	0.41	0.50	0.104
Age 2+	0.410	0.41	1.0	0.330
Age 3+	0.410	0.41	1.0	0.728
Age 4+	0.410	0.41	1.0	1.15
Age 5+	0.410	0.41	1.0	1.92
Age 6+	0.410	0.41	1.0	2.41
Age 7+	0.410	0.41	1.0	3.45
Age 8+	0.410	0.41	1.0	4.01
Age 9+	0.410	0.41	1.0	5.06
Age 10+	0.410	0.41	1.0	8.08
Age 11+	0.410	0.41	1.0	8.39
Age 12+	0.410	0.41	1.0	8.53

[a] Includes channel catfish and flathead catfish.

Sources: Miller, 1966; Carlander, 1969; Geo-Marine, Inc., 1978; Wang, 1986; Saila et al., 1997; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-13: Freshwater Drum Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.27	0	0	0.00000115
Larvae	6.13	0	0	0.00000295
Juvenile	2.30	0	0	0.0166
Age 1+	0.310	0	0	0.0500
Age 2+	0.155	0.16	0.50	0.206
Age 3+	0.155	0.16	1.0	0.438
Age 4+	0.155	0.16	1.0	0.638
Age 5+	0.155	0.16	1.0	0.794
Age 6+	0.155	0.16	1.0	0.950
Age 7+	0.155	0.16	1.0	1.09
Age 8+	0.155	0.16	1.0	1.26
Age 9+	0.155	0.16	1.0	1.44
Age 10+	0.155	0.16	1.0	1.60
Age 11+	0.155	0.16	1.0	1.78
Age 12+	0.155	0.16	1.0	2.00

Sources: Scott and Crossman, 1973; Virginia Tech, 1998; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-14: Gizzard Shad Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.000000487
Larvae	6.33	0	0	0.00000663
Juvenile	0.511	0	0	0.0107
Age 1+	1.45	0	0	0.141
Age 2+	1.27	0	0	0.477
Age 3+	0.966	0	0	0.640
Age 4+	0.873	0	0	0.885
Age 5+	0.303	0	0	1.17
Age 6+	0.303	0	0	1.54

[a] Includes gizzard shad and other shad not identified to species level.

Sources: Wapora, 1979; Froese and Pauly, 2003; and NMFS, 2003a.

Table F1-15: Logperch Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000260
Larvae	1.90	0	0	0.000512
Juvenile	1.90	0	0	0.00434
Age 1+	0.700	0	0	0.0132
Age 2+	0.700	0	0	0.0251
Age 3+	0.700	0	0	0.0377

Sources: Carlander, 1997; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-16: Pike Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.08	0	0	0.0000189
Larvae	5.49	0	0	0.0133
Juvenile	5.49	0	0	0.0451
Age 1+	0.150	0	0	0.365
Age 2+	0.150	0	0	1.10
Age 3+	0.150	0	0	1.53
Age 4+	0.150	0	0	2.72
Age 5+	0.150	0	0	6.19
Age 6+	0.150	0	0	7.02
Age 7+	0.150	0	0	8.92
Age 8+	0.150	0	0	12.3
Age 9+	0.150	0	0	13.9
Age 10+	0.075	0.08	0.50	16.6
Age 11+	0.075	0.08	1.0	19.0
Age 12+	0.075	0.08	1.0	24.2
Age 13+	0.075	0.08	1.0	25.3
Age 14+	0.075	0.08	1.0	30.0
Age 15+	0.075	0.08	1.0	32.4
Age 16+	0.075	0.08	1.0	34.3
Age 17+	0.075	0.08	1.0	45.6
Age 18+	0.075	0.08	1.0	45.8
Age 19+	0.075	0.08	1.0	47.7
Age 20+	0.075	0.08	1.0	48.8
Age 21+	0.075	0.08	1.0	48.9
Age 22+	0.075	0.08	1.0	49.0
Age 23+	0.075	0.08	1.0	49.1
Age 24+	0.075	0.08	1.0	49.2
Age 25+	0.075	0.08	1.0	49.3
Age 26+	0.075	0.08	1.0	49.4
Age 27+	0.075	0.08	1.0	49.4

[a] Includes grass pickerel, muskellunge, and northern pike.

Sources: Carlander, 1969; Pennsylvania, 1999; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-17: Rainbow Smelt Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	11.5	0	0	0.000000990
Larvae	5.50	0	0	0.00110
Juvenile	0.916	0	0	0.00395
Age 1+	0.400	0	0	0.0182
Age 2+	0.400	0.03	0.50	0.0460
Age 3+	0.400	0.03	1.0	0.0850
Age 4+	0.400	0.03	1.0	0.131
Age 5+	0.400	0.03	1.0	0.180
Age 6+	0.400	0.03	1.0	0.228

Sources: Spigarelli et al., 1981; PG&E National Energy Group, 2001; Froese and Pauly, 2003; and NMFS, 2003a.

Table F1-18: Redhorse Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000115
Larvae	2.30	0	0	0.00000370
Juvenile	2.99	0	0	0.0267
Age 1+	0.548	0	0	0.0521
Age 2+	0.548	0	0	0.180
Age 3+	0.548	0	0	0.493
Age 4+	0.548	0	0	0.653
Age 5+	0.548	0	0	0.916
Age 6+	0.548	0	0	2.78
Age 7+	0.548	0	0	3.07

[a] Includes golden redhorse, shorthead redhorse, and silver redhorse.

Sources: Carlander, 1969; Bartell and Campbell, 2000; Froese and Pauly, 2001, 2003; and NMFS, 2003a.

Table F1-19: Salmonids Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.0000240
Larvae	8.20	0	0	0.000171
Juvenile	0.250	0	0	0.0117
Age 1+	0.250	1.0	0.50	0.705
Age 2+	0.250	1.0	1.0	1.27
Age 3+	0.250	1.0	1.0	2.32
Age 4+	0.250	1.0	1.0	2.85
Age 5+	0.250	1.0	1.0	3.52
Age 6+	0.250	1.0	1.0	4.09
Age 7+	0.250	1.0	1.0	4.76
Age 8+	0.250	1.0	1.0	5.70
Age 9+	0.250	1.0	1.0	5.73
Age 10+	0.250	1.0	1.0	5.85
Age 11+	0.250	1.0	1.0	6.10
Age 12+	0.250	1.0	1.0	6.83
Age 13+	0.250	1.0	1.0	7.11
Age 14+	0.250	1.0	1.0	7.29
Age 15+	0.250	1.0	1.0	7.32
Age 16+	0.250	1.0	1.0	8.66

[a] Includes bloater, brown trout, chinook salmon, coho salmon, lake herring, lake trout, lake whitefish, rainbow trout, round whitefish, and other salmonids not identified to species level.

Sources: Fish, 1932; Schorfhaar and Schneeberger, 1997; Scott and Crossman, 1998; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-20: Shiner Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000473
Larvae	4.61	0	0	0.000285
Juvenile	0.777	0	0	0.00209
Age 1+	0.371	0	0	0.00387
Age 2+	4.61	0	0	0.00683
Age 3+	4.61	0	0	0.0143

[a] Includes common shiner, emerald shiner, golden shiner, spotfin shiner, spottail shiner and other shiners not identified to species level.

Sources: Fuchs, 1967; Wapora, 1979; Trautman, 1981; Froese and Pauly, 2003; and NMFS, 2003a.

Table F1-21: Spotted Sucker Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.79	0	0	0.00000115
Larvae	2.81	0	0	0.00000198
Juvenile	3.00	0	0	0.0213
Age 1+	0.548	0	0	0.0863
Age 2+	0.548	0	0	0.690
Age 3+	0.548	0	0	1.24
Age 4+	0.548	0	0	1.70
Age 5+	0.548	0	0	1.92
Age 6+	0.548	0	0	1.99

Sources: Carlander, 1969; Bartell and Campbell, 2000; Froese and Pauly, 2001, 2003; and NMFS, 2003a.

Table F1-22: Sucker Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.05	0	0	0.0000312
Larvae	2.56	0	0	0.0000343
Juvenile	2.30	0	0	0.000239
Age 1+	0.274	0	0	0.0594
Age 2+	0.274	0	0	0.310
Age 3+	0.274	0	0	0.377
Age 4+	0.274	0	0	0.735
Age 5+	0.274	0	0	0.981
Age 6+	0.274	0	0	1.10

[a] Includes carpsucker buffalo, lake chubsucker, longnose sucker, northern hog sucker, quillback, white sucker, and other suckers not identified to species.

Sources: Carlander, 1969; Bartell and Campbell, 2000; Froese and Pauly, 2003; and NMFS, 2003a.

Table F1-23: Sunfish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.71	0	0	0.00000115
Larvae	0.687	0	0	0.00000123
Juvenile	0.687	0	0	0.000878
Age 1+	1.61	0	0	0.00666
Age 2+	1.61	0	0	0.0271
Age 3+	1.50	1.5	0.50	0.0593
Age 4+	1.50	1.5	1.0	0.0754
Age 5+	1.50	1.5	1.0	0.142
Age 6+	1.50	1.5	1.0	0.180
Age 7+	1.50	1.5	1.0	0.214
Age 8+	1.50	1.5	1.0	0.232

[a] Includes green sunfish, orange-spotted sunfish, pumpkinseed, rock bass, warmouth, and other sunfish not identified to species.

Sources: Carlander, 1977; Wang, 1986; PSE&G, 1999; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-24: Walleye Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.05	0	0	0.00000619
Larvae	3.55	0	0	0.0000768
Juvenile	1.93	0	0	0.0300
Age 1+	0.431	0	0	0.328
Age 2+	0.161	0.27	0.50	0.907
Age 3+	0.161	0.27	1.0	1.77
Age 4+	0.161	0.27	1.0	2.35
Age 5+	0.161	0.27	1.0	3.37
Age 6+	0.161	0.27	1.0	3.97
Age 7+	0.161	0.27	1.0	4.66
Age 8+	0.161	0.27	1.0	5.58
Age 9+	0.161	0.27	1.0	5.75

Sources: Carlander, 1997; Bartell and Campbell, 2000; Thomas and Haas, 2000; Froese and Pauly, 2001, 2003; and NMFS, 2003a.

Table F1-25: White Bass Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.000000396
Larvae	4.61	0	0	0.00000174
Juvenile	1.39	0	0	0.174
Age 1+	0.420	0	0	0.467
Age 2+	0.420	0.70	0.50	0.644
Age 3+	0.420	0.70	1.0	1.02
Age 4+	0.420	0.70	1.0	1.16
Age 5+	0.420	0.70	1.0	1.26
Age 6+	0.420	0.70	1.0	1.66
Age 7+	0.420	0.70	1.0	1.68

Sources: Van Oosten, 1942; Geo-Marine, Inc., 1978; Carlander, 1997; Virginia Tech, 1998; McDermot and Rose, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table F1-26: White Perch Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.75	0	0	0.000000330
Larvae	5.37	0	0	0.00000271
Juvenile	1.71	0	0	0.00259
Age 1+	0.693	0	0	0.0198
Age 2+	0.693	0	0	0.0567
Age 3+	0.693	0	0	0.103
Age 4+	0.689	0	0	0.150
Age 5+	1.58	0	0	0.214
Age 6+	1.54	0	0	0.265
Age 7+	1.48	0	0	0.356
Age 8+	1.46	0	0	0.387
Age 9+	1.46	0	0	0.516
Age 10+	1.46	0	0	0.619

Sources: Horseman and Shirey, 1974; PSE&G, 1999; and NMFS, 2003a.

Table F1-27: Yellow Perch Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.75	0	0	0.000000655
Larvae	3.56	0	0	0.000000728
Juvenile	2.53	0	0	0.0232
Age 1+	0.361	0	0	0.0245
Age 2+	0.249	0	0	0.0435
Age 3+	0.844	0.36	0.50	0.0987
Age 4+	0.844	0.36	1.0	0.132
Age 5+	0.844	0.36	1.0	0.166
Age 6+	0.844	0.36	1.0	0.214

Sources: Wapora, 1979; PSE&G, 1999; Thomas and Haas, 2000; and NMFS, 2003a.

Table F1-28: Other Recreational Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes deepwater sculpin, mottled sculpin, slimy sculpin, and other sculpins not identified to species.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; ASMFC, 2001b; and NMFS, 2003a.

Table F1-29: Other Forage Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Larvae	7.70	0	0	0.00000158
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] Includes central mudminnow, chestnut lamprey, johnny darter, lake sturgeon, longnose gar, ninespine stickleback, pirate perch, sea lamprey, silver lamprey, and other forage fish not identified to species.

Sources: Derickson and Price, 1973; and PSE&G, 1999.

Appendix F2: Reductions in I&E in the Great Lakes Region Under Five Other Options Evaluated for the Proposed Section 316(b) Phase III Regulation

Table F2-1: Estimated Reductions in I&E in the Great Lakes Region Under Five Other Options Evaluated for the Proposed Section 316(b) Regulation

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
20 MGD All	13,300,000	192,000
2	13,300,000	192,000
3	13,200,000	190,000
4	13,300,000	192,000
All Phase III Facilities	14,300,000	206,000

Appendix F3: Commercial Fishing Benefits for Five Other Options Evaluated for Phase III Existing Facilities in the Great Lakes Region

Section F3-2 in Chapter F3 displays the results of the commercial fishing benefits analysis for the 50 MGD option, the 200 MGD option, and the 100 MGD option. To facilitate comparisons among the options, this appendix displays results for the following additional options: All Potentially Regulated Phase III Existing Facilities option (All Phase III Facilities); the 20 MGD option (20 MGD All); Option 2; Option 3; and Option 4.

Table F3-1: Annualized Commercial Fishing Benefits Attributable to the All Phase III Facilities Option at Facilities in the Great Lakes Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$152,000	$28,600	$180,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$60,600	$11,400	$72,000
Expected reduction due to rule	41%	48%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$30,400
3% discount rate			$25,000
7% discount rate			$19,600

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table F3-2: Annualized Commercial Fishing Benefits Attributable to the 20 MGD All Option at Facilities in the Great Lakes Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$152,000	$28,600	$180,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$60,600	$11,400	$72,000
Expected reduction due to rule	38%	46%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$28,300
3% discount rate			$23,300
7% discount rate			$18,100

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table F3-3: Annualized Commercial Fishing Benefits Attributable to Option 2 at Facilities in the Great Lakes Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$152,000	$28,600	$180,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$60,600	$11,400	$72,000
Expected reduction due to rule	38%	46%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$28,300
3% discount rate			$23,300
7% discount rate			$18,100

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table F3-4: Annualized Commercial Fishing Benefits Attributable to Option 3 at Facilities in the Great Lakes Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$152,000	$28,600	$180,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$60,600	$11,400	$72,000
Expected reduction due to rule	38%	43%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$28,000
3% discount rate			$23,000
7% discount rate			$18,000

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Table F3-5: Annualized Commercial Fishing Benefits Attributable to Option 4 at Facilities in the Great Lakes Region (2003$)[a]

	Impingement	Entrainment	Total
Baseline loss — gross revenue			
Undiscounted	$152,000	$28,600	$180,000
Producer surplus lost — low	$0	$0	$0
Producer surplus lost — high (gross revenue * 0.4)			
Undiscounted	$60,600	$11,400	$72,000
Expected reduction due to rule	38%	46%	
Benefits attributable to rule — low	$0	$0	$0
Benefits attributable to rule — high			
Undiscounted			$28,300
3% discount rate			$23,300
7% discount rate			$18,100

[a] Annualized benefits represent the value of all commercial benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a 30 year period. For a more detailed discussion of the discounting methodology, refer to Chapter A8, and see Chapter H1 for a timeline of benefits.

Appendix F4: Recreational Use Benefits of Other Policy Options

Introduction

Chapter F4 presents EPA's estimates of the recreational benefits of the three proposed options for the section 316(b) rule for Phase III facilities, for electric generators and manufacturers in the Great Lakes region. This appendix supplements Chapter F4 by presenting estimates of the recreational fishing benefits of five other options that EPA evaluated for the purpose of comparison:

- Option 3,
- Option 4,
- Option 2,
- Option 1, and
- Option 6.

Appendix Contents

Recreational fishing benefits presented in this chapter were estimated using the benefit transfer approach discussed in Chapter F4 and in Chapter A5, "Recreational Fishing Benefits Methodology."

F4-1 Recreational Fishing Benefits of the Other Evaluated Options

F4-1.1 Estimated Reductions in Recreational Fishing Losses under the Other Evaluated Options

Table F4-1 presents EPA's estimates of the annual reduction in baseline (i.e., current) recreational fishing losses from impingement and entrainment (I&E) in the Great Lakes region under the other evaluated options.

Table F4-1: Reductions in Recreational Fishing Losses from I&E under the Other Evaluated Options in the Great Lakes Region

	Annual Reduction in Recreational Losses (# of fish)[b]				
Species[a]	**Option 3**	**Option 4**	**Option 2**	**Option 1**	**Option 6**
Salmon	35	36	36	36	39
Total (salmon)	**35**	**36**	**36**	**36**	**39**
Northern pike	0[c]	0[c]	0[c]	0[c]	0[c]
Walleye	1,098	1,119	1,119	1,119	1,196
Total (walleye/pike)	**1,099**	**1,120**	**1,120**	**1,120**	**1,197**
Smallmouth bass	318	335	335	335	351
White bass	24,164	24,644	24,644	24,644	26,331
Total (bass)	**24,482**	**24,979**	**24,979**	**24,979**	**26,682**
Black crappie	10	10	10	10	11
Bluegill	6	7	7	7	7
Channel catfish	1,100	1,157	1,157	1,157	1,215
Crappie	549	577	577	577	606
Rainbow smelt	538	546	546	546	585
Sculpin	254	268	268	268	281
Smelts	62	62	62	62	67
Sunfish	2,003	2,112	2,112	2,112	2,216
Yellow perch	10,006	10,252	10,252	10,252	10,925
Total (panfish)	**14,528**	**14,991**	**14,991**	**14,991**	**15,913**
Whitefish	571	571	571	571	617
Total (trout)	**571**	**571**	**571**	**571**	**617**
Total (unidentified)	**62,276**	**62,514**	**62,514**	**62,514**	**67,388**
Total (all species)	**102,991**	**104,211**	**104,211**	**104,211**	**111,836**

[a] EPA assigned each species with I&E losses to one of the species groups used in the meta-analysis. The 'unidentified' group includes fish lost indirectly through trophic transfer.

[b] In the Great Lakes region, the set of facilities with technology requirements under Option 4 is the same as under Option 2 and Option 1. Thus, reductions in recreational losses under these options are also identical.

[c] Denotes a non-zero value less than 0.5 fish.

Source: U.S. EPA analysis for this report.

F4-1.2 Recreational Fishing Benefits of the Other Evaluated Options

Tables F4-2, F4-3, and F4-4 present EPA's estimates of the annualized recreational benefits of the other evaluated options in the Great Lakes region.

In the Great Lakes region, all potentially regulated facilities that would install new technology under Option 4, Option 2, and Option 1 have design intake flows greater than or equal to 20 MGD. Because the requirements under these three options are identical for this class of facilities, the I&E reductions and benefits resulting from these three options are also identical. Thus, the benefits estimates presented in Table F4-3 apply to all three options.

Table F4-2: Recreational Fishing Benefits of Option 3 in the Great Lakes Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Salmon	0.0[d]	$6.53	$11.19	$19.39	$0.2	$0.4	$0.7
Trout	0.6	$1.23	$7.99	$9.53	$0.7	$4.6	$5.4
Walleye/Pike	1.1	$2.37	$4.58	$8.92	$2.6	$5.0	$9.8
Bass	24.5	$3.00	$5.90	$11.66	$73.4	$144.5	$285.5
Panfish	14.5	$0.52	$1.06	$2.21	$7.6	$15.5	$32.1
Unidentified	62.3	$2.09	$4.21	$8.25	$130.2	$262.1	$513.9
Total (undiscounted)	**103.0**				**$214.7**	**$432.1**	**$847.5**
Total (evaluated at 3%)	**103.0**				**$176.6**	**$355.3**	**$697.0**
Total (evaluated at 7%)	**103.0**				**$137.7**	**$277.0**	**$543.4**

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[b] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.
[d] Denotes a non-zero value less than 50 fish.

Source: U.S. EPA analysis for this report.

Table F4-3: Recreational Fishing Benefits of Option 4, Option 2, and Option 1, in the Great Lakes Region (2003$)[a]

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Salmon	0.0[e]	$6.53	$11.19	$19.39	$0.2	$0.4	$0.7
Trout	0.6	$1.23	$7.99	$9.53	$0.7	$4.6	$5.4
Walleye/Pike	1.1	$2.37	$4.58	$8.92	$2.7	$5.1	$10.0
Bass	25.0	$3.00	$5.90	$11.66	$74.9	$147.5	$291.3
Panfish	15.0	$0.52	$1.06	$2.21	$7.8	$16.0	$33.1
Unidentified	62.5	$2.09	$4.21	$8.25	$130.7	$263.1	$515.9
Total (undiscounted)	**104.2**				**$217.0**	**$436.6**	**$856.5**
Total (evaluated at 3%)	**104.2**				**$178.4**	**$359.1**	**$704.4**
Total (evaluated at 7%)	**104.2**				**$139.1**	**$280.0**	**$549.2**

[a] In the Great Lakes region, the set of facilities with technology requirements under Option 4 is the same as under Option 2 and Option 1. Thus, reductions in recreational losses under these options are also identical.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.
[e] Denotes a non-zero value less than 50 fish.

Source: U.S. EPA analysis for this report.

Table F4-4: Recreational Fishing Benefits of Option 6 in the Great Lakes Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Salmon	0.0[d]	$6.53	$11.19	$19.39	$0.3	$0.4	$0.8
Trout	0.6	$1.23	$7.99	$9.53	$0.8	$4.9	$5.9
Walleye/Pike	1.2	$2.37	$4.58	$8.92	$2.8	$5.5	$10.7
Bass	26.7	$3.00	$5.90	$11.66	$80.0	$157.5	$311.2
Panfish	15.9	$0.52	$1.06	$2.21	$8.3	$16.9	$35.2
Unidentified	67.4	$2.09	$4.21	$8.25	$140.9	$283.6	$556.1
Total (undiscounted)	**111.8**				**$233.0**	**$468.9**	**$919.8**
Total (evaluated at 3%)	**111.8**				**$192.0**	**$386.3**	**$757.8**
Total (evaluated at 7%)	**111.8**				**$150.1**	**$302.0**	**$592.3**

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[b] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.
[d] Denotes a non-zero value less than 50 fish.

Source: U.S. EPA analysis for this report.

F4-2 Comparison of Recreational Fishing Benefits by Option

Table F4-5 compares the recreational fishing benefits of the five other evaluated options. The table shows that recreational fishing benefits are very similar under all of the options.

Table F4-5: Annual Recreational Benefits of the Other Evaluated Options in the Great Lakes Region (2003$)

Policy Option[a]	Annual Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands; 2003$)[b]		
		Low	Mean	High
Option 3	103.0	$214.7	$432.1	$847.5
Option 4	104.2	$217.0	$436.6	$856.5
Option 2	104.2	$217.0	$436.6	$856.5
Option 1	104.2	$217.0	$436.6	$856.5
Option 6	111.8	$233.0	$468.9	$919.8

[a] In the Great Lakes region, the set of facilities with technology requirements under Option 4 is the same as under Option 2 and Option 1. Thus, reductions in recreational losses under these options are also identical.
[b] These benefit estimates were calculated using the meta-analysis approach discussed in Chapter A5 and Chapter F4. EPA did not use the RUM approach from the Phase II analysis to analyze the other evaluated options.

Source: U.S. EPA analysis for this report.

Part G: The Inland Region

Chapter G1: Background

Introduction

Chapter Contents

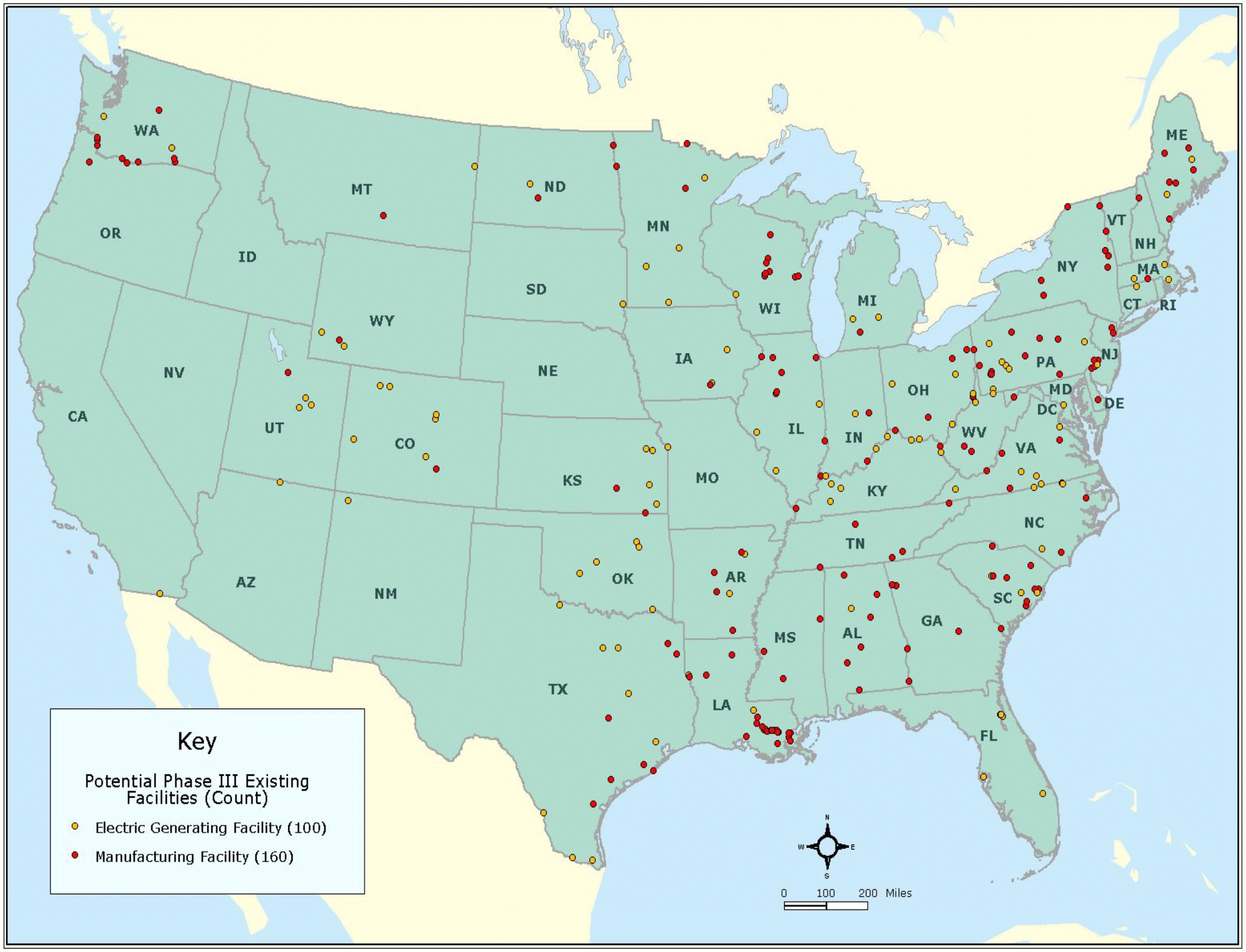
This chapter presents an overview of the potential Phase III existing facilities in the Inland study region and summarizes their key cooling water and compliance characteristics. For further discussion of the technical and compliance characteristics of potential Phase III existing facilities, refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* and the *Technical Development Document for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a,b).

G1-1 Facility Characteristics

The Inland Regional Study includes 260 sample facilities that are potentially subject to the proposed standards for Phase III existing facilities. One hundred and sixty facilities are manufacturing facilities and 100 are electric generators. Industry-wide, these 260 sample facilities represent 493 facilities.[1] Figure G1-1 presents a map of these facilities.

[1] EPA applied sample weights to the survey respondents to account for non-sampled facilities and facilities that did not respond to the survey. For more information on EPA's 2000 Section 316(b) Industry Survey, please refer to the Information Collection Request (U.S. EPA, 2000).

Figure G1-1: Potential Existing Phase III Facilities in the Inland Regional Study



Source: U.S. EPA analysis for this report.

Table G1-1 summarizes key technical and compliance characteristics for all potentially regulated Phase III existing facilities in the Inland study region and for the three proposed regulatory options considered by EPA for this proposal (the "50 MGD for All Waterbodies" option, the "200 MGD for All Waterbodies" option, and the "100 MGD for Certain Waterbodies" option). Facilities with a design intake flow below the three applicability thresholds would be subject to permitting based on best professional judgment and are excluded from EPA's analyses.[2] Therefore, a different number of facilities is affected under each option.

Table G1-1 shows that 493 Phase III existing facilities in the Inland study region would potentially be subject to the national requirements. Under the "50 MGD for All Waterbodies" option, the most inclusive of the three proposed options, 97 facilities would be subject to the national requirements for Phase III existing facilities. Under the less inclusive "200 MGD for All Waterbodies" option, 14 facilities would be subject to the national requirements, and under the "100 MGD for Certain Waterbodies" option, no facilities would be subject to the national requirements. One hundred and sixty nine facilities in the Inland study region have a recirculating system in the baseline.

Table G1-1: Technical and Compliance Characteristics of Existing Phase III Facilities (Sample-Weighted)

	All Potentially Regulated Facilities	Proposed Options		
		50 MGD All	200 MGD All	100 MGD CWB
Total Number of Facilities (sample-weighted)	**493**	**97**	**14**	**-**
Number of Facilities with Recirculating System in Baseline	**169**	**5**	**1**	**-**
Design Intake Flow (MGD)	**16,920**	**12,702**	**8,404**	**-**
Number of Facilities by Compliance Response				
Fish H&R	56	23	2	-
New larger intake structure with fine mesh and fish H&R	12	-	-	-
Velocity cap	40	7	-	-
Fine mesh traveling screens with fish H&R	25	11	4	-
Double-entry, single-exit with fine mesh and fish H&R	3	3	2	-
Passive fine mesh screens	66	25	3	-
None	292	27	2	-
Compliance Cost at 3%[a]	$40.07	$19.66	$12.30	$0.00
Compliance Cost at 7%[a]	$41.80	$20.65	$13.70	$0.00

[a] Annualized pre-tax compliance cost (2003$, millions)

Source: U.S. EPA, 2000; U.S. EPA analysis for this report.

[2] Also excluded are facilities that are estimated to be baseline closures. For additional information on EPA's baseline closure analyses, please refer to the *Economic Analysis for the Proposed Section 316(b) Rule for Phase III Facilities* (U.S. EPA, 2004a).

Chapter G2: Evaluation of Impingement and Entrainment in the Inland Region

G2-1 I&E Species/Species Groups Evaluated

Table G2-1 provides a list of species/species groups that were evaluated in EPA's analysis of impingement and entrainment (I&E) in the Inland region. There is not a significant level of commercial fishing in the interior U.S. Therefore, EPA has assumed that all I&E losses in this region affect recreational fisheries only.

Chapter Contents

Table G2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in the Inland Region

Species/Species Group	Recreational	Commercial	Forage
Alewife			X
American shad	X		
Bay anchovy			X
Bigmouth buffalo	X		
Black bullhead	X		
Black crappie	X		
Blueback herring			X
Bluegill	X		
Bluntnose minnow			X
Brown bullhead	X		
Bullhead species	X		
Burbot			X
Carp			X
Channel catfish	X		
Chinook salmon			X
Crappie	X		
Darter species	X		
Emerald shiner			X
Freshwater drum	X		
Gizzard shad			X

Table G2-1: Species/Species Groups Evaluated by EPA that are Subject to I&E in the Inland Region

Species/Species Group	Recreational	Commercial	Forage
Gobies			X
Golden redhorse	X		
Herring			X
Hogchoker			X
Logperch	X		
Menhaden species	X		
Muskellunge	X		
Other (forage)			X
Other (recreational)	X		
Other (recreational and commercial)	X		
Paddlefish	X		
Pallid sturgeon			X
Rainbow smelt	X		
Recreational sea bass	X		
River carpsucker	X		
Salmon	X		
Sauger	X		
Sculpin species	X		
Shiner species			X
Silversides			X
Skipjack herring			X
Smallmouth bass	X		
Smelt	X		
Spotted sucker	X		
Striped bass	X		
Striped killifish	X		
Sturgeon species	X		
Sucker species	X		
Sunfish	X		
Threespine stickleback			X
Walleye	X		
White bass	X		
White perch	X		
Whitefish	X		
Yellow perch	X		

The life history data used in EPA's analysis and associated data sources are provided in Appendix G1 of this report.

G2-2 I&E Data Evaluated

Table G2-2 lists Inland facility I&E data evaluated by EPA to estimate current I&E rates for the region. Data for both Phase II and Phase III facilities were used as a basis for extrapolation of I&E rates to Phase III facilities without I&E data. Chapter A1 of Part A presents the extrapolation methods.

Table G2-2: Facility I&E Data Evaluated for the Inland Region Analysis

Facility	Phase	Years of Data
Albany Generating Station	II	1974-1984
Barry Steam Plant	II	1976
Walter C. Beckjord Generating Station	II	1977
Braidwood Nuclear Generating Station	II	1988
Cardinal Plant	II	1978
AES Cayuga	II	1976-1987
Clifty Creek Station	II	1977-1986
Comanche	II	1993
Council Bluffs	II	1976
Dexter Corp./Nonwoven Div. (CT)	III	1990
Dickerson Generating Station	II	1978
Duane Arnold Nuclear Power Plant (IA)	III	1980
Eastman Chemical Company Arkansas Eastman Division (AR)	III	1980
Eckert Station	II	1975
Elrama Power Plant	II	1978
Erickson (MI)	III	1976
Finch, Pruyn, & Company Inc. (NY)	III	1993
G.G. Allen Steam Station	II	1973
Gorgas Steam Plant	II	1985
Hatfield's Ferry Power Station (PA)	III	1980
H B. Robinson	II	1973-1975
AES Huntington Beach	III	1979-2001
James H. Miller Jr. (AL)	III	1978-1986
Kammer Plant	II	1978
Kyger Creek Station	II	1978
Labadie	II	1974
Meramec	II	1974
Miami Fort Generating Station	II	1978
Newton	II	1983-1986
Oak Creek Energy Systems, Inc.	II	1975

Table G2-2: Facility I&E Data Evaluated for the Inland Region Analysis

Facility	Phase	Years of Data
Oconee	II	1974-1976
Pearl Station (IL)	III	1977
Philip Sporn Plant	II	1978
Cogentrix Roxboro	II	1980
Seminole (FL)	III	1979
Sherburne Co. (MN)	III	1974-1975
Tanners Creek Plant	II	1977
Wabash River Plant	II	1976
Wateree Generating Station	II	1976
W.H. Sammis Generating Station	II	1977
Winyah Generating Station (SC)	III	1981

G2-3 EPA's Estimate of Current I&E at Phase III Facilities in the Inland Region Expressed as Age-1 Equivalents and Foregone Yield

Table G2-3 provides EPA's estimate of the annual age-1 equivalents and foregone fishery yield resulting from the impingement of aquatic species at facilities located in the Inland region. Table G2-4 displays this information for entrainment. Note that in these tables, "total yield" includes direct losses of harvested species and the yield of harvested species that is lost due to losses of forage species. As discussed in Chapter A1 of Part A of the section 316(b) Phase III Regional Benefits Assessment, the conversion of forage to yield contributes only a very small fraction to total yield.

Table G2-3: Estimated Current Annual Impingement at Phase III Facilities in the Inland Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Alewife	56,500	na
American shad	6,650	1,630
Bay anchovy	2,680	na
Bigmouth buffalo	342	na
Black bullhead	1,050	84
Black crappie	1,870	316
Blueback herring	234,000	na
Bluegill	268,000	5,180
Bluntnose minnow	2,880	na
Brown bullhead	3,020	249
Bullhead species	782	62
Burbot	74	na
Carp	6,580	na

Table G2-3: Estimated Current Annual Impingement at Phase III Facilities in the Inland Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Channel catfish	97,700	20,200
Chinook salmon	55	na
Crappie	13,700	2,300
Darter species	143	na
Emerald shiner	3,210,000	na
Freshwater drum	88,000	21,200
Gizzard shad	8,210,000	na
Golden redhorse	420	na
Herrings	8,880,000	na
Hogchoker	1,950	na
Logperch	1,230	na
Menhaden	66	13
Muskellunge	15	55
Other (forage)	5,610,000	na
Other (recreational)	9,470	1,870
Other (recreational and commercial)	228	45
Paddlefish	1,330	7,000
Pallid sturgeon	8	na
Rainbow smelt	3	<1
Recreational seabass	58	14
River carpsucker	886	na
Salmon	46	196
Sauger	12,000	3,260
Sculpin	82	3
Shiner species	130,000	na
Silversides	4,610	na
Skipjack herring	7,120	na
Smallmouth bass	16,200	655
Smelts	817,000	20,300
Spotted sucker	44	na
Striped bass	20,100	28,100
Striped killifish	154	na
Sturgeon	133	635
Sucker species	2,110	na
Sunfish	548,000	395
Threespine stickleback	2,410	na

Table G2-3: Estimated Current Annual Impingement at Phase III Facilities in the Inland Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species/Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Trophic transfer[a]	na	102,000
Walleye	159	142
White bass	46,300	14,200
White perch	85,100	38
White fish	302	271
Yellow perch	172,000	2,390

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

Table G2-4: Estimated Current Annual Entrainment at Phase III Facilities in the Inland Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Alewife	11	na
Black crappie	9	2
Blueback herring	1,000	na
Bluegill	190	4
Bluntnose minnow	6,170,000	na
Brown bullhead	5,250	433
Bullhead species	145	12
Burbot	31	na
Carp	848,000	na
Channel catfish	36,400	7,530
Crappie	116,000	19,500
Darter species	165,000	na
Emerald shiner	319,000	na
Freshwater drum	57,700	13,900
Gizzard shad	488,000	na
Gobies	1,760	na
Golden redhorse	1,450	na
Herring	888,000	na
Logperch	30,500	na
Muskellunge	<1	<1
Other (forage)	569,000	na
Other (recreational)	9	2
Paddlefish	796	4,170
Rainbow smelt	2	<1
River carpsucker	4,090	na

Table G2-4: Estimated Current Annual Entrainment at Phase III Facilities in the Inland Region Expressed as Age-1 Equivalents and Foregone Fishery Yield

Species Group	Age-1 Equivalents (#s)	Total Yield (lbs)
Sauger	192,000	52,100
Sculpin	1,470	58
Shiner species	447	na
Silversides	504	na
Skipjack herring	421	na
Smallmouth bass	175,000	7,090
Smelt	926	23
Sturgeon	2,480	11,800
Sucker species	1,800,000	na
Sunfish	3,690,000	2,660
Threespine stickleback	<1	na
Trophic transfer[a]	na	75,300
Walleye	71,000	63,300
White bass	14,900	4,570
White perch	16,800	na
Whitefish	<1	<1
Yellow perch	9,750	135

[a] Contribution of forage fish to yield based on trophic transfer (see Chapter A1).

G2-4 Reductions in I&E at Phase III Facilities in the Inland Region Under Three Alternative Options

Table G2-5 presents estimated reductions in I&E under the “50 MGD for All Waterbodies” option, the “200 MGD for All Waterbodies” option, and the “100 MGD for Certain Waterbodies” option. Reductions under all other options are presented in Appendix G2.

Table G2-5: Estimated Reductions in I&E Under Three Alternative Options

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
50 MGD All Option	14,800,000	157,000
200 MGD All Option	9,650,000	107,000
100 MGD Option	0	0

G2-5 Assumptions Used in Calculating Recreational and Commercial Losses

Unlike the other regions, all losses in the Inland region are assumed to be to recreational fisheries. Therefore, it was not necessary to partition losses between commercial and recreational fisheries.

See Chapter G4 for results of the recreational fishing benefits analysis. As discussed in Chapter A8, benefits were discounted to account for 1) the time to achieve compliance once the rule goes into effect in 2007, and 2) the time it takes for fish spared from I&E to reach a harvestable age.

Chapter G3: Commercial Fishing Valuation

There is not a significant level of commercial fishing in the interior U.S. Therefore, EPA has assumed that all I&E losses in this region affect recreational fisheries only. As a result, baseline commercial fishing losses and benefits for the Inland region are assumed to be $0.

Chapter G4: Recreational Use Benefits

Chapter Contents

Introduction

This chapter presents the results of the recreational fishing benefits analysis for the Inland region. The chapter presents EPA's estimates of baseline (i.e., current) annual recreational fishery losses from impingement and entrainment (I&E) at potentially regulated facilities in the Inland region and annual reduction in these losses under the three proposed regulatory options for Phase III existing facilities:[1]

- the "50 MGD for All Waterbodies" option,
- the "200 MGD for All Waterbodies" option, and
- the "100 MGD for Certain Waterbodies" option.

The chapter then presents the estimated welfare gain to Inland anglers from eliminating baseline recreational fishing losses from I&E and the expected benefits under the three proposed options.

EPA estimated the recreational benefits of reducing and eliminating I&E losses using a benefit transfer methodology based on a meta-analysis of the marginal value of catching different species of fish. This meta-analysis is discussed in detail in Chapter A5, "Recreational Fishing Benefits Methodology."

EPA considered a wide range of policy options in developing this regulation. Results of the recreational fishing benefits analysis for five other options evaluated by EPA are presented in Appendix G4.

G4-1 Benefit Transfer Approach Based on Meta-Analysis

EPA estimated the recreational welfare gain from the reduction in annual I&E losses expected under the policy options, and the welfare gain from eliminating I&E at potentially regulated facilities, using a benefit transfer approach. As discussed in Chapter A5, the Agency used the meta-analysis regression equation to estimate the marginal recreational value per additional fish caught by anglers, for different species in different regions. Since I&E at potentially regulated facilities affects a variety of species, EPA assigned each species with I&E losses to one of the general species groups used in the meta-analysis. The Agency then calculated the economic value of reducing or eliminating baseline I&E losses, for each species group, by multiplying the value per fish for that species group by the number of fish in the group that are lost in the baseline or saved under the policy options.[2]

In general, the fit between the species with I&E losses and the species groups in the meta-analysis was good. However, EPA's estimates of baseline I&E losses and reductions in I&E under the policy options included losses

[1] See the introduction to this report for a description of the three proposed options.

[2] Note that the estimates of I&E presented in this chapter include only the fraction of impinged and entrained recreational fish that would otherwise be caught by anglers. The total amount of I&E of recreational species is actually much higher.

of ‘unidentified’ species. The ‘unidentified’ group includes fish lost indirectly through trophic transfer, as well as species for which no species information was available.[3] Rather than using the meta-analysis regression to try to predict the value per fish for an “unidentified” species, EPA assumed that per-fish values for these species can be approximated by the weighted average value per fish for all species affected by I&E in the Inland region.[4]

G4-1.1 Estimated Reductions in Recreational Fishery Losses under the Proposed Regulation

Table G4-1 presents EPA’s estimates of baseline (i.e., current) annual recreational I&E losses at potentially regulated facilities, and annual reductions in these losses under each of the proposed options, in the Inland region. The table shows that total baseline losses to recreational fisheries are 0.51 million fish per year. In comparison, the “50 MGD for All Waterbodies” option prevents losses of 0.17 million fish per year, and the “200 MGD for All Waterbodies” option prevents losses of 0.11 million fish per year. No reduction in losses is expected under the “100 MGD for Certain Waterbodies” option. Of all the affected species, bluegill, sunfish, and smelts, along with unidentified species, have the highest losses in the baseline and the highest prevented losses under the proposed options.

Table G4-1: Baseline Recreational Fishing Losses from I&E at Potentially Regulated Phase III Facilities and Reductions in Recreational Losses under the Proposed Regulatory Options in the Inland Region

Species[a]	Baseline Annual Recreational Fishing Losses (# of fish)	Annual Reductions in Recreational Fishing Losses (# of fish)		
		50 MGD All	200 MGD All	100 MGD CWB[d]
American shad	393	147	88	0
Paddlefish[b]	406	135	88	0
Striped bass	2,519	939	562	0
Sturgeon[b]	179	49	37	0
Total (small game)	**3,497**	**1,269**	**776**	**0**
Salmon	9	3	2	0
Total (salmon)	**9**	**3**	**2**	**0**
Northern pike	2	1	0	0
Sauger	19,932	5,454	4,178	0
Walleye	20,211	5,411	4,220	0
Total (walleye/pike)	**40,145**	**10,866**	**8,399**	**0**
Smallmouth bass	9,270	2,562	1,947	0
Spotted bass	10	4	2	0
White bass	20,214	7,015	4,442	0
Total (bass)	**29,494**	**9,581**	**6,391**	**0**
Black bullhead	175	65	39	0
Black crappie	481	179	107	0
Bluegill	50,742	18,906	11,328	0
Brown bullhead	1,757	537	376	0
Bullhead	154	55	34	0

[3] In addition to recreational fish that are lost because they are impinged or entrained, some recreational fish are lost because the forage fish that they feed on are impinged or entrained, and thus removed from the food chain. These trophic transfer losses of recreational species are included in EPA’s estimates of total I&E losses. However, since it is difficult to predict which recreational species would be affected by losses of forage fish, these losses are classified as ‘unidentified’ recreational species. Also included in the ‘unidentified’ group are losses of fish that were reported by facilities without information about their exact species.

[4] EPA used the estimated level of baseline recreational losses for each species group as a weighting factor.

Table G4-1: Baseline Recreational Fishing Losses from I&E at Potentially Regulated Phase III Facilities and Reductions in Recreational Losses under the Proposed Regulatory Options in the Inland Region

Species[a]	Baseline Annual Recreational Fishing Losses (# of fish)	Annual Reductions in Recreational Fishing Losses (# of fish)		
		50 MGD All	200 MGD All	100 MGD CWB[d]
Channel catfish	22,438	7,721	4,921	0
Crappie	33,150	9,234	6,972	0
Menhaden	20	7	4	0
Sculpin	464	127	97	0
Smelts	42,739	15,922	9,541	0
Sunfish	49,245	13,842	10,373	0
White perch	161	60	36	0
Yellow perch	20,033	7,352	4,457	0
Total (panfish)	**221,558**	**74,009**	**48,288**	**0**
Whitefish	185	69	41	0
Total (trout)	**185**	**69**	**41**	**0**
Freshwater drum[c]	36,116	11,954	7,856	0
Unidentified	180,016	59,150	39,098	0
Total (unidentified)	**216,132**	**71,104**	**46,955**	**0**
Total (all species)	***511,020***	***166,901***	***110,851***	***0***

[a] This table includes several species of anadromous fish (such as American shad and striped bass) that are classified in saltwater species groups, but that are commonly caught in freshwater during part of their life cycle.
[b] No valuation studies were available for freshwater sturgeon or paddlefish. EPA included these two species in the ‘small game’ group because the typical size of these species is consistent with (or larger than) the size of other species in the ‘small game’ group. Adult lake sturgeon generally weigh 10 to 80 pounds and measure three to five feet in length, and may grow as large as 300 pounds and seven feet long (NY State Department of Environmental Conservation, 2003). White sturgeon, which are anadromous, can grow to 400 pounds or 10 feet in length (Monterey Bay Aquarium, 1999). Paddlefish are also very large, averaging between 3.3 and 4.8 feet in length (Jenkins and Burkhead, 1993).
[c] No valuation studies were available for freshwater drum. Because this species does not correspond well with any of the species groups, EPA included it in the ‘unidentified’ group (i.e., valued it using an average weighted value from all other freshwater species).
[d] No facilities in the Inland region would be regulated under the “100 MGD for Certain Waterbodies” option, so no benefits are expected in this region under this option.

Source: U.S. EPA analysis for this report.

G4-1.2 Recreational Fishing Benefits from Eliminating Baseline I&E Losses

Table G4-2 shows the results of EPA’s analysis of the welfare gain to recreational anglers from eliminating baseline recreational fishery losses at potentially regulated facilities in the Inland region. The table presents baseline annual recreational I&E losses, the estimated value per fish, and the monetized annual welfare gain from eliminating recreational losses, for each species group. Total baseline recreational fishing losses for the Inland region are 0.51 million fish per year. The undiscounted annual welfare gain to Inland anglers from eliminating these losses is $1.12 million (2003$), with lower and upper bounds of $0.59 million and $2.11 million. Evaluated at 3% and 7%, the mean annualized welfare gain of eliminating these losses is $1.08 million and $1.04 million, respectively. The majority of monetized recreational losses from I&E under baseline conditions are attributable to losses of freshwater drum (categorized in the ‘unidentified’ group) and other ‘unidentified’ species.

Table G4-2: Recreational Fishing Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities in the Inland Region (2003$)

Species Group	Baseline Annual Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Benefits from Eliminating Recreational Fishing Losses (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game[e]	3.5	$3.03	$7.38	$17.56	$10.6	$25.8	$61.4
Salmon	0.0[f]	$11.47	$24.69	$53.44	$0.1	$0.2	$0.5
Trout	0.2	$0.49	$2.79	$4.51	$0.1	$0.5	$0.8
Walleye/Pike	40.1	$2.82	$5.15	$9.42	$113.3	$206.6	$378.1
Bass	29.5	$3.66	$6.96	$13.13	$107.9	$205.3	$387.2
Panfish	221.6	$0.51	$0.97	$1.85	$113.6	$216.0	$409.6
Unidentified	216.1	$1.15	$2.16	$4.04	$248.5	$466.3	$872.4
Total (undiscounted)	**511.0**				**$594.0**	**$1,120.7**	**$2,110.1**
Total (evaluated at 3%)	**511.0**				**$576.2**	**$1,087.0**	**$2,046.7**
Total (evaluated at 7%)	**511.0**				**$554.9**	**$1,046.8**	**$1,970.9**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See Section A5-5.1 for more details on this approach.
[c] Monetized benefits are calculated by multiplying baseline losses by the estimated value per fish.
[d] Annualized values represent the total welfare gain over the time frame of the analysis from eliminating recreational losses, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] The small game species group includes sturgeon. However, applying the use value for small game to sturgeon may understate the value of this species. A marine fishing valuation study indicates that California anglers are willing to pay $61.43 to catch a sturgeon in saltwater (U.S. EPA, 2004a). However, sturgeon in freshwater are often landlocked and may not be as large as sturgeon found in saltwater, and therefore not as valuable.
[f] Denotes a positive value less than 50 fish.

Source: U.S. EPA analysis for this report.

G4-1.3 Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option

Table G4-3 shows the results of EPA's analysis of the recreational benefits of the "50 MGD for All Waterbodies" option for the Inland region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 0.17 million fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.36 million (2003$), with lower and upper bounds of $0.19 million and $0.67 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.31 million and $0.25 million, respectively. The majority of benefits result from reduced losses of freshwater drum (categorized in the 'unidentified' group) and other 'unidentified' species.

Table G4-3: Recreational Fishing Benefits of the "50 MGD for All Waterbodies" Option in the Inland Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game[e]	1.3	$3.03	$7.38	$17.56	$3.8	$9.4	$22.3
Salmon	0.0[f]	$11.47	$24.69	$53.44	$0.0[g]	$0.1	$0.2
Trout	0.1	$0.49	$2.79	$4.51	$0.0[g]	$0.2	$0.3
Walleye/Pike	10.9	$2.82	$5.15	$9.42	$30.7	$55.9	$102.3
Bass	9.6	$3.66	$6.96	$13.13	$35.0	$66.7	$125.8
Panfish	74.0	$0.51	$0.97	$1.85	$38.0	$72.1	$136.8
Unidentified	71.1	$1.15	$2.16	$4.04	$81.7	$153.4	$287.0
Total (undiscounted)	**166.9**				**$189.3**	**$357.8**	**$674.7**
Total (evaluated at 3%)	**166.9**				**$161.9**	**$306.0**	**$577.1**
Total (evaluated at 7%)	**166.9**				**$132.8**	**$250.9**	**$473.1**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See Section A5-5.1 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] The small game species group includes sturgeon. However, applying the use value for small game to sturgeon may understate the value of this species. A marine fishing valuation study indicates that California anglers are willing to pay $61.43 to catch a sturgeon in saltwater (U.S. EPA, 2004a). However, sturgeon in freshwater are often landlocked and may not be as large as sturgeon found in saltwater, and therefore not as valuable.
[f] Denotes a positive value less than 50 fish.
[g] Denotes a positive value less than $50.

Source: U.S. EPA analysis for this report.

G4-1.4 Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option

Table G4-4 shows the results of EPA's analysis of the recreational benefits of the "200 MGD for All Waterbodies" option for the Inland region. The table presents the annual reduction in recreational I&E losses expected under this option, the estimated value per fish, and annual monetized recreational welfare gain from this option, by species group. The table shows that this option reduces recreational losses by 0.11 million fish per year, resulting in an undiscounted welfare gain to recreational anglers of $0.24 million (2003$), with lower and upper bounds of $0.13 million and $0.46 million. Evaluated at 3% and 7%, the mean annualized welfare gain from this reduction in recreational losses is $0.21 million and $0.17 million, respectively. The majority of benefits result from reduced losses of freshwater drum (categorized in the 'unidentified' group) and other 'unidentified' species.

Table G4-4: Recreational Fishing Benefits of the "200 MGD for All Waterbodies" Option in the Inland Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)[a]	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game[e]	0.8	$3.03	$7.38	$17.56	$2.4	$5.7	$13.6
Salmon	0.0[f]	$11.47	$24.69	$53.44	$0.0[g]	$0.0[g]	$0.1
Trout	0.0[f]	$0.49	$2.79	$4.51	$0.0[g]	$0.1	$0.2
Walleye/Pike	8.4	$2.82	$5.15	$9.42	$23.7	$43.2	$79.1
Bass	6.4	$3.66	$6.96	$13.13	$23.4	$44.5	$83.9
Panfish	48.3	$0.51	$0.97	$1.85	$24.8	$47.1	$89.3
Unidentified	47.0	$1.15	$2.16	$4.04	$54.0	$101.3	$189.5
Total (undiscounted)	**110.9**				**$128.2**	**$242.0**	**$455.7**
Total (evaluated at 3%)	**110.9**				**$109.8**	**$207.3**	**$390.4**
Total (evaluated at 7%)	**110.9**				**$90.2**	**$170.3**	**$320.7**

[a] Recreational fishing losses include only the portion of impinged and entrained fish that would have otherwise been caught by recreational anglers.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See Section A5-5.1 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the annual reduction in recreational losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting and annualization methodology, refer to Chapter A8.
[e] The small game species group includes losses of sturgeon. However, applying the use value for small game to sturgeon may understate the value of this species. A marine fishing valuation study indicates that California anglers are willing to pay $61.43 to catch a sturgeon in saltwater (U.S. EPA, 2004a). However, sturgeon in freshwater are often landlocked and may not be as large as sturgeon found in saltwater, and therefore not as valuable.
[f] Denotes a positive value less than 50 fish.
[g] Denotes a positive value less than $50.

Source: U.S. EPA analysis for this report.

G4-1.5 Recreational Fishing Benefits of the "100 MGD for Certain Waterbodies" Option

No facilities in the Inland region are regulated under the "100 MGD for Certain Waterbodies" option. Thus, no recreational benefits are expected under this option in this region.

G4-2 Summary of Benefit Transfer Results

Table G4-5 presents a summary of the undiscounted results of the benefit transfer based on the meta-analysis. The table shows that the expected welfare gain to recreational anglers is $0.36 million (2003$) under the "50 MGD for All Waterbodies" option, and $0.24 million under the "200 MGD for All Waterbodies" option. No benefits are expected in the Inland region under the "100 MGD for Certain Waterbodies" option. The welfare gain from eliminating baseline recreational I&E losses at potentially regulated facilities is $1.12 million.

Table G4-5: Recreational Benefits in the Inland Region Calculated from Benefit Transfer Approach

Policy Option	Estimated Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands, 2003$)		
		Low	Mean	High
Eliminating baseline recreational fishing losses from I&E	511.0	$594.0	$1,120.7	$2,110.1
50 MGD All	166.9	$189.3	$357.8	$674.7
200 MGD All	110.9	$128.2	$242.0	$455.7
100 MGD CWB[a]	0.0	$0.0	$0.0	$0.0

[a] Because no facilities in the Inland region are regulated under the "100 MGD for Certain Waterbodies" option, no benefits are expected in the Inland region under this option.

Source: U.S. EPA analysis for this report.

G4-3 Limitations and Uncertainty

The results of the benefit transfer based on the meta-analysis results represent EPA's best estimate of the recreational benefits of the proposed options. Nonetheless, there are a number of limitations and uncertainties inherent in these estimates. General limitations pertaining to the development of the meta-analysis model, the use of the model to estimate per-fish values, and the validity of the benefit transfer are discussed in Section A5-3.3e and Section A5-5.3 of the recreational methodology chapter. In addition to these general concerns about the analysis, there are several limitations and uncertainties that are specific to the Inland region.

One limitation of applying the meta-analysis to the Inland region is that the Inland region is extremely diverse (by definition, it includes the entire continental U.S.). The studies on which the meta-analysis is based were conducted primarily in only a few geographic regions. In particular, most of the studies that evaluated WTP for walleye, pike, and panfish were conducted in the Great Lakes (in Michigan or Wisconsin). Thus, the average values per fish predicted by the regression equation may not represent the actual value per fish in all areas of the U.S.

Another limitation of the analysis is that EPA was unable to locate any studies that evaluated WTP for channel catfish or for freshwater drum, two species with high I&E losses in the Inland region. However, the Agency believes that the per-fish values for channel catfish and freshwater drum can be approximated by the per-fish values for 'panfish' and 'unidentified' species, respectively.

Chapter G5: Threatened and Endangered Species Analysis

Introduction

Chapter Contents

This chapter presents EPA's estimates of baseline (i.e., current) annual losses of special status species from impingement and entrainment (I&E) at potentially regulated facilities in the Inland region and annual reduction in these losses under the three proposed regulatory options for Phase III existing facilities:[1,2]

- the "50 MGD for All Waterbodies" option,
- the "200 MGD for All Waterbodies" option, and
- the "100 MGD for Certain Waterbodies" option.

The analysis focuses on pallid sturgeon only. Pallid sturgeon are found in the Mississippi and Missouri Rivers and in their larger tributaries. The pallid sturgeon is one of the largest (30-60 inches) fishes found in the Missouri-Mississippi River drainage, with specimens weighing up to 85 pounds. In 1990, the U.S. Fish and Wildlife Service (USFWS) added the pallid sturgeon to the federal endangered species list, which is reserved for species in danger of extinction. Populations of the pallid sturgeon are now so small that this species is rarely seen or caught by anglers (USFWS, 2004b).

This chapter also presents the benefit transfer approach explored by EPA to estimate public willingness-to-pay (WTP) for protection of special status fish species from I&E in the Inland region.

G5-1 Estimated Reductions in Losses of Special Status Species in the Inland Region under the Proposed Section 316(b) Regulation for Phase III Facilities

Table G5-1 presents EPA's estimates of baseline (i.e., current) annual I&E losses of special status species at potentially regulated Phase III facilities and annual reductions in these losses under each of the proposed options in the Inland region. The table shows that total baseline losses of special status species are eight sturgeon per year. The "50 MGD for All Waterbodies" and "200 MGD for All Waterbodies" options prevent losses of three and two sturgeon per year, respectively. The "100 MGD for Certain Waterbodies" option does not prevent any losses of special status species in the Inland region because no facilities that withdraw water from rivers, streams, lakes, or reservoirs are subject to this option.

[1] See the introduction to this report for a description of the three proposed options.

[2] "Special status species" is a term used to refer to species that have been listed as "threatened and endangered" (T&E) or that have been given a special status designation at the State or federal level.

Table G5-1: I&E Losses of Special Status Species in the Inland Region

Special Status Fish Species	Total Baseline Losses of Special Status Species (age-1 equivalents)	Annual Reductions in Losses of Special Status Species		
		50 MGD All	200 MGD All	100 MGD CWB[a]
Pallid sturgeon	8	3	2	0
Total	**8**	**3**	**2**	**0**

[a] No facilities that withdraw water from rivers, streams, lakes, and reservoirs are subject to the "100 MGD for Certain Waterbodies" option.

Source: U.S. EPA analysis for this report.

G5-2 An Exploration of Benefit Transfer to Estimate Non-use Benefits of Reduced Impingement and Entrainment Losses of Special Status Species in the Inland Region

Case-specific estimates of non-use values for the protection of special status species can only be derived by primary research using stated preference techniques (e.g., the contingent valuation method). However, the cost, administrative burden, and time required to develop primary research estimates is beyond the schedule and resources available to EPA for the section 316(b) rulemaking. As an alternative, EPA explored a benefit transfer approach that relies on information from existing studies. Boyle and Bergstrom (1992) define benefit transfer as "the transfer of existing estimates of nonmarket values to a new study which is different from the study for which the values were originally estimated."

There are three commonly-used types of benefit transfer studies: point estimate, benefit function, and meta-analysis techniques (U.S. EPA, 2000). The point estimate approach involves taking the mean value (or range of values) from the study case and applying it directly to the policy case (U.S. EPA, 2000). This approach may be used to transfer estimates of values for preserving certain endangered species in one region to another region or to another species. A conceptually preferred benefit transfer approach is to use the benefit function transfer approach, which is more refined but also more complex than the point estimate approach. If the study case provides a WTP function, valuation estimates can be updated by substituting applicable values of key variables, such as baseline risk and population characteristics (e.g., mean or median income, racial or age distribution) from the policy case into the benefit function (U.S. EPA, 2000). The meta-analysis technique involves two steps: (1) regressing WTP values from a large number of studies on variables representing study methodology, population, and species characteristics, and (2) estimating WTP for the policy case by evaluating the regression equation using input values that describe the policy case. In many cases, this technique can provide superior results to either the point estimate or the benefit function transfer techniques. However, because the academic literature contains few studies valuing endangered aquatic species, EPA did not consider implementing the meta-analysis technique for the T&E analysis for the 316(b) rule.

Ideally, the point estimate approach would be implemented using transfer studies that value pallid sturgeon. EPA, however, was unable to identify such studies. Thus, the Agency selected benefit transfer studies that valued aquatic species that have attributes similar to those of pallid sturgeon. Pallid sturgeon were formerly harvested commercially, and their large size makes them a desirable trophy sport fish. They are considered fine eating and have roe that is suitable for caviar. If recovery efforts are successful, the fish may become delisted and available once again for sportfishing (Montana Fish, Wildlife, and Parks, 2004). Therefore, pallid sturgeon have potentially significant direct use values. Table B5-2 presents types of values associated with pallid sturgeon lost to I&E in the Inland region.

Table B5-2: Type of Value Associated with Special Status Species Lost to I&E in the Inland Region

Special Status Fish Species	Type of Value
Pallid sturgeon	Use and non-use
Source: U.S. EPA analysis for this report.	

After comparing the biological and use characteristics of pallid sturgeon to species valued in other studies, EPA identified three potentially useful studies that estimated non-use and use values for different species of sturgeon. Kotchen and Reiling (2000) found that citizens of Maine are willing to pay $30.48 (2003$) as a one-time tax to create a self-sustaining population of shortnose sturgeon, which is listed as a federally endangered species (NOAA Fisheries, 2004).[3] EPA's study of the recreational fishing benefits of the section 316(b) Phase II regulation indicated that California anglers are willing to pay $61.43 to catch a sturgeon (U.S. EPA, 2004a).[4] A stated preference study by Stokes (2002) found that lake sturgeon is a popular wildlife viewing species in the state of Wisconsin and that sturgeon viewers place a substantial value on protection of the lake sturgeon population. The study indicated that an individual viewer's WTP to maintain the current sturgeon population of the Winnebago system is equal to $101.44 (2002$). Given that the 2002 sturgeon viewer population was estimated at 3,176 viewers, total WTP to maintain sturgeon viewing opportunities in the Winnebago system was $344,198. Taken together, the results of these three studies indicate that sturgeon have large recreational use values, and that non-use values for preservation of sturgeon are also likely to be significant.

EPA considered using the point estimate approach to derive WTP values for the reduction in pallid sturgeon losses in the Missouri-Mississippi River basin that would be caused by the section 316(b) regulation for Phase III facilities. Because pallid sturgeon is not currently targeted by sport anglers and is seldom seen, EPA deemed it inappropriate to use recreational fishing and viewing values to value reductions in I&E losses of pallid sturgeon. However, by applying the per taxpayer value for restoring shortnose sturgeon from the Kotchen and Reiling (2000) study to the number of taxpayers in the Mississippi-Missouri River basin, it would be possible to approximate the non-use value of restoring the pallid sturgeon population in the Missouri-Mississippi River basin. However, because I&E is only one of several factors that affect populations of pallid sturgeon, the social benefit achieved by preventing I&E losses is lower than the benefit of reducing the risk of species extinction to zero. One reasonable assumption would be to assume that the fraction of per taxpayer WTP for species preservation programs that is attributable to preventing I&E losses is directly proportional to the percent of the current population of pallid sturgeon that is lost to baseline I&E. There are about 223 to 365 pallid sturgeon remaining in the Missouri/Yellowstone river and 2,750 to 4,100 pallid sturgeon remaining in the Atchafalaya River (a distributary of the Mississippi River), so the estimated impact of I&E amounts to less than 0.1% of the estimated current population of this species in the Mississippi-Missouri River basin (Krentz, 1997; FWS, 2004a). Thus, the per taxpayer WTP for I&E reductions would be less than 0.1% of per taxpayer WTP to prevent extinction.

EPA notes that although the Agency explored using the point estimate benefit transfer approach to estimate non-use values of improved protection of pallid sturgeon, benefits based on this method were not included in the Phase III benefits estimates due to data uncertainties and limitations. However, EPA also notes the encouraging point that the valuation results are highly consistent across the relevant T&E studies available in the literature. As more studies become available, it may be possible to obtain insights into the effects of different variables (e.g., population and resource characteristics) and to develop welfare estimates that may be adjusted for the attributes of the policy or region under consideration. Researchers and policy makers have placed increasing focus on meta-analysis and similar empirical approaches to improve the performance of benefit transfer in policy analysis.

---

[3] The original WTP amount, $26.63 (1997$), was converted to 2003$ using the consumer price index (CPI) (U.S. Bureau of Labor Statistics, 2004).

[4] There two sturgeon species in California – white sturgeon and green sturgeon.

Appendix G1: Life History Parameter Values Used to Evaluate I&E in the Inland Region

The tables in this appendix summarize the life history parameter values used by EPA to calculate age-1 equivalents and fishery yield from impingement and entrainment (I&E) data for the Inland region.

Table G1-1: Alewife Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lb)
Eggs	11.5	0	0	0.00000128
Larvae	5.50	0	0	0.00000141
Juvenile	6.21	0	0	0.00478
Age 1+	0.500	0	0	0.0160
Age 2+	0.500	0	0	0.0505
Age 3+	0.500	0	0	0.0764
Age 4+	0.500	0	0	0.0941
Age 5+	0.500	0	0	0.108
Age 6+	0.500	0	0	0.130
Age 7+	0.500	0	0	0.149

Sources: Spigarelli et al., 1981; PG&E National Energy Group, 2001; Froese and Pauly, 2003; and NMFS, 2003a.

Table G1-2: American Shad Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	0.496	0	0	0.000000716
Yolksac larvae	0.496	0	0	0.000000728
Post-yolksac larvae	2.52	0	0	0.00000335
Juvenile	7.40	0	0	0.000746
Age 1+	0.300	0	0	0.309
Age 2+	0.300	0	0	1.17
Age 3+	0.300	0	0	2.32
Age 4+	0.540	0.21	0.45	3.51
Age 5+	1.02	0.21	0.9	4.56
Age 6+	1.50	0.21	1.0	5.47
Age 7+	1.50	0.21	1.0	6.20
Age 8+	1.50	0.21	1.0	6.77

Sources: USFWS, 1978; Able and Fahay, 1998; PSE&G, 1999; and Froese and Pauly, 2001.

Table G1-3: Bass Species (*Micropterus* sp.) Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000731
Larvae	2.70	0	0	0.0000198
Juvenile	0.446	0	0	0.0169
Age 1+	0.860	0	0	0.202
Age 2+	1.17	0.32	0.5	0.518
Age 3+	0.755	0.21	1.0	0.733
Age 4+	1.05	0.29	1.0	1.04
Age 5+	0.867	0.24	1.0	1.44
Age 6+	0.867	0.24	1.0	2.24
Age 7+	0.867	0.24	1.0	2.56
Age 8+	0.867	0.24	1.0	2.92
Age 9+	0.867	0.24	1.0	3.30

[a] Includes largemouth bass, red bass, smallmouth bass, spotted bass, and other sunfish not identified to species.

Sources: Scott and Crossman, 1973; Carlander, 1977; Wang, 1986; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-4: Black Bullhead Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.0000312
Larvae	4.61	0	0	0.000186
Juvenile+	1.39	0	0	0.00132
Age 1+	0.446	0	0	0.0362
Age 2+	0.223	0.22	0.50	0.0797
Age 3+	0.223	0.22	1.0	0.137
Age 4+	0.223	0.22	1.0	0.233
Age 5+	0.223	0.22	1.0	0.402
Age 6+	0.223	0.22	1.0	0.679
Age 7+	0.223	0.22	1.0	0.753
Age 8+	0.223	0.22	1.0	0.815
Age 9+	0.223	0.22	1.0	0.823

Sources: Carlander, 1969; Scott and Crossman, 1973; Geo-Marine, Inc., 1978; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-5: Black Crappie Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.80	0	0	0.000000929
Larvae	0.498	0	0	0.00000857
Juvenile	2.93	0	0	0.0120
Age 1+	0.292	0	0	0.128
Age 2+	0.292	0.29	0.50	0.193
Age 3+	0.292	0.29	1.0	0.427
Age 4+	0.292	0.29	1.0	0.651
Age 5+	0.292	0.29	1.0	0.888
Age 6+	0.292	0.29	1.0	0.925
Age 7+	0.292	0.29	1.0	0.972
Age 8+	0.292	0.29	1.0	1.08
Age 9+	0.292	0.29	1.0	1.26

Sources: Carlander, 1977; Wang, 1986; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-6: Blueback Herring Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lb)
Eggs	0.558	0	0	0.000000716
Larvae	3.18	0	0	0.00000204
Juvenile	6.26	0	0	0.000746
Age 1+	0.300	0	0	0.0160
Age 2+	0.300	0	0	0.0905
Age 3+	0.300	0	0	0.204
Age 4+	0.900	0	0	0.318
Age 5+	1.50	0	0	0.414
Age 6+	1.50	0	0	0.488
Age 7+	1.50	0	0	0.540
Age 8+	1.50	0	0	0.576

[a] Includes blueback herring and other herrings not identified to the species.

Sources: USFWS, 1978; Able and Fahay, 1998; PSE&G, 1999; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-7: Bluegill Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.73	0	0	0.00000130
Larvae	0.576	0	0	0.00000156
Juvenile	4.62	0	0	0.00795
Age 1+	0.390	0	0	0.00992
Age 2+	0.151	0	0	0.0320
Age 3+	0.735	0.74	0.50	0.0594
Age 4+	0.735	0.74	1.0	0.104
Age 5+	0.735	0.74	1.0	0.189
Age 6+	0.735	0.74	1.0	0.193
Age 7+	0.735	0.74	1.0	0.209
Age 8+	0.735	0.74	1.0	0.352
Age 9+	0.735	0.74	1.0	0.393

Sources: Carlander, 1977; Wang, 1986; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-8: Brown Bullhead Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000115
Larvae	4.61	0	0	0.0000192
Juvenile	1.39	0	0	0.00246
Age 1+	0.446	0	0	0.0898
Age 2+	0.223	0.22	0.50	0.172
Age 3+	0.223	0.22	1.0	0.278
Age 4+	0.223	0.22	1.0	0.330
Age 5+	0.223	0.22	1.0	0.570
Age 6+	0.223	0.22	1.0	0.582

[a] Includes brown bullhead, stonecat, yellow bullhead, and other bullheads not identified to the species.

Sources: Carlander, 1969; Geo-Marine, Inc., 1978; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-9: Carp Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000673
Larvae	4.61	0	0	0.0000118
Juvenile	1.39	0	0	0.0225
Age 1+	0.130	0	0	0.790
Age 2+	0.130	0	0	1.21
Age 3+	0.130	0	0	1.81
Age 4+	0.130	0	0	5.13
Age 5+	0.130	0	0	5.52
Age 6+	0.130	0	0	5.82
Age 7+	0.130	0	0	6.76
Age 8+	0.130	0	0	8.17
Age 9+	0.130	0	0	8.55
Age 10+	0.130	0	0	8.94
Age 11+	0.130	0	0	9.76
Age 12+	0.130	0	0	10.2
Age 13+	0.130	0	0	10.6
Age 14+	0.130	0	0	11.1
Age 15+	0.130	0	0	11.5
Age 16+	0.130	0	0	12.0
Age 17+	0.130	0	0	12.5

[a] Includes carp, goldfish, and other minnows not identified to species.

Sources: Carlander, 1969; Geo-Marine, Inc., 1978; Wang, 1986; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-10: Carp/Minnow Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000115
Larvae	2.06	0	0	0.000375
Juvenile	2.06	0	0	0.00208
Age 1+	1.00	0	0	0.00585
Age 2+	1.00	0	0	0.0121
Age 3+	1.00	0	0	0.0171

[a] Includes bluntnose minnow, central stoneroller, creek chub, fathead minnow, silver chub, silverjaw minnow, and other minnows not identified to species.

Sources: Carlander, 1969; Froese and Pauly, 2001; NMFS, 2003a; and Ohio Department of Natural Resources, 2003.

Table G1-11: Crappie Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.80	0	0	0.000000929
Larvae	0.498	0	0	0.00000857
Juvenile	2.93	0	0	0.0120
Age 1+	0.292	0	0	0.128
Age 2+	0.292	0.29	0.50	0.193
Age 3+	0.292	0.29	1.0	0.427
Age 4+	0.292	0.29	1.0	0.651
Age 5+	0.292	0.29	1.0	0.888
Age 6+	0.292	0.29	1.0	0.925
Age 7+	0.292	0.29	1.0	0.972
Age 8+	0.292	0.29	1.0	1.08
Age 9+	0.292	0.29	1.0	1.26

[a] Includes white crappie and other crappies not identified to the species.

Sources: Carlander, 1977; Wang, 1986; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-12: Darter Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000619
Larvae	1.95	0	0	0.0000497
Juvenile	1.95	0	0	0.000490
Age 1+	0.700	0	0	0.00161
Age 2+	0.700	0	0	0.00321
Age 3+	0.700	0	0	0.00496

[a] Includes fantail darter, river darter, tessallated darter, and other darters not identified to species.

Sources: Carlander, 1997; Froese and Pauly, 2001, 2003; and NMFS, 2003a.

Table G1-13: Freshwater Catfish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.0000539
Larvae	4.61	0	0	0.0000563
Juvenile	1.39	0	0	0.0204
Age 1+	0.410	0.41	0.50	0.104
Age 2+	0.410	0.41	1.0	0.330
Age 3+	0.410	0.41	1.0	0.728
Age 4+	0.410	0.41	1.0	1.15
Age 5+	0.410	0.41	1.0	1.92
Age 6+	0.410	0.41	1.0	2.41
Age 7+	0.410	0.41	1.0	3.45
Age 8+	0.410	0.41	1.0	4.01
Age 9+	0.410	0.41	1.0	5.06
Age 10+	0.410	0.41	1.0	8.08
Age 11+	0.410	0.41	1.0	8.39
Age 12+	0.410	0.41	1.0	8.53

[a] Includes blue catfish, channel catfish, flathead catfish, white catfish, and other catfish not identified to the species.

Sources: Miller, 1966; Carlander, 1969; Geo-Marine, Inc., 1978; Wang, 1986; Saila et al., 1997; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-14: Freshwater Drum Life History Parameters[a]				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.27	0	0	0.00000115
Larvae	6.13	0	0	0.00000295
Juvenile	2.30	0	0	0.0166
Age 1+	0.310	0	0	0.0500
Age 2+	0.155	0.16	0.50	0.206
Age 3+	0.155	0.16	1.0	0.438
Age 4+	0.155	0.16	1.0	0.638
Age 5+	0.155	0.16	1.0	0.794
Age 6+	0.155	0.16	1.0	0.950
Age 7+	0.155	0.16	1.0	1.09
Age 8+	0.155	0.16	1.0	1.26
Age 9+	0.155	0.16	1.0	1.44
Age 10+	0.155	0.16	1.0	1.60
Age 11+	0.155	0.16	1.0	1.78
Age 12+	0.155	0.16	1.0	2.00

[a] Includes freshwater drum and other drum not identified in species.

Sources: Scott and Crossman, 1973; Virginia Tech, 1998; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-15: Gizzard Shad Life History Parameters[a]				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	1.90	0	0	0.000000487
Larvae	6.33	0	0	0.00000663
Juvenile	0.511	0	0	0.0107
Age 1+	1.45	0	0	0.141
Age 2+	1.27	0	0	0.477
Age 3+	0.966	0	0	0.640
Age 4+	0.873	0	0	0.885
Age 5+	0.303	0	0	1.17
Age 6+	0.303	0	0	1.54

[a] Includes gizzard shad, threadfin shad, and other shad not identified to species.

Sources: Wapora, 1979; Froese and Pauly, 2003; and NMFS, 2003a.

Table G1-16: Killifish Life History Parameters[a]				
Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.0000180
Larvae	3.00	0	0	0.0000182
Juvenile	0.916	0	0	0.000157
Age 1+	0.777	0	0	0.0121
Age 2+	0.777	0	0	0.0327
Age 3+	0.777	0	0	0.0551
Age 4+	0.777	0	0	0.0778
Age 5+	0.777	0	0	0.0967
Age 6+	0.777	0	0	0.113
Age 7+	0.777	0	0	0.158

[a] Includes eastern banded killifish.

Sources: Carlander, 1969; Stone & Webster Engineering Corporation, 1977; Meredith and Lotrich, 1979; Able and Fahay, 1998; and NMFS, 2003a.

Table G1-17: Logperch Life History Parameters				
Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000260
Larvae	1.90	0	0	0.000512
Juvenile	1.90	0	0	0.00434
Age 1+	0.700	0	0	0.0132
Age 2+	0.700	0	0	0.0251
Age 3+	0.700	0	0	0.0377

Sources: Carlander, 1997; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-18: Paddlefish Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.0000434
Larvae	3.23	0	0	0.0000816
Juvenile	3.23	0	0	0.0578
Age 1+	0.570	0	0	0.453
Age 2+	0.285	0.29	0.50	7.10
Age 3+	0.285	0.29	1.0	16.3
Age 4+	0.285	0.29	1.0	27.4
Age 5+	0.285	0.29	1.0	31.6
Age 6+	0.285	0.29	1.0	37.3
Age 7+	0.285	0.29	1.0	41.6
Age 8+	0.285	0.29	1.0	43.7
Age 9+	0.285	0.29	1.0	49.2
Age 10+	0.285	0.29	1.0	51.9
Age 11+	0.285	0.29	1.0	54.6
Age 12+	0.285	0.29	1.0	60.6
Age 13+	0.285	0.29	1.0	63.5
Age 14+	0.285	0.29	1.0	68.1
Age 15+	0.285	0.29	1.0	72.7
Age 16+	0.285	0.29	1.0	75.5
Age 17+	0.285	0.29	1.0	80.8
Age 18+	0.285	0.29	1.0	82.6
Age 19+	0.285	0.29	1.0	85.4
Age 20+	0.285	0.29	1.0	87.9
Age 21+	0.285	0.29	1.0	96.2
Age 22+	0.285	0.29	1.0	102

Sources: Carlander, 1969; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-19: Pike Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.08	0	0	0.0000189
Larvae	5.49	0	0	0.0133
Juvenile	5.49	0	0	0.0451
Age 1+	0.150	0	0	0.365
Age 2+	0.150	0	0	1.10
Age 3+	0.150	0	0	1.53
Age 4+	0.150	0	0	2.72
Age 5+	0.150	0	0	6.19
Age 6+	0.150	0	0	7.02
Age 7+	0.150	0	0	8.92
Age 8+	0.150	0	0	12.3
Age 9+	0.150	0	0	13.9
Age 10+	0.075	0.08	0.50	16.6
Age 11+	0.075	0.08	1.0	19.0
Age 12+	0.075	0.08	1.0	24.2
Age 13+	0.075	0.08	1.0	25.3
Age 14+	0.075	0.08	1.0	30.0
Age 15+	0.075	0.08	1.0	32.4
Age 16+	0.075	0.08	1.0	34.3
Age 17+	0.075	0.08	1.0	45.6
Age 18+	0.075	0.08	1.0	45.8
Age 19+	0.075	0.08	1.0	47.7
Age 20+	0.075	0.08	1.0	48.8
Age 21+	0.075	0.08	1.0	48.9
Age 22+	0.075	0.08	1.0	49.0
Age 23+	0.075	0.08	1.0	49.1
Age 24+	0.075	0.08	1.0	49.2
Age 25+	0.075	0.08	1.0	49.3
Age 26+	0.075	0.08	1.0	49.4
Age 27+	0.075	0.08	1.0	49.4

[a] Includes grass pickerel, muskellunge, and northern pike.

Sources: Carlander, 1969; Pennsylvania, 1999; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-20: Rainbow Smelt Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	11.5	0	0	0.000000990
Larvae	5.50	0	0	0.00110
Juvenile	0.916	0	0	0.00395
Age 1+	0.400	0	0	0.0182
Age 2+	0.400	0.03	0.50	0.0460
Age 3+	0.400	0.03	1.0	0.0850
Age 4+	0.400	0.03	1.0	0.131
Age 5+	0.400	0.03	1.0	0.180
Age 6+	0.400	0.03	1.0	0.228

Sources: Spigarelli et al., 1981; PG&E National Energy Group, 2001; Froese and Pauly, 2003; and NMFS, 2003a.

Table G1-21: Redhorse Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.00000115
Larvae	2.30	0	0	0.00000370
Juvenile	2.99	0	0	0.0267
Age 1+	0.548	0	0	0.0521
Age 2+	0.548	0	0	0.180
Age 3+	0.548	0	0	0.493
Age 4+	0.548	0	0	0.653
Age 5+	0.548	0	0	0.916
Age 6+	0.548	0	0	2.78
Age 7+	0.548	0	0	3.07

[a] Includes golden redhorse, river redhorse, shorthead redhorse, silver redhorse, and other redhorses not identified to species.

Sources: Carlander, 1969; Bartell and Campbell, 2000; Froese and Pauly, 2001, 2003; and NMFS, 2003a.

Table G1-22: River Carpsucker Life History Parameters				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	2.05	0	0	0.0000312
Larvae	2.56	0	0	0.0000343
Juvenile	2.30	0	0	0.000239
Age 1+	0.548	0	0	0.0594
Age 2+	0.548	0	0	0.310
Age 3+	0.548	0	0	0.377
Age 4+	0.548	0	0	0.735
Age 5+	0.548	0	0	0.981
Age 6+	0.548	0	0	1.10

Sources: Carlander, 1969; Bartell and Campbell, 2000; Froese and Pauly, 2001, 2003; and NMFS, 2003a.

Table G1-23: Sauger Life History Parameters[a]				
Stage Name	**Instantaneous Natural Mortality (M)**	**Instantaneous Fishing Mortality (F)**	**Fraction Vulnerable to Fishery**	**Weight (lbs)**
Eggs	1.05	0	0	0.00000619
Larvae	3.55	0	0	0.00000681
Juvenile	1.62	0	0	0.0341
Age 1+	0.230	0.05	0.50	0.505
Age 2+	0.230	0.05	1.0	1.03
Age 3+	0.230	0.05	1.0	1.53
Age 4+	0.230	0.05	1.0	2.19
Age 5+	0.230	0.05	1.0	2.27
Age 6+	0.230	0.05	1.0	3.82
Age 7+	0.230	0.05	1.0	4.65
Age 8+	0.230	0.05	1.0	4.80

[a] Includes sauger and walleye.

Sources: Carlander, 1997; Bartell and Campbell, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-24: Shiner Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.00000473
Larvae	4.61	0	0	0.000285
Juvenile	0.777	0	0	0.00209
Age 1+	0.371	0	0	0.00387
Age 2+	4.61	0	0	0.00683
Age 3+	4.61	0	0	0.0143

[a] Includes bigeye shiner, common shiner, emerald shiner, golden shiner, mimic shiner, river shiner, rosyface shiner, sand shiner, spotfin shiner, spottail shiner, and other shiners not identified to species.

Sources: Fuchs, 1967; Wapora, 1979; Trautman, 1981; Froese and Pauly, 2003; and NMFS, 2003a.

Table G1-25: Skipjack Herring Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.30	0	0	0.0000227
Larvae	4.25	0	0	0.000381
Juvenile	4.25	0	0	0.0572
Age 1+	0.700	0	0	0.301
Age 2+	0.700	0	0	0.833
Age 3+	0.700	0	0	1.74

Sources: Trautman, 1981; Wallus et al., 1990; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-26: Spotted Sucker Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.79	0	0	0.00000115
Larvae	2.81	0	0	0.00000198
Juvenile	3.00	0	0	0.0213
Age 1+	0.548	0	0	0.0863
Age 2+	0.548	0	0	0.690
Age 3+	0.548	0	0	1.24
Age 4+	0.548	0	0	1.70
Age 5+	0.548	0	0	1.92
Age 6+	0.548	0	0	1.99

Sources: Carlander, 1969; Bartell and Campbell, 2000; Froese and Pauly, 2001, 2003; and NMFS, 2003a.

Table G1-27: Striped Bass Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.39	0	0	0.000000224
Larvae	7.32	0	0	0.00000606
Juvenile	3.29	0	0	0.0109
Age 1+	1.10	0	0	0.485
Age 2+	0.150	0.31	0.06	2.06
Age 3+	0.150	0.31	0.20	3.31
Age 4+	0.150	0.31	0.63	4.93
Age 5+	0.150	0.31	0.94	6.50
Age 6+	0.150	0.31	1.0	8.58
Age 7+	0.150	0.31	0.90	12.3
Age 8+	0.150	0.31	0.90	14.3
Age 9+	0.150	0.31	0.90	16.1
Age 10+	0.150	0.31	0.90	18.8
Age 11+	0.150	0.31	0.90	19.6
Age 12+	0.150	0.31	0.90	22.4
Age 13+	0.150	0.31	0.90	27.0
Age 14+	0.150	0.31	0.90	34.6
Age 15+	0.150	0.31	0.90	41.5

Sources: Bason, 1971; PSE&G, 1999; and NMFS, 2003a.

Table G1-28: Sucker (*Ictiobus* sp.) Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.87	0	0	0.00000390
Larvae	1.73	0	0	0.00214
Juvenile	2.98	0	0	0.00851
Age 1+	0.548	0	0	1.14
Age 2+	0.548	0	0	1.82
Age 3+	0.548	0	0	2.63
Age 4+	0.548	0	0	3.48
Age 5+	0.548	0	0	4.64
Age 6+	0.548	0	0	5.04
Age 7+	0.548	0	0	11.1
Age 8+	0.548	0	0	12.7
Age 9+	0.548	0	0	16.8
Age 10+	0.548	0	0	27.8
Age 11+	0.548	0	0	28.0
Age 12+	0.548	0	0	36.1
Age 13+	0.548	0	0	36.2
Age 14+	0.548	0	0	36.3
Age 15+	0.548	0	0	36.5

[a] Includes bigmouth buffalo and smallmouth buffalo.

Sources: Carlander, 1969; Bartell and Campbell, 2000; Kleinholz, 2000; and NMFS, 2003a.

Table G1-29: Sucker Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.05	0	0	0.0000312
Larvae	2.56	0	0	0.0000343
Juvenile	2.30	0	0	0.000239
Age 1+	0.274	0	0	0.0594
Age 2+	0.274	0	0	0.310
Age 3+	0.274	0	0	0.377
Age 4+	0.274	0	0	0.735
Age 5+	0.274	0	0	0.981
Age 6+	0.274	0	0	1.10

[a] Includes carpsuckers, highfin carpsucker, northern hog sucker, quillback, white sucker, and other suckers not identified to species.

Sources: Carlander, 1969; Bartell and Campbell, 2000; Froese and Pauly, 2003; and NMFS, 2003a.

Table G1-30: Sunfish Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.71	0	0	0.00000115
Larvae	0.687	0	0	0.00000123
Juvenile	0.687	0	0	0.000878
Age 1+	1.61	0	0	0.00666
Age 2+	1.61	0	0	0.0271
Age 3+	1.50	1.5	0.50	0.0593
Age 4+	1.50	1.5	1.0	0.0754
Age 5+	1.50	1.5	1.0	0.142
Age 6+	1.50	1.5	1.0	0.180
Age 7+	1.50	1.5	1.0	0.214
Age 8+	1.50	1.5	1.0	0.232

[a] Includes green sunfish, longear sunfish, pumpkinseed, redear sunfish, rock bass, warmouth, and other sunfish not identified to species.

Sources: Carlander, 1977; Wang, 1986; PSE&G, 1999; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-31: Walleye Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.05	0	0	0.00000619
Larvae	3.55	0	0	0.0000768
Juvenile	1.93	0	0	0.0300
Age 1+	0.431	0	0	0.328
Age 2+	0.161	0.27	0.50	0.907
Age 3+	0.161	0.27	1.0	1.77
Age 4+	0.161	0.27	1.0	2.35
Age 5+	0.161	0.27	1.0	3.37
Age 6+	0.161	0.27	1.0	3.97
Age 7+	0.161	0.27	1.0	4.66
Age 8+	0.161	0.27	1.0	5.58
Age 9+	0.161	0.27	1.0	5.75

Sources: Carlander, 1997; Bartell and Campbell, 2000; Thomas and Haas, 2000; Froese and Pauly, 2001, 2003; and NMFS, 2003a.

Table G1-32: White Bass Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.90	0	0	0.000000396
Larvae	4.61	0	0	0.00000174
Juvenile	1.39	0	0	0.174
Age 1+	0.420	0	0	0.467
Age 2+	0.420	0.70	0.50	0.644
Age 3+	0.420	0.70	1.0	1.02
Age 4+	0.420	0.70	1.0	1.16
Age 5+	0.420	0.70	1.0	1.26
Age 6+	0.420	0.70	1.0	1.66
Age 7+	0.420	0.70	1.0	1.68

[a] Includes white bass and temperate bass not identified to species.

Sources: Van Oosten, 1942; Geo-Marine, Inc., 1978; Carlander, 1997; Virginia Tech, 1998; McDermot and Rose, 2000; Froese and Pauly, 2001; and NMFS, 2003a.

Table G1-33: White Perch Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lb)
Eggs	2.75	0	0	0.000000330
Larvae	5.37	0	0	0.00000271
Juvenile	1.71	0	0	0.00259
Age 1+	0.693	0	0	0.0198
Age 2+	0.693	0	0	0.0567
Age 3+	0.693	0.15	0.0008	0.103
Age 4+	0.689	0.15	0.027	0.150
Age 5+	1.58	0.15	0.21	0.214
Age 6+	1.54	0.15	0.48	0.265
Age 7+	1.48	0.15	0.84	0.356
Age 8+	1.46	0.15	1.0	0.387
Age 9+	1.46	0.15	1.0	0.516
Age 10+	1.46	0.15	1.0	0.619

Sources: Horseman and Shirey, 1974; PSE&G, 1999; and NMFS, 2003a.

Table G1-34: Yellow Perch Life History Parameters

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.75	0	0	0.000000655
Larvae	3.56	0	0	0.000000728
Juvenile	2.53	0	0	0.0232
Age 1+	0.361	0	0	0.0245
Age 2+	0.249	0	0	0.0435
Age 3+	0.844	0.36	0.50	0.0987
Age 4+	0.844	0.36	1.0	0.132
Age 5+	0.844	0.36	1.0	0.166
Age 6+	0.844	0.36	1.0	0.214

Sources: Wapora, 1979; PSE&G, 1999; Thomas and Haas, 2000; and NMFS, 2003a.

Table G1-35: Other Recreational Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	2.08	0	0	0.000000716
Larvae	5.71	0	0	0.00000204
Juvenile	2.85	0	0	0.000746
Age 1+	0.450	0	0	0.0937
Age 2+	0.450	0.80	0.50	0.356
Age 3+	0.450	0.80	1.0	0.679
Age 4+	0.450	0.80	1.0	0.974
Age 5+	0.450	0.80	1.0	1.21
Age 6+	0.450	0.80	1.0	1.38

[a] Includes banded sculpin, coho salmon, rainbow trout, and trout-perch.

Sources: USFWS, 1978; Durbin et al., 1983; Ruppert et al., 1985; Able and Fahay, 1998; PSE&G, 1999; Entergy Nuclear Generation Company, 2000; ASMFC, 2001b; and NMFS, 2003a.

Table G1-36: Other Forage Species Life History Parameters[a]

Stage Name	Instantaneous Natural Mortality (M)	Instantaneous Fishing Mortality (F)	Fraction Vulnerable to Fishery	Weight (lbs)
Eggs	1.04	0	0	0.0000000186
Larvae	7.70	0	0	0.00000158
Juvenile	1.29	0	0	0.000481
Age 1+	1.62	0	0	0.00381
Age 2+	1.62	0	0	0.00496
Age 3+	1.62	0	0	0.00505

[a] Includes American eel, chestnut lamprey, goldeye, longnose gar, madtoms, mooneye, silver lamprey, and other forage fish not identified to species.

Sources: Derickson and Price, 1973; and PSE&G, 1999.

Appendix G2: Reductions in I&E in the Inland Region Under Five Other Options Evaluated for the Proposed Section 316(b) Phase III Regulation

Table G2-1: Estimated Reductions in I&E in the Inland Region Under Five Other Options Evaluated for the Proposed Section 316(b) Regulation

Option	Age-1 Equivalents (#s)	Foregone Fishery Yield (lbs)
20 MGD All	16,900,000	177,000
2	14,800,000	157,000
3	16,600,000	171,000
4	14,800,000	157,000
All Phase III Facilities	17,600,000	183,000

Appendix G4: Recreational Use Benefits of Other Policy Options

Introduction

Chapter G4 presents EPA's estimates of the recreational benefits of the three proposed options for the section 316(b) rule for Phase III facilities, for electric generators and manufacturers in the Inland region. This appendix supplements Chapter G4 by presenting estimates of the recreational fishing benefits of five other options that EPA evaluated for the purposes of comparison:

- Option 3,
- Option 4,
- Option 2,
- Option 1, and
- Option 6.

Appendix Contents

Recreational fishing benefits presented in this chapter were estimated using the benefit transfer approach discussed in Chapter G4 and in Chapter A5, "Recreational Fishing Benefits Methodology."

G4-1 Recreational Fishing Benefits of the Other Evaluated Options

G4-1.1 Estimated Reductions in Recreational Fishing Losses under the Other Evaluated Options

Table G4-1 presents EPA's estimates of the annual reduction in baseline (i.e., current) recreational fishing losses from impingement and entrainment (I&E) in the Inland region under the other evaluated options.

Table G4-1: Reductions in Recreational Fishing Losses from I&E under the Other Evaluated Options in the Inland Region

Species[a]	Annual Reduction in Recreational Losses (# of fish)[b]				
	Option 3	Option 4	Option 2	Option 1	Option 6
American shad	171	147	147	171	178
Paddlefish[c]	151	135	135	154	160
Striped bass	1,092	939	939	1,092	1,139
Sturgeon[c]	49	49	49	53	55
Total (small game)	**1,463**	**1,269**	**1,269**	**1,470**	**1,531**
Salmon	4	3	3	4	4
Total (salmon)	**4**	**3**	**3**	**4**	**4**
Northern pike	1	1	1	1	1
Sauger	5,526	5,454	5,454	5,932	6,110
Walleye	5,413	5,411	5,411	5,850	6,019
Total (walleye/pike)	**10,940**	**10,866**	**10,866**	**11,783**	**12,130**
Smallmouth bass	2,610	2,562	2,562	2,794	2,879
Spotted bass	5	4	4	5	5
White bass	7,945	7,015	7,015	8,052	8,375
Total (bass)	**10,560**	**9,581**	**9,581**	**10,850**	**11,258**
Black bullhead	76	65	65	76	79
Black crappie	208	179	179	208	217
Bluegill	21,990	18,906	18,906	21,991	22,926
Brown bullhead	576	537	537	601	622
Bullhead	63	55	55	63	66
Channel catfish	8,716	7,721	7,721	8,848	9,200
Crappie	9,447	9,234	9,234	10,089	10,401
Menhaden	9	7	7	9	9
Sculpin	128	127	127	138	142
Smelts	18,519	15,922	15,922	18,520	19,307
Sunfish	14,230	13,842	13,842	15,159	15,634
White perch	70	60	60	70	73
Yellow perch	8,506	7,352	7,352	8,529	8,887
Total (panfish)	**82,537**	**74,009**	**74,009**	**84,300**	**87,562**
Whitefish	80	69	69	80	83
Total (trout)	**80**	**69**	**69**	**80**	**83**
Freshwater drum[d]	13,281	11,954	11,954	13,591	14,112
Unidentified	65,511	59,150	59,150	67,146	69,702

Table G4-1: Reductions in Recreational Fishing Losses from I&E under the Other Evaluated Options in the Inland Region

Species[a]	Annual Reduction in Recreational Losses (# of fish)[b]				
	Option 3	Option 4	Option 2	Option 1	Option 6
Total (unidentified)	**78,793**	**71,104**	**71,104**	**80,737**	**83,815**
Total (all species)	***184,376***	***166,901***	***166,901***	***189,223***	***196,384***

[a] This table includes several species of anadromous fish (such as American shad and striped bass) that are classified in saltwater species groups, but that are commonly caught in freshwater during part of their life cycle.

[b] In the Inland region, the set of facilities with technology requirements under Option 4 is the same as under Option 2. Thus, reductions in recreational losses under these options are also identical.

[c] No valuation studies were available for freshwater sturgeon or paddlefish. EPA included these two species in the ‘small game’ group because the typical size of these species is consistent with (or larger than) the size of other species in the ‘small game’ group. Adult lake sturgeon generally weigh 10 to 80 pounds and measure three to five feet in length, and may grow as large as 300 pounds and seven feet long (NY State Department of Environmental Conservation, 2003). White sturgeon, which are anadromous, can grow to 400 pounds or 10 feet in length (Monterey Bay Aquarium, 1999). Paddlefish are also very large, averaging between 3.3 and 4.8 feet in length (Jenkins and Burkhead, 1993).

[d] No valuation studies were available for freshwater drum. Because this species does not correspond well with any of the species groups, EPA included it in the ‘unidentified’ group (i.e., valued it using an average weighted value from all other freshwater species).

Source: U.S. EPA analysis for this report.

G4-1.2 Recreational Fishing Benefits of the Other Evaluated Options

Tables G4-2 through G4-5 present EPA's estimates of the annualized recreational benefits of the other evaluated options in the Inland region.

In the Inland region, all potentially regulated facilities that would install new technology under Option 4 and Option 2 have design intake flows greater than 50 MGD. Because the requirements under these two options are identical for this class of facilities, the I&E reductions and benefits resulting from these two options are also identical. Thus, the benefits estimates presented in Table G4-3 apply to both options.

Table G4-2: Recreational Fishing Benefits of Option 3 in the Inland Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Small game[d]	1.5	$3.03	$7.38	$17.56	$4.4	$10.8	$25.7
Salmon	0.0[e]	$11.47	$24.69	$53.44	$0.0[e]	$0.1	$0.2
Trout	0.1	$0.49	$2.79	$4.51	$0.0[e]	$0.2	$0.4
Walleye/Pike	10.9	$2.82	$5.15	$9.42	$30.9	$56.3	$103.0
Bass	10.6	$3.66	$6.96	$13.13	$38.6	$73.5	$138.6
Panfish	82.5	$0.51	$0.97	$1.85	$42.3	$80.5	$152.6
Unidentified	78.8	$1.15	$2.16	$4.04	$90.6	$170.0	$318.1
Total (undiscounted)	**184.4**				**$206.9**	**$391.4**	**$738.6**
Total (evaluated at 3%)	**184.4**				**$176.5**	**$333.8**	**$629.9**
Total (evaluated at 7%)	**184.4**				**$144.2**	**$272.7**	**$514.6**

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[b] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.
[d] The small game species group includes sturgeon. However, applying the use value for small game to sturgeon may understate the value of this species. A marine fishing valuation study indicates that California anglers are willing to pay $61.43 to catch a sturgeon in saltwater (U.S. EPA, 2004a). However, sturgeon in freshwater are often landlocked and may not be as large as sturgeon found in saltwater, and therefore not as valuable.
[e] Denotes a nonzero value less than 50 fish or $50.

Source: U.S. EPA analysis for this report.

Table G4-3: Recreational Fishing Benefits of Option 4 and Option 2, in the Inland Region (2003$)[a]

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[b]			Annualized Recreational Fishing Benefits (thousands)[c,d]		
		Low	Mean	High	Low	Mean	High
Small game[d]	1.3	$3.03	$7.38	$17.56	$3.8	$9.4	$22.3
Salmon	0.0[e]	$11.47	$24.69	$53.44	$0.0[e]	$0.1	$0.2
Trout	0.1	$0.49	$2.79	$4.51	$0.0[e]	$0.2	$0.3
Walleye/Pike	10.9	$2.82	$5.15	$9.42	$30.7	$55.9	$102.3
Bass	9.6	$3.66	$6.96	$13.13	$35.0	$66.7	$125.8
Panfish	74.0	$0.51	$0.97	$1.85	$38.0	$72.1	$136.8
Unidentified	71.1	$1.15	$2.16	$4.04	$81.7	$153.4	$287.0
Total (undiscounted)	**166.9**				**$189.3**	**$357.8**	**$674.7**
Total (evaluated at 3%)	**166.9**				**$161.9**	**$306.0**	**$577.1**
Total (evaluated at 7%)	**166.9**				**$132.8**	**$250.9**	**$473.1**

[a] In the Inland region, the set of facilities with technology requirements under Option 4 is the same as under Option 2. Thus, reductions in recreational losses under these options are also identical.
[b] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[c] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[d] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.
[d] The small game species group includes sturgeon. However, applying the use value for small game to sturgeon may understate the value of this species. A marine fishing valuation study indicates that California anglers are willing to pay $61.43 to catch a sturgeon in saltwater (U.S. EPA, 2004a). However, sturgeon in freshwater are often landlocked and may not be as large as sturgeon found in saltwater, and therefore not as valuable.
[e] Denotes a nonzero value less than 50 fish or $50.

Source: U.S. EPA analysis for this report.

Table G4-4: Recreational Fishing Benefits of Option 1 in the Inland Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Small game[d]	1.5	$3.03	$7.38	$17.56	$4.5	$10.8	$25.8
Salmon	0.0[e]	$11.47	$24.69	$53.44	$0.0[e]	$0.1	$0.2
Trout	0.1	$0.49	$2.79	$4.51	$0.0[e]	$0.2	$0.4
Walleye/Pike	11.8	$2.82	$5.15	$9.42	$33.3	$60.6	$111.0
Bass	10.9	$3.66	$6.96	$13.13	$39.7	$75.5	$142.5
Panfish	84.3	$0.51	$0.97	$1.85	$43.2	$82.2	$155.8
Unidentified	80.7	$1.15	$2.16	$4.04	$92.8	$174.2	$325.9
Total (undiscounted)	**189.2**				**$213.5**	**$403.7**	**$761.5**
Total (evaluated at 3%)	**189.2**				**$182.1**	**$344.3**	**$649.5**
Total (evaluated at 7%)	**189.2**				**$148.8**	**$281.3**	**$530.6**

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[b] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.
[d] The small game species group includes sturgeon. However, applying the use value for small game to sturgeon may understate the value of this species. A marine fishing valuation study indicates that California anglers are willing to pay $61.43 to catch a sturgeon in saltwater (U.S. EPA, 2004a). However, sturgeon in freshwater are often landlocked and may not be as large as sturgeon found in saltwater, and therefore not as valuable.
[e] Denotes a nonzero value less than 50 fish or $50.

Source: U.S. EPA analysis for this report.

Table G4-5: Recreational Fishing Benefits of Option 6 in the Inland Region (2003$)

Species Group	Annual Reduction in Recreational Fishing Losses (thousands of fish)	Value per Fish[a]			Annualized Recreational Fishing Benefits (thousands)[b,c]		
		Low	Mean	High	Low	Mean	High
Small game[d]	1.5	$3.03	$7.38	$17.56	$4.6	$11.3	$26.9
Salmon	0.0[e]	$11.47	$24.69	$53.44	$0.0[e]	$0.1	$0.2
Trout	0.1	$0.49	$2.79	$4.51	$0.0[e]	$0.2	$0.4
Walleye/Pike	12.1	$2.82	$5.15	$9.42	$34.2	$62.4	$114.2
Bass	11.3	$3.66	$6.96	$13.13	$41.2	$78.4	$147.8
Panfish	87.6	$0.51	$0.97	$1.85	$44.9	$85.4	$161.9
Unidentified	83.8	$1.15	$2.16	$4.04	$96.4	$180.8	$338.3
Total (undiscounted)	**196.4**				**$221.4**	**$418.6**	**$789.7**
Total (evaluated at 3%)	**196.4**				**$188.7**	**$356.8**	**$673.1**
Total (evaluated at 7%)	**196.4**				**$154.0**	**$291.2**	**$549.5**

[a] Lower and upper bounds on per-fish values are based on the 5% and 95% confidence bounds predicted by the Krinsky and Robb approach. See section A5-5.1 of Chapter A5 for more details on this approach.
[b] Monetized benefits are calculated by multiplying the reduction in losses by the estimated value per fish.
[c] Annualized benefits represent the value of all recreational benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period. For a detailed discussion of the discounting methodology, refer to Chapter A8.
[d] The small game species group includes sturgeon. However, applying the use value for small game to sturgeon may understate the value of this species. A marine fishing valuation study indicates that California anglers are willing to pay $61.43 to catch a sturgeon in saltwater (U.S. EPA, 2004a). However, sturgeon in freshwater are often landlocked and may not be as large as sturgeon found in saltwater, and therefore not as valuable.
[e] Denotes a nonzero value less than 50 fish or $50.

Source: U.S. EPA analysis for this report.

G4-2 Comparison of Recreational Fishing Benefits by Option

Table G4-6 compares the recreational fishing benefits of the five other evaluated options. The table shows that the annual recreational welfare gain is largest under Option 6 and smallest under Option 4 and Option 2.

Table G4-6: Annual Recreational Benefits of the Other Evaluated Options in the Inland Region

Policy Option[a]	Annual Reduction in Recreational Fishing Losses from I&E (thousands of fish)	Undiscounted Recreational Fishing Benefits (thousands; 2003$)[b]		
		Low	Mean	High
Option 3	184.4	$206.9	$391.4	$738.6
Option 4	166.9	$189.3	$357.8	$674.7
Option 2	166.9	$189.3	$357.8	$674.7
Option 1	189.2	$213.5	$403.7	$761.5
Option 6	196.4	$221.4	$418.6	$789.7

[a] In the Inland region, the set of facilities with technology requirements under Option 4 is the same as under Option 2. Thus, reductions in recreational losses under these options are also identical.
[b] These benefit estimates were calculated using the meta-analysis approach discussed in Chapter A5 and Chapter G4. EPA did not use the RUM approach from the Phase II analysis to analyze the other evaluated options.

Source: U.S. EPA analysis for this report.

Part H: National Benefits

Chapter H1: National Benefits

Introduction

Chapter Contents

This chapter summarizes the results of the six regional analyses and presents EPA's estimates of the national commercial and recreational benefits of the three co-proposed regulatory options for Phase III existing facilities:

- the "50 MGD for All Waterbodies" option,
- the "200 MGD for All Waterbodies" option, and
- the "100 MGD for Certain Waterbodies" option.

EPA considered a wide range of policy options in developing this regulation. Results of the national benefits analysis for other options evaluated by EPA are presented in Appendix H1.

Greater detail on the methods and data used in the regional analyses is provided in the previous chapters of this report. See Chapter A1 for a discussion of the methods used to estimate impingement and entrainment (I&E), and Chapters A2 through A9 for a discussion of the methods used to estimate the value of I&E losses and the benefits of the policy options considered for the proposed rule. The results of the regional analyses are presented in Parts B through G.

EPA was unable to assess benefits of reducing I&E at new offshore oil and gas facilities due to significant data gaps at the time of proposal. Therefore, the benefits estimates presented in this section are underestimates because they do not reflect benefits associated with reducing I&E at new offshore oil and gas facilities.

H1-1 Calculating National Losses and Benefits

EPA's analysis of national baseline losses and benefits under the policy options includes 603 sample-weighted facilities, excluding facilities that are expected to close in the baseline. Of these facilities, 599 are located in the six case study regions, and four are located in the South Atlantic region, which was not included in the regional studies. The Agency calculated baseline losses by summing losses from all 603 facilities in the six case study regions and in the South Atlantic region. EPA's estimates of benefits are based on only those facilities that are estimated to install compliance technologies under each option. This South Atlantic region was not included in the benefits analysis of the proposed options because the four facilities in the South Atlantic region withdraw less than 50 MGD and, as a result, are not subject to the proposed policy options.

EPA notes that quantifying and monetizing reductions in I&E due to the policy options considered for the proposed section 316(b) rule for Phase III facilities is extremely challenging. As described in Chapters A3 and A6, EPA has estimated non-use values only qualitatively and, as a result, the estimated total benefits of the regulatory options reflect use values only. The preceding sections of this report discuss specific limitations and uncertainties associated with estimating commercial and recreational benefits. National benefit estimates, which are based on the regional estimates, are subject to the same uncertainties inherent in the valuation approaches used for assessing the two benefits categories. The combined effect of these uncertainties is of unknown magnitude and direction (i.e., the estimates may over- or understate the anticipated national level of use benefits); however, EPA has no data to indicate that the results for any of the benefit categories are atypical or unreasonable.

H1-2 Summary of Baseline Losses and Expected Reductions in I&E

Based on the results of the regional analyses, EPA calculated total I&E losses under baseline (i.e., pre-Phase III regulatory) conditions and the total amount by which losses would be reduced under each of the policy options. Losses are presented using two measures of I&E:

1. Age-1 equivalent losses (the number of individual fish of different ages impinged and entrained by facility intakes, expressed as age-1 equivalents); and
2. Foregone fishery yield (pounds of commercial harvest and numbers of recreational fish and shellfish that are not harvested due to I&E, including indirect losses of harvested species due to losses of forage species).

Table H1-1 presents baseline I&E losses using each of these measures. The table shows that total national losses of age-1 equivalents for all 603 facilities are 120 million fish. Nationwide, EPA estimates that 4 million pounds of fishery yield is foregone under current rates of I&E. The table shows that about 37% of all age-1 equivalent losses, or 44.2 million fish, occur in the Inland region. The Gulf of Mexico region has the highest foregone fishery yield, with 2 million pounds, followed by the Mid-Atlantic region with 0.9 million pounds. More detailed discussions of the I&E losses in each region are provided in Parts B through G of this report.

Table H1-1: Total Annual Baseline I&E Losses for Potential Phase III Existing Facilities by Region

Region	Age-1 Equivalents (thousands)	Foregone Fishery Yield (thousands; lbs)
California	1,310	96
North Atlantic	2,340	45
Mid-Atlantic	23,200	920
South Atlantic	1,520	123
Gulf of Mexico	12,700	1,990
Great Lakes	34,400	489
Inland	44,200	495
National Total	120,000	4,160

Source: U.S. EPA analysis for this report.

EPA also calculated the total national I&E losses prevented by each of the policy options. These prevented losses are based on the expected reductions in I&E at each facility due to technology required under each option. Table H1-2 presents expected percent reductions in I&E, by region and option. The table also presents estimates of regional and national expected reductions in I&E losses, expressed as age-1 equivalents lost and foregone fishery yield. The table shows that at the 603 national facilities potentially subject to regulation, the “50 MGD for All Waterbodies” option reduces age-1 equivalent losses by 49.5 million fish and prevents 2.2 million pounds of fishery yield. In comparison, the “200 MGD for All Waterbodies” option and the “100 MGD for Certain Waterbodies” option reduce age-1 equivalent losses by 34.0 million fish and 29.8 million fish and prevent 1.4 million pounds and 1.9 million pounds of fishery yield from being lost, respectively.

Table H1-2 also shows that expected reductions vary across the regions. Under the “50 MGD for All Waterbodies” and “100 MGD for Certain Waterbodies” options, facilities in the Gulf of Mexico region are expected to make the largest average percentage reductions in impingement (76%) and entrainment (57%). Under the "200 MGD for All Waterbodies" option, facilities in the Mid-Atlantic region have the largest average percentage reductions in I&E with 65% and 49%, respectively. Under the 50 MGD option, 30% of age-1 equivalent losses that are prevented are attributable to the Inland region. Under the 200 MGD and 100 MGD options, the largest percentage of age-1 equivalent losses that are prevented are attributed to facilities in the Mid-Atlantic region with 35% and 40%, respectively. Under all three options, the largest prevented losses of fishery yield are occur in the Gulf of Mexico (56% under the 50 MGD option, 47% under the 200 MGD option, and 65% under the 100 MGD option). More detailed discussions of regional benefits are provided in Parts B through G of this report.

Table H1-2: Expected Reduction in I&E for Existing Phase III Facilities by Option

Region	Number of Facilities Installing Technology	Reduction in Impingement	Reduction in Entrainment	Prevented Age-1 Equivalent Losses (thousands)	Prevented Foregone Fishery Yield (thousands; lbs)
50 MGD All					
California	1	39%	29%	383	28
North Atlantic	4	43%	40%	930	18
Mid-Atlantic	3	73%	55%	13,400	600
South Atlantic[a]	0	0%	0%	0	0
Gulf of Mexico	7	76%	57%	8,380	1,250
Great Lakes	19	33%	43%	11,600	169
Inland	69	37%	27%	14,800	157
National Total	103			49,493	2,222
200 MGD All					
California[b]	0	0%	0%	0	0
North Atlantic	1	11%	8%	198	4
Mid-Atlantic	2	65%	49%	11,900	534
South Atlantic[a]	0	0%	0%	0	0
Gulf of Mexico	2	41%	31%	4,580	682
Great Lakes	5	21%	37%	7,710	116
Inland	12	22%	21%	9,650	107
National Total	22			34,038	1,443
100 MGD Certain Waterbodies					
California[b]	0	0%	0%	0	0
North Atlantic	3	43%	32%	754	15
Mid-Atlantic	2	65%	49%	11,900	534
South Atlantic[a]	0	0%	0%	0	0
Gulf of Mexico	7	76%	57%	8,380	1,250
Great Lakes	6	24%	40%	8,740	130
Inland[c]	0	0%	0%	0	0
National Total	18			29,774	1,929

[a] No I&E reductions are expected at the potentially regulated facilities in the South Atlantic region. Since these facilities withdraw less than 50 MGD, none of the facilities in this region would be required to install technology to comply with the proposed options.

[b] No I&E reductions are expected at the potentially regulated facilities in the California region. Since these facilities withdraw less than 100 MGD, none of the facilities in this region would be required to install technology to comply with the 200 MGD All and 100 MGD CWB options.

[c] None of the facilities in the Inland region would be required to install technology to comply with the 100 MGD CWB option. Thus, no I&E reductions are expected at the potentially regulated facilities in the Inland region. See the Introduction of this document for a description of the proposed options.

Source: U.S. EPA analysis for this report.

H1-3 Time Profile of Benefits

EPA's estimates of total national baseline losses and total national benefits under each option are based on EPA's regional estimates of monetized baseline losses and policy option benefits. To recognize the difference in timing of benefits and costs, EPA developed a time profile of total benefits from all potentially regulated Phase III facilities that reflects when benefits from compliance-related changes at each facility will be realized. For each study region, EPA first calculated the undiscounted use benefits (i.e., commercial and recreational fishing benefits) from the expected annual I&E reductions under the proposed options, based on the assumptions that all facilities in each region have achieved compliance with the rule and that benefits are realized immediately following compliance. Then, since there are regulatory and biological time lags between promulgation of the rule and the realization of benefits, EPA created a time profile of benefits that takes into account the fact that benefits do not begin immediately. The development of the time profile of benefits is discussed in detail in Chapter A8, "Discounting Benefits." Table H1-3 below presents a profile of the benefits of eliminating baseline I&E at all potentially regulated facilities. Time profiles of benefits for the "50 MGD for All Waterbodies," "200 MGD for All Waterbodies," and "100 MGD for Certain Waterbodies" options are presented in Tables H1-4, H1-5, and H1-6, respectively.

Table H1-3: Time Profile of Mean Total Use Benefits of Eliminating Baseline I&E at Potentially Regulated Phase III Facilities (thousands; 2003$)[a,b]

Year	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland	National Total
2007	$0	$0	$0	$0	$111	$118	$112	$341
2008	$12	$20	$111	$8	$222	$236	$224	$833
2009	$23	$41	$222	$16	$887	$945	$897	$3,031
2010	$93	$163	$889	$65	$998	$1,063	$1,009	$4,280
2011	$105	$183	$1,001	$73	$1,054	$1,122	$1,065	$4,602
2012	$110	$194	$1,056	$77	$1,109	$1,181	$1,121	$4,848
2013	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2014	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2015	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2016	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2017	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2018	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2019	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2020	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2021	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2022	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2023	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2024	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2025	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2026	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2027	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2028	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2029	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2030	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2031	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2032	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2033	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2034	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2035	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2036	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
2037	$116	$204	$1,112	$81	$998	$1,063	$1,009	$4,583
2038	$105	$183	$1,001	$73	$887	$945	$897	$4,090
2039	$93	$163	$889	$65	$222	$236	$224	$1,892
2040	$23	$41	$222	$16	$111	$118	$112	$644
2041	$12	$20	$111	$8	$55	$59	$56	$322
2042	$6	$10	$56	$4	$0	$0	$0	$76
2043	$0	$0	$0	$0	$0	$0	$0	$0
2044	$0	$0	$0	$0	$0	$0	$0	$0
2045	$0	$0	$0	$0	$0	$0	$0	$0
2046	$0	$0	$0	$0	$0	$0	$0	$0
2047	$0	$0	$0	$0	$0	$0	$0	$0
2048	$0	$0	$0	$0	$0	$0	$0	$0
Evaluated at 0% (i.e., undiscounted)								
Present value[c]	$3,484	$6,112	$33,350	$2,435	$33,277	$35,429	$33,621	$147,708
Annualized value[d]	$116	$204	$1,112	$81	$1,109	$1,181	$1,121	$4,924
Evaluated at 3%								
Present value[c]	$2,143	$3,761	$20,519	$1,498	$21,088	$22,452	$21,306	$92,769
Annualized value[d]	$109	$192	$1,047	$76	$1,076	$1,146	$1,087	$4,733
Evaluated at 7%								
Present value[c]	$1,258	$2,207	$12,042	$879	$12,857	$13,688	$12,990	$55,921
Annualized value[d]	$101	$178	$970	$71	$1,036	$1,103	$1,047	$4,506

Table H1-3: Time Profile of Mean Total Use Benefits of Eliminating Baseline I&E at Potentially Regulated Phase III Facilities (thousands; 2003$)[a,b]

Year	California	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico	Great Lakes	Inland	National Total

[a] This table presents the benefits of eliminating baseline I&E at potentially regulated Phase III facilities from 2007 to 2036.
[b] Because EPA estimated non-use benefits only qualitatively, the monetary value of benefits includes only use values.
[c] Values for a given year in the table are not discounted. Total present values of benefits are discounted with the corresponding rate.
[d] Annualized benefits represent the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

Source: U.S. EPA analysis for this report.

Table H1-4: Time Profile of Mean Total Use Benefits of the "50 MGD for All Waterbodies" Option (thousands; 2003$)[a]

Year	California	North Atlantic	Mid-Atlantic	South Atlantic[b]	Gulf of Mexico	Great Lakes	Inland	National Total
2007	$0	$0	$0	$0	$0	$0	$0	$0
2008	$0	$0	$0	$0	$0	$0	$0	$0
2009	$0	$0	$0	$0	$0	$0	$0	$0
2010	$0	$0	$0	$0	$0	$0[e]	$7	$7
2011	$3	$0	$7	$0	$0	$11	$33	$54
2012	$7	$5	$14	$0	$76	$26	$96	$223
2013	$27	$10	$99	$0	$152	$106	$231	$625
2014	$31	$42	$164	$0	$608	$160	$275	$1,280
2015	$32	$50	$439	$0	$684	$291	$329	$1,826
2016	$34	$72	$571	$0	$722	$371	$349	$2,120
2017	$34	$78	$607	$0	$760	$391	$354	$2,225
2018	$34	$79	$636	$0	$760	$406	$358	$2,272
2019	$34	$81	$643	$0	$760	$410	$358	$2,286
2020	$34	$81	$643	$0	$760	$410	$358	$2,286
2021	$34	$81	$643	$0	$760	$410	$358	$2,286
2022	$34	$81	$643	$0	$760	$410	$358	$2,286
2023	$34	$81	$643	$0	$760	$410	$358	$2,286
2024	$34	$81	$643	$0	$760	$410	$358	$2,286
2025	$34	$81	$643	$0	$760	$410	$358	$2,286
2026	$34	$81	$643	$0	$760	$410	$358	$2,286
2027	$34	$81	$643	$0	$760	$410	$358	$2,286
2028	$34	$81	$643	$0	$760	$410	$358	$2,286
2029	$34	$81	$643	$0	$760	$410	$358	$2,286
2030	$34	$81	$643	$0	$760	$410	$358	$2,286
2031	$34	$81	$643	$0	$760	$410	$358	$2,286
2032	$34	$81	$643	$0	$760	$410	$358	$2,286
2033	$34	$81	$643	$0	$760	$410	$358	$2,286
2034	$34	$81	$643	$0	$760	$410	$358	$2,286
2035	$34	$81	$643	$0	$760	$410	$358	$2,286
2036	$34	$81	$643	$0	$760	$410	$358	$2,286
2037	$34	$81	$643	$0	$760	$410	$358	$2,286
2038	$34	$81	$643	$0	$760	$410	$358	$2,286
2039	$34	$81	$643	$0	$760	$410	$358	$2,286
2040	$34	$81	$643	$0	$760	$410	$351	$2,279
2041	$31	$81	$636	$0	$760	$400	$324	$2,232
2042	$27	$76	$629	$0	$684	$384	$262	$2,063
2043	$7	$71	$543	$0	$608	$304	$127	$1,661
2044	$3	$39	$479	$0	$152	$250	$83	$1,006
2045	$2	$31	$203	$0	$76	$120	$28	$460
2046	$0	$9	$71	$0	$38	$39	$8	$166
2047	$0	$3	$36	$0	$0	$19	$4	$61
2048	$0	$2	$7	$0	$0	$5	$0[e]	$14
Evaluated at 0% (i.e., undiscounted)								
Present Value[c]	$1,024	$2,430	$19,287	$0	$22,799	$12,306	$10,734	$68,581
Annualized Value[d]	$34	$81	$643	$0	$760	$410	$358	$2,286
Evaluated at 3%								
Present Value[c]	$577	$1,298	$10,239	$0	$12,463	$6,602	$5,998	$37,177
Annualized Value[d]	$29	$66	$522	$0	$636	$337	$306	$1,897
Evaluated at 7%								
Present Value[c]	$302	$635	$4,973	$0	$6,280	$3,252	$3,113	$18,556
Annualized Value[d]	$24	$51	$401	$0	$506	$262	$251	$1,495

Table H1-4: Time Profile of Mean Total Use Benefits of the "50 MGD for All Waterbodies" Option (thousands; 2003$)[a]

Year	California	North Atlantic	Mid-Atlantic	South Atlantic[b]	Gulf of Mexico	Great Lakes	Inland	National Total

[a] Because EPA estimated non-use benefits only qualitatively, the monetary value of benefits includes only use values.
[b] No I&E reductions are expected at the potentially regulated facilities in the South Atlantic region. Since these facilities withdraw less than 50 MGD, none of the facilities in this region would be required to install technology to comply with this option.
[c] Values for a given year in the table are not discounted. Total present values of benefits are discounted with the corresponding rate.
[d] Annualized benefits represent the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.
[e] Denotes a positive value less than $500.

Source: U.S. EPA analysis for this report.

Table H1-5: Time Profile of Mean Total Use Benefits of the "200 MGD for All Waterbodies" Option (thousands; 2003$)[a]

Year	California[b]	North Atlantic	Mid-Atlantic	South Atlantic[b]	Gulf of Mexico	Great Lakes	Inland	National Total
2007	$0	$0	$0	$0	$0	$0	$0	$0
2008	$0	$0	$0	$0	$0	$0	$0	$0
2009	$0	$0	$0	$0	$0	$0	$0	$0
2010	$0	$0	$0	$0	$0	$0	$3	$3
2011	$0	$0	$0	$0	$0	$4	$23	$27
2012	$0	$0	$0	$0	$42	$8	$58	$108
2013	$0	$0	$43	$0	$83	$48	$168	$343
2014	$0	$2	$100	$0	$332	$77	$191	$702
2015	$0	$3	$372	$0	$374	$185	$225	$1,159
2016	$0	$14	$501	$0	$394	$251	$238	$1,398
2017	$0	$15	$537	$0	$415	$267	$240	$1,474
2018	$0	$16	$565	$0	$415	$279	$242	$1,518
2019	$0	$17	$572	$0	$415	$283	$242	$1,530
2020	$0	$17	$572	$0	$415	$283	$242	$1,530
2021	$0	$17	$572	$0	$415	$283	$242	$1,530
2022	$0	$17	$572	$0	$415	$283	$242	$1,530
2023	$0	$17	$572	$0	$415	$283	$242	$1,530
2024	$0	$17	$572	$0	$415	$283	$242	$1,530
2025	$0	$17	$572	$0	$415	$283	$242	$1,530
2026	$0	$17	$572	$0	$415	$283	$242	$1,530
2027	$0	$17	$572	$0	$415	$283	$242	$1,530
2028	$0	$17	$572	$0	$415	$283	$242	$1,530
2029	$0	$17	$572	$0	$415	$283	$242	$1,530
2030	$0	$17	$572	$0	$415	$283	$242	$1,530
2031	$0	$17	$572	$0	$415	$283	$242	$1,530
2032	$0	$17	$572	$0	$415	$283	$242	$1,530
2033	$0	$17	$572	$0	$415	$283	$242	$1,530
2034	$0	$17	$572	$0	$415	$283	$242	$1,530
2035	$0	$17	$572	$0	$415	$283	$242	$1,530
2036	$0	$17	$572	$0	$415	$283	$242	$1,530
2037	$0	$17	$572	$0	$415	$283	$242	$1,530
2038	$0	$17	$572	$0	$415	$283	$242	$1,530
2039	$0	$17	$572	$0	$415	$283	$242	$1,530
2040	$0	$17	$572	$0	$415	$283	$239	$1,527
2041	$0	$17	$572	$0	$415	$279	$219	$1,503
2042	$0	$17	$572	$0	$374	$275	$184	$1,422
2043	$0	$17	$529	$0	$332	$235	$74	$1,188
2044	$0	$15	$472	$0	$83	$207	$51	$828
2045	$0	$14	$200	$0	$42	$99	$17	$371
2046	$0	$3	$71	$0	$21	$32	$4	$132
2047	$0	$2	$36	$0	$0	$16	$2	$56
2048	$0	$1	$7	$0	$0	$4	$0	$12
Evaluated at 0% (i.e., undiscounted)								
Present Value[c]	$0	$516	$17,171	$0	$12,457	$8,499	$7,259	$45,902
Annualized Value[d]	$0	$17	$572	$0	$415	$283	$242	$1,530
Evaluated at 3%								
Present Value[c]	$0	$266	$9,047	$0	$6,810	$4,513	$4,063	$24,698
Annualized Value[d]	$0	$14	$462	$0	$347	$230	$207	$1,260
Evaluated at 7%								
Present Value[c]	$0	$124	$4,349	$0	$3,431	$2,192	$2,113	$12,209
Annualized Value[d]	$0	$10	$350	$0	$277	$177	$170	$984

Table H1-5: Time Profile of Mean Total Use Benefits of the "200 MGD for All Waterbodies" Option (thousands; 2003$)[a]

Year	California[b]	North Atlantic	Mid-Atlantic	South Atlantic[b]	Gulf of Mexico	Great Lakes	Inland	National Total

[a] Because EPA estimated non-use benefits only qualitatively, the monetary value of benefits includes only use values.
[b] No I&E reductions are expected at the potentially regulated facilities in the California and South Atlantic regions. Since these facilities withdraw less than 200 MGD, none of the facilities in these regions would be required to install technology to comply with this option.
[c] Values for a given year in the table are not discounted. Total present values of benefits are discounted with the corresponding rate.
[d] Annualized benefits represent the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

Source: U.S. EPA analysis for this report.

Table H1-6: Time Profile of Mean Total Use Benefits for the "100 MGD for Certain Waterbodies" Option (thousands; 2003$)[a]

Year	California[b]	North Atlantic	Mid-Atlantic	South Atlantic[b]	Gulf of Mexico	Great Lakes	Inland[c]	National Total
2007	$0	$0	$0	$0	$0	$0	$0	$0
2008	$0	$0	$0	$0	$0	$0	$0	$0
2009	$0	$0	$0	$0	$0	$0	$0	$0
2010	$0	$0	$0	$0	$0	$0	$0	$0
2011	$0	$0	$0	$0	$0	$6	$0	$6
2012	$0	$5	$0	$0	$76	$12	$0	$93
2013	$0	$10	$43	$0	$152	$66	$0	$270
2014	$0	$40	$100	$0	$608	$98	$0	$846
2015	$0	$47	$372	$0	$684	$212	$0	$1,316
2016	$0	$60	$501	$0	$722	$284	$0	$1,566
2017	$0	$64	$537	$0	$760	$301	$0	$1,661
2018	$0	$65	$565	$0	$760	$314	$0	$1,703
2019	$0	$66	$572	$0	$760	$318	$0	$1,716
2020	$0	$66	$572	$0	$760	$318	$0	$1,716
2021	$0	$66	$572	$0	$760	$318	$0	$1,716
2022	$0	$66	$572	$0	$760	$318	$0	$1,716
2023	$0	$66	$572	$0	$760	$318	$0	$1,716
2024	$0	$66	$572	$0	$760	$318	$0	$1,716
2025	$0	$66	$572	$0	$760	$318	$0	$1,716
2026	$0	$66	$572	$0	$760	$318	$0	$1,716
2027	$0	$66	$572	$0	$760	$318	$0	$1,716
2028	$0	$66	$572	$0	$760	$318	$0	$1,716
2029	$0	$66	$572	$0	$760	$318	$0	$1,716
2030	$0	$66	$572	$0	$760	$318	$0	$1,716
2031	$0	$66	$572	$0	$760	$318	$0	$1,716
2032	$0	$66	$572	$0	$760	$318	$0	$1,716
2033	$0	$66	$572	$0	$760	$318	$0	$1,716
2034	$0	$66	$572	$0	$760	$318	$0	$1,716
2035	$0	$66	$572	$0	$760	$318	$0	$1,716
2036	$0	$66	$572	$0	$760	$318	$0	$1,716
2037	$0	$66	$572	$0	$760	$318	$0	$1,716
2038	$0	$66	$572	$0	$760	$318	$0	$1,716
2039	$0	$66	$572	$0	$760	$318	$0	$1,716
2040	$0	$66	$572	$0	$760	$318	$0	$1,716
2041	$0	$66	$572	$0	$760	$312	$0	$1,710
2042	$0	$61	$572	$0	$684	$306	$0	$1,623
2043	$0	$56	$529	$0	$608	$252	$0	$1,445
2044	$0	$25	$472	$0	$152	$220	$0	$870
2045	$0	$19	$200	$0	$76	$105	$0	$400
2046	$0	$6	$71	$0	$38	$34	$0	$150
2047	$0	$2	$36	$0	$0	$17	$0	$55
2048	$0	$1	$7	$0	$0	$4	$0	$12
Evaluated at 0% (i.e., undiscounted)								
Present Value[d]	$0	$1,966	$17,171	$0	$22,799	$9,533	$0	$51,468
Annualized Value[e]	$0	$66	$572	$0	$760	$318	$0	$1,716
Evaluated at 3%								
Present Value[d]	$0	$1,059	$9,047	$0	$12,463	$5,079	$0	$27,647
Annualized Value[e]	$0	$54	$462	$0	$636	$259	$0	$1,411
Evaluated at 7%								
Present Value[d]	$0	$524	$4,349	$0	$6,280	$2,479	$0	$13,632
Annualized Value[e]	$0	$42	$350	$0	$506	$200	$0	$1,099

Table H1-6: Time Profile of Mean Total Use Benefits for the "100 MGD for Certain Waterbodies" Option (thousands; 2003$)[a]

Year	California[b]	North Atlantic	Mid-Atlantic	South Atlantic[b]	Gulf of Mexico	Great Lakes	Inland[c]	National Total

[a] Because EPA estimated non-use benefits only qualitatively, the monetary value of benefits includes only use values.
[b] No I&E reductions are expected at the potentially regulated facilities in the California and South Atlantic regions. Since these facilities withdraw less than 100 MGD, none of the facilities in these regions would be required to install technology to comply with this option.
[c] None of the facilities in the Inland region would be required to install technology to comply with the 100 MGD CWB option. Thus, no I&E reductions are expected at the potentially regulated facilities in the Inland region. See the Introduction of this document for a description of the proposed options.
[d] Values for a given year in the table are not discounted. Total present values of benefits are discounted with the corresponding rate.
[e] Annualized benefits represent the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.
Source: U.S. EPA analysis for this report.

H1-4 National Benefits from Eliminating and Reducing I&E Losses

EPA used the profiles of benefits, by region, to calculate a total present value of benefits and then to calculate a constant annual equivalent value (annualized value) of the present value. EPA calculated present value and annualized value using two discount rate values: a real rate of 3% and a real rate of 7%. EPA estimated mean values, as well as lower and upper bound values reflecting uncertainty in the recreational benefits estimates. Tables H1-7, H1-8, H1-9, and H1-10 present these results, for each region and for the nation as a whole. Because EPA did not estimate non-use benefits quantitatively, the monetized benefits presented in these tables reflect only use values.[1] As described in Chapter A3, the Agency was not able to monetize benefits for 96.7% of the age-1 equivalent losses of all commercial, recreational, and forage species evaluated for the policy options for the proposed section 316(b) regulation for Phase III facilities. This means that the estimates of benefits presented in this section represent the benefits associated with less than 3.3% of the total age-1 equivalents prevented from being lost to I&E by cooling water intake structures, and should be interpreted with caution.

Table H1-7 shows that the total annual national value of fishery resources lost to I&E (i.e., benefits of eliminating baseline I&E losses at Phase III facilities) includes $0.28 million in commercial fishing losses, $4.45 million in recreational fishing losses, and an unknown amount in foregone non-use benefits (2003$, discounted at 3%). The total use value of fishery resources lost is $4.73 million per year, with lower and upper bounds of $2.44 million and $9.45 million, respectively (discounted at 3%). Discounted at 7%, total annual national value of fishery resources lost to I&E includes $0.27 million in commercial fishing losses, $4.34 million in recreational fishing losses, and an unknown amount in foregone non-use benefits. The total use value of fishery resources lost discounted at 7% is $4.51 million per year, with lower and upper bounds of $2.33 million and $9.00 million, respectively. Total monetized losses are greatest in the Great Lakes region. More detailed discussions of the valuation of recreational and commercial fishing losses under the baseline conditions in each region are provided in Parts B through G of this document.

Tables H1-8, H1-9 and H1-10 present EPA's estimates of the national and regional use benefits of reducing I&E under each of the policy options (2003$, discounted at 3% and 7%). The national value of these reductions in I&E losses, evaluated at a 3% discount rate, are as follows:

- the "50 MGD for All Waterbodies" option results in national use benefits of $1.90 million per year, with lower and upper bounds of $0.97 million and $3.84 million (see Table H1-8);
- the "200 MGD for All Waterbodies" option results in national use benefits of $1.26 million per year, with lower and upper bounds of $0.65 million and $2.54 million (see Table H1-9); and

[1] Use values include commercial and recreational fishing benefits from reduced I&E. See Chapter A6 of this report for a detailed description of the ecological benefits from reduced I&E.

- the "100 MGD for Certain Waterbodies" option results in national use benefits of $1.41 million per year, with lower and upper bounds of $0.72 million and $2.90 million (see Table H1-10).

Evaluated at a 7% discount rate, the national use benefits of the proposed are somewhat smaller:

- the 50 MGD option results in national use benefits of $1.50 million per year, with lower and upper bounds of $0.77 million and $3.02 million (see Table H1-8);
- the 200 MGD option results in national use benefits of $0.98 million per year, with lower and upper bounds of $0.51 million and $1.98 million (see Table H1-9); and
- the 100 MGD option results in national use benefits of $1.10 million per year, with lower and upper bounds of $0.56 million and $2.26 million (see Table H1-10).

EPA also considered how benefits might increase if facilities that meet technology requirements in the baseline optimize their operation and maintenance (O&M) procedures (e.g., by rotating screens more often to reduce impingement mortality due to the proposed regulation). For this analysis, EPA evaluated facilities that (1) are expected to install no new technology and (2) are expected to meet impingement standards with a 0.5 fps screen. If there were a 5% increase in the efficacy of O&M at these facilities, the total annualized national benefits from the proposed regulation would increase by approximately $19,000 for the "50 MGD for All Waterbodies" option, from $1.897 million to $1.916 million (based on a 3% discount rate). If there were a 15% increase in efficacy, the estimated annualized benefits would increase by over $58,000, to $1.955 million (based on a 3% discount rate). Using the 7% discount rate, total annualized national benefits from the proposed regulation would increase by approximately $18,000 and $55,000, for the 5% and 15% increases in efficacy, respectively. Therefore, optimization of O&M procedures would result in 1.0% to 3.5% increase in the estimated total use benefits of the proposed regulation, depending on the assumed increase in efficacy and the discount rate being used. Optimization of O&M procedures would result in similar increases in the estimated use benefits under "200 MGD for All Waterbodies" and "100 MGD for Certain Waterbodies" options.

The majority of the value of use benefits is attributable to benefits to recreational anglers from improved catch rates. As shown in Tables H1-8, H1-10, and H1-9, use benefits are largest in the Gulf of Mexico for the "50 MGD for All Waterbodies" and "100 MGD for Certain Waterbodies" options and the Mid-Atlantic region under the "200 MGD for All Waterbodies" option, respectively. More detailed discussions of regional benefits under each option are provided in Parts B through G of this report.

Table H1-7: Summary of Use Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities

Region	Annualized Use Benefits from Eliminating Baseline I&E (thousands; 2003$)[a]						
	Commercial Fishing	Recreational Fishing			Total Use Value[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California	$0 - $20	$38	$90	$211	$58	$109	$231
North Atlantic	$0 - $9	$84	$183	$401	$93	$192	$409
Mid-Atlantic	$0 - $47	$473	$1,000	$2,124	$520	$1,047	$2,171
South Atlantic	$0	$34	$76	$171	$34	$76	$171
Gulf of Mexico	$0 - $139	$419	$937	$2,105	$558	$1,076	$2,244
Great Lakes	$0 - $70	$534	$1,076	$2,109	$604	$1,146	$2,179
Inland[c]	n/a	$576	$1,087	$2,047	$576	$1,087	$2,047
National Total	$0 - $284	$2,159	$4,449	$9,168	$2,443	$4,733	$9,452
Evaluated at a 7 percent discount rate							
California	$0 - $18	$35	$83	$196	$54	$101	$214
North Atlantic	$0 - $8	$78	$170	$371	$86	$178	$379
Mid-Atlantic	$0 - $44	$438	$927	$1,969	$482	$970	$2,012
South Atlantic	$0	$32	$71	$158	$32	$71	$158
Gulf of Mexico	$0 - $133	$404	$903	$2,028	$537	$1,036	$2,161
Great Lakes	$0 - $67	$515	$1,036	$2,031	$582	$1,103	$2,099
Inland[c]	n/a	$555	$1,047	$1,971	$555	$1,047	$1,971
National Total	$0 - $271	$2,057	$4,236	$8,724	$2,328	$4,506	$8,995

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.
[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.
[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

Source: U.S. EPA analysis for this report.

Table H1-8: Summary of Use Benefits of the "50 MGD for All Waterbodies" Option (thousands; 2003$)[a]

Region	Annualized Commercial Fishing Benefits	Annualized Recreational Fishing Benefits			Total Annualized Use Benefits[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California	$0 - $5	$10	$24	$57	$16	$29	$62
North Atlantic	$0 - $3	$29	$63	$138	$32	$66	$141
Mid-Atlantic	$0 - $25	$235	$497	$1,057	$260	$522	$1,082
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $78	$249	$558	$1,254	$327	$636	$1,332
Great Lakes	$0 - $20	$157	$316	$621	$178	$337	$641
Inland[d]	n/a	$162	$306	$577	$162	$306	$577
National Total	$0 - $132	$843	$1,765	$3,704	$975	$1,897	$3,836
Evaluated at a 7 percent discount rate							
California	$0 - $4	$9	$20	$47	$13	$24	$51
North Atlantic	$0 - $2	$22	$49	$107	$25	$51	$109
Mid-Atlantic	$0 - $19	$181	$382	$811	$200	$401	$830
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $62	$198	$444	$998	$260	$506	$1,061
Great Lakes	$0 - $16	$122	$246	$483	$138	$262	$499
Inland[d]	n/a	$133	$251	$473	$133	$251	$473
National Total	$0 - $104	$665	$1,391	$2,919	$769	$1,495	$3,023

Table H1-8: Summary of Use Benefits of the "50 MGD for All Waterbodies" Option (thousands; 2003$)[a]

Region	Annualized Commercial Fishing Benefits	Annualized Recreational Fishing Benefits			Total Annualized Use Benefits[b]		
		Low	Mean	High	Low	Mean	High

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.

[c] No I&E reductions are expected at the potentially regulated facilities in the South Atlantic region. Since these facilities withdraw less than 50 MGD, none of the facilities in this region would be required to install technology to comply with this option .

[d] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

Source: U.S. EPA analysis for this report.

Table H1-9: Summary of Use Benefits of the"200 MGD for All Waterbodies" Option (thousands; 2003$)[a]

Region	Annualized Commercial Fishing Benefits	Annualized Recreational Fishing Benefits			Total Annualized Use Benefits[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California[c]	$0	$0	$0	$0	$0	$0	$0
North Atlantic	$0 - $1	$6	$13	$28	$7	$14	$29
Mid-Atlantic	$0 - $22	$208	$440	$934	$230	$462	$956
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $43	$136	$305	$685	$179	$347	$728
Great Lakes	$0 - $14	$108	$216	$425	$122	$230	$439
Inland[d]	n/a	$110	$207	$390	$110	$207	$390
National Total	$0 - $79	$567	$1,181	$2,463	$647	$1,260	$2,542
Evaluated at a 7 percent discount rate							
California[c]	$0	$0	$0	$0	$0	$0	$0
North Atlantic	$0	$4	$10	$21	$5	$10	$21
Mid-Atlantic	$0 - $17	$158	$334	$709	$175	$350	$726
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $34	$108	$243	$545	$142	$277	$579
Great Lakes	$0 - $11	$83	$166	$326	$93	$177	$337
Inland[d]	n/a	$90	$170	$321	$90	$170	$321
National Total	$0 - $62	$443	$922	$1,922	$505	$984	$1,984

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.
[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.
[c] No I&E reductions are expected at the potentially regulated facilities in the California and South Atlantic regions. Since these facilities withdraw less than 200 MGD, none of the facilities in this region would be required to install technology to comply with this option.
[d] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

Source: U.S. EPA analysis for this report.

Table H1-10: Summary of Use Benefits of the "100 MGD for Certain Waterbodies" Option (thousands; 2003$)[a]

Region	Annualized Commercial Fishing Benefits	Annualized Recreational Fishing Benefits			Total Annualized Use Benefits[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California[c]	$0	$0	$0	$0	$0	$0	$0
North Atlantic	$0 - $2	$24	$52	$113	$26	$54	$115
Mid-Atlantic	$0 - $22	$208	$440	$934	$230	$462	$956
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $78	$249	$558	$1,254	$327	$636	$1,332
Great Lakes	$0 - $16	$121	$243	$478	$137	$259	$494
Inland[d,e]	n/a	$0	$0	$0	$0	$0	$0
National Total	$0 - $118	$602	$1,292	$2,779	$720	$1,411	$2,897
Evaluated at a 7 percent discount rate							
California[c]	$0	$0	$0	$0	$0	$0	$0
North Atlantic	$0 - $2	$19	$40	$88	$20	$42	$90
Mid-Atlantic	$0 - $17	$158	$334	$709	$175	$350	$726
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $62	$198	$444	$998	$260	$506	$1,061
Great Lakes	$0 - $12	$93	$188	$368	$105	$200	$381
Inland[d,e]	n/a	$0	$0	$0	$0	$0	$0
National Total	$0 - $93	$468	$1,006	$2,164	$561	$1,099	$2,257

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.

[c] No I&E reductions are expected at the potentially regulated facilities in the California and South Atlantic regions. Since these facilities withdraw less than 100 MGD, none of the facilities in this region would be required to install technology to comply with this option.

[d] None of the facilities in the Inland region would be required to install technology to comply with the 100 MGD CWB option. Thus, no I&E reductions are expected at the potentially regulated facilities in the Inland region. See the Introduction of this document for a description of the proposed options.

[e] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis

Source: U.S. EPA analysis for this report.

Appendix H1: National Benefits for Other Options Evaluated by EPA

Introduction

This appendix supplements Chapter H1 by presenting EPA's estimates of the national commercial and recreational benefits of five other options that EPA evaluated for the purposes of comparison:

- Option 3,
- Option 4,
- Option 2,
- Option 1, and
- Option 6.

Appendix Contents

Greater detail on the methods and data used in the regional analyses is provided in the previous chapters of this report: see Chapter A1 for a discussion of the methods used to estimate I&E, and Chapters A2 through A9 for discussion of the methods used to estimate the value of I&E losses and the benefits of the proposed options. The results of the regional analyses are presented in Parts B through G of this report. Chapter H1 presents estimates of baseline losses and discusses methods used to calculate national benefits under each of the proposed options.

H1-1 Summary of Expected Reductions in I&E

Table H1-1 presents the number of facilities with technology requirements under the other evaluated options, by region, and EPA's estimates of the percentage by which I&E will be reduced under each option. The table also presents estimates of regional and national prevented fishery losses under each option, expressed as age-1 equivalents and fishery yield.

Table H1-1: Expected Reductions in I&E for Existing Phase III Facilities by Option

Region	Number of Facilities Installing Technology	Reduction in Impingement	Reduction in Entrainment	Prevented Age-1 Equivalent Losses (thousands)	Prevented Foregone Fishery Yield (thousands; lbs)
Option 3					
California	4	78%	29%	391	28
North Atlantic	4	43%	40%	930	18
Mid-Atlantic	4	74%	55%	13,400	606
South Atlantic[a]	0	0%	0%	0	0
Gulf of Mexico	11	80%	57%	8,650	1,270
Great Lakes	38	38%	43%	13,200	190
Inland	130	43%	27%	16,600	171
National Total	190			53,171	2,283
Option 4					

Table H1-1: Expected Reductions in I&E for Existing Phase III Facilities by Option

Region	Number of Facilities Installing Technology	Reduction in Impingement	Reduction in Entrainment	Prevented Age-1 Equivalent Losses (thousands)	Prevented Foregone Fishery Yield (thousands; lbs)
California	4	78%	59%	771	56
North Atlantic	4	43%	40%	930	18
Mid-Atlantic	4	74%	55%	13,600	610
South Atlantic[a]	0	0%	0%	0	0
Gulf of Mexico	11	80%	60%	8,860	1,320
Great Lakes	38	38%	46%	13,300	192
Inland	69	37%	27%	14,800	157
National Total	130			52,261	2,353
Option 2					
California	4	78%	59%	771	56
North Atlantic	4	43%	40%	930	18
Mid-Atlantic	4	74%	55%	13,600	610
South Atlantic[a]	0	0%	0%	0	0
Gulf of Mexico	11	80%	60%	8,860	1,320
Great Lakes	38	38%	46%	13,300	192
Inland	69	37%	27%	14,800	157
National Total	130			52,261	2,353
Option 1					
California	4	78%	59%	771	56
North Atlantic	4	43%	40%	930	18
Mid-Atlantic	4	74%	55%	13,600	610
South Atlantic[a]	0	0%	0%	0	0
Gulf of Mexico	11	80%	60%	8,860	1,320
Great Lakes	38	38%	46%	13,300	192
Inland	134	43%	29%	16,900	177
National Total	194			54,361	2,373
Option 6					
California	4	78%	59%	771	56
North Atlantic	4	43%	40%	930	18
Mid-Atlantic	5	75%	56%	13,700	615
South Atlantic[a]	0	0%	0%	0	0
Gulf of Mexico	11	80%	60%	8,860	1,320
Great Lakes	61	41%	48%	14,300	206
Inland	203	45%	30%	17,600	183
National Total	288			56,161	2,398

Table H1-1: Expected Reductions in I&E for Existing Phase III Facilities by Option

Region	Number of Facilities Installing Technology	Reduction in Impingement	Reduction in Entrainment	Prevented Age-1 Equivalent Losses (thousands)	Prevented Foregone Fishery Yield (thousands; lbs)

[a] No I&E reductions are expected at the potentially regulated facilities in the South Atlantic region. Since these facilities meet the BTA requirements in the baseline, none of the facilities in this region would be required to install technology to comply with these options.

Source: U.S. EPA analysis for this report.

H1-2 Total Annualized Monetary Value of National Losses and Benefits

Tables H1-3, H1-4, H1-5, H1-6, and H1-7 present EPA's estimates of the value of national and regional reductions in I&E under the other evaluated options analyzed for the proposed rule. The tables show for these options that benefits to recreational anglers account for the majority of use benefits. National use benefits are largest in the Gulf of Mexico region under all five options. More detailed discussions of regional benefits under each option are provided in Sections B through G of this report.

Table H1-2: Summary of Use Benefits from Eliminating Baseline I&E at Potentially Regulated Phase III Facilities

Region	Annualized Use Benefits from Eliminating Baseline I&E (thousands; 2003$)[a]						
	Commercial Fishing	Recreational Fishing			Total Use Value[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California	$0 - $20	$38	$90	$211	$58	$109	$231
North Atlantic	$0 - $9	$84	$183	$401	$93	$192	$409
Mid-Atlantic	$0 - $47	$473	$1,000	$2,124	$520	$1,047	$2,171
South Atlantic	$0	$34	$76	$171	$34	$76	$171
Gulf of Mexico	$0 - $139	$419	$937	$2,105	$558	$1,076	$2,244
Great Lakes	$0 - $70	$534	$1,076	$2,109	$604	$1,146	$2,179
Inland[c]	n/a	$576	$1,087	$2,047	$576	$1,087	$2,047
National Total	$0 - $284	$2,159	$4,449	$9,168	$2,443	$4,733	$9,452
Evaluated at a 7 percent discount rate							
California	$0 - $18	$35	$83	$196	$54	$101	$214
North Atlantic	$0 - $8	$78	$170	$371	$86	$178	$379
Mid-Atlantic	$0 - $44	$438	$927	$1,969	$482	$970	$2,012
South Atlantic	$0	$32	$71	$158	$32	$71	$158
Gulf of Mexico	$0 - $133	$404	$903	$2,028	$537	$1,036	$2,161
Great Lakes	$0 - $67	$515	$1,036	$2,031	$582	$1,103	$2,099
Inland[c]	n/a	$555	$1,047	$1,971	$555	$1,047	$1,971
National Total	$0 - $271	$2,057	$4,236	$8,724	$2,328	$4,506	$8,995

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.

[c] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

Source: U.S. EPA analysis for this report.

Table H1-3: Summary of Use Benefits of Option 3 (thousands; 2003$)[a]

Region	Annualized Commercial Fishing Benefits	Annualized Recreational Fishing Benefits			Total Annualized Use Benefits[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California	$0 - $5	$10	$24	$57	$15	$29	$62
North Atlantic	$0 - $3	$29	$63	$138	$32	$66	$141
Mid-Atlantic	$0 - $25	$236	$499	$1,061	$261	$525	$1,086
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $80	$259	$580	$1,305	$339	$660	$1,385
Great Lakes	$0 - $23	$177	$355	$697	$200	$378	$720
Inland[d]	n/a	$176	$334	$630	$176	$334	$630
National Total	$0 - $137	$888	$1,856	$3,888	$1,024	$1,993	$4,025
Evaluated at a 7 percent discount rate							
California	$0 - $4	$8	$19	$45	$12	$23	$49
North Atlantic	$0 - $2	$22	$49	$107	$25	$51	$109
Mid-Atlantic	$0 - $19	$181	$383	$814	$201	$403	$834
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $64	$206	$462	$1,038	$270	$526	$1,102
Great Lakes	$0 - $18	$138	$277	$543	$156	$295	$561
Inland[d]	n/a	$144	$273	$515	$144	$273	$515
National Total	$0 - $107	$700	$1,463	$3,063	$807	$1,570	$3,170

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.

[c] No I&E reductions are expected at the potentially regulated facilities in the South Atlantic region. Since these facilities meet the BTA requirements in the baseline, none of the facilities in this region would be required to install technology to comply with these options.

[d] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

Source: U.S. EPA analysis for this report.

Table H1-4: Summary of Use Benefits of Option 4 (thousands; 2003$)[a]

Region	Annualized Commercial Fishing Benefits	Annualized Recreational Fishing Benefits			Total Annualized Use Benefits[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California	$0 - $10	$20	$47	$110	$30	$57	$120
North Atlantic	$0 - $3	$29	$63	$138	$32	$66	$141
Mid-Atlantic	$0 - $25	$239	$506	$1,074	$265	$531	$1,100
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $83	$263	$589	$1,325	$346	$672	$1,408
Great Lakes	$0 - $23	$178	$359	$704	$202	$382	$728
Inland[d]	n/a	$162	$306	$577	$162	$306	$577
National Total	$0 - $144	$892	$1,870	$3,929	$1,036	$2,014	$4,073
Evaluated at a 7 percent discount rate							
California	$0 - $8	$16	$37	$86	$24	$44	$94
North Atlantic	$0 - $2	$22	$49	$107	$25	$51	$109
Mid-Atlantic	$0 - $19	$184	$388	$825	$203	$408	$844
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $66	$209	$469	$1,055	$275	$535	$1,120
Great Lakes	$0 - $18	$139	$280	$549	$157	$298	$567
Inland[d]	n/a	$133	$251	$473	$133	$251	$473
National Total	$0 - $114	$703	$1,473	$3,095	$816	$1,587	$3,208

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.

[c] No I&E reductions are expected at the potentially regulated facilities in the South Atlantic region. Since these facilities meet the BTA requirements in the baseline, none of the facilities in this region would be required to install technology to comply with these options.

[d] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

Source: U.S. EPA analysis for this report.

Table H1-5: Summary of Use Benefits of Option 2 (thousands; 2003$)[a]

Region	Annualized Commercial Fishing Benefits	Annualized Recreational Fishing Benefits			Total Annualized Use Benefits[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California	$0 - $10	$20	$47	$110	$30	$57	$120
North Atlantic	$0 - $3	$29	$63	$138	$32	$66	$141
Mid-Atlantic	$0 - $25	$239	$506	$1,074	$265	$531	$1,100
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $83	$263	$589	$1,325	$346	$672	$1,408
Great Lakes	$0 - $23	$178	$359	$704	$202	$382	$728
Inland[d]	n/a	$162	$306	$577	$162	$306	$577
National Total	$0 - $144	$892	$1,870	$3,929	$1,036	$2,014	$4,073
Evaluated at a 7 percent discount rate							
California	$0 - $8	$16	$37	$86	$24	$44	$94
North Atlantic	$0 - $2	$22	$49	$107	$25	$51	$109
Mid-Atlantic	$0 - $19	$184	$388	$825	$203	$408	$844
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $66	$209	$469	$1,055	$275	$535	$1,120
Great Lakes	$0 - $18	$139	$280	$549	$157	$298	$567
Inland[d]	n/a	$133	$251	$473	$133	$251	$473
National Total	$0 - $114	$703	$1,473	$3,095	$816	$1,587	$3,208

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.

[c] No I&E reductions are expected at the potentially regulated facilities in the South Atlantic region. Since these facilities meet the BTA requirements in the baseline, none of the facilities in this region would be required to install technology to comply with these options.

[d] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

Source: U.S. EPA analysis for this report.

Table H1-6: Summary of Use Benefits of Option 1 (thousands; 2003$)[a]

Region	Annualized Commercial Fishing Benefits	Annualized Recreational Fishing Benefits			Total Annualized Use Benefits[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California	$0 - $10	$20	$47	$110	$30	$57	$120
North Atlantic	$0 - $3	$29	$63	$138	$32	$66	$141
Mid-Atlantic	$0 - $25	$239	$506	$1,074	$265	$531	$1,100
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $83	$263	$589	$1,325	$346	$672	$1,408
Great Lakes	$0 - $23	$178	$359	$704	$202	$382	$728
Inland[d]	n/a	$182	$344	$649	$182	$344	$649
National Total	$0 - $144	$912	$1,908	$4,001	$1,056	$2,052	$4,146
Evaluated at a 7 percent discount rate							
California	$0 - $8	$16	$37	$86	$24	$44	$94
North Atlantic	$0 - $2	$22	$49	$107	$25	$51	$109
Mid-Atlantic	$0 - $19	$184	$388	$825	$203	$408	$844
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $66	$209	$469	$1,055	$275	$535	$1,120
Great Lakes	$0 - $18	$139	$280	$549	$157	$298	$567
Inland[d]	n/a	$149	$281	$531	$149	$281	$531
National Total	$0 - $114	$719	$1,504	$3,152	$832	$1,617	$3,266

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.

[c] No I&E reductions are expected at the potentially regulated facilities in the South Atlantic region. Since these facilities meet the BTA requirements in the baseline, none of the facilities in this region would be required to install technology to comply with these options.

[d] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

Source: U.S. EPA analysis for this report.

Table H1-7: Summary of Use Benefits of Option 6 (thousands; 2003$)[a]

Region	Annualized Commercial Fishing Benefits	Annualized Recreational Fishing Benefits			Total Annualized Use Benefits[b]		
		Low	Mean	High	Low	Mean	High
Evaluated at a 3 percent discount rate							
California	$0 - $10	$20	$47	$110	$30	$57	$120
North Atlantic	$0 - $3	$29	$63	$138	$32	$66	$141
Mid-Atlantic	$0 - $26	$241	$510	$1,083	$267	$535	$1,109
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $83	$263	$589	$1,325	$346	$672	$1,408
Great Lakes	$0 - $25	$192	$386	$758	$217	$411	$783
Inland[d]	n/a	$189	$357	$673	$189	$357	$673
National Total	$0 - $146	$934	$1,952	$4,087	$1,080	$2,098	$4,233
Evaluated at a 7 percent discount rate							
California	$0 - $8	$16	$37	$86	$24	$44	$94
North Atlantic	$0 - $2	$22	$49	$107	$25	$51	$109
Mid-Atlantic	$0 - $20	$185	$391	$831	$205	$411	$850
South Atlantic[c]	$0	$0	$0	$0	$0	$0	$0
Gulf of Mexico	$0 - $66	$209	$469	$1,055	$275	$535	$1,120
Great Lakes	$0 - $20	$150	$302	$592	$170	$322	$612
Inland[d]	n/a	$154	$291	$549	$154	$291	$549
National Total	$0 - $115	$736	$1,539	$3,220	$852	$1,654	$3,335

[a] All benefits presented in this table are annualized, i.e., equal to the value of all benefits generated over the time frame of the analysis, discounted to 2007, and then annualized over a thirty year period.

[b] The total monetizable value of I&E reductions includes use benefits only. EPA evaluated non-use benefits only qualitatively. A range of recreational fishing benefits is provided, based on the Krinsky and Robb technique to estimated the 95th and 5th percentile limits on the marginal value per fish predicted by the meta-analysis. Commercial fishing benefits are computed based on a range from 0% to 40% of the change in gross revenue, as explained in Chapter A4 of this report. To calculate the total monetizable value columns (low, mean, and high), the high end value for commercial fishing benefits is added to the low, mean, and high values for recreational fishing benefits, respectively.

[c] No I&E reductions are expected at the potentially regulated facilities in the South Atlantic region. Since these facilities meet the BTA requirements in the baseline, none of the facilities in this region would be required to install technology to comply with these options.

[d] No significant commercial fishing takes place in the Inland region. Thus, this region is excluded from the commercial fishing analysis.

Source: U.S. EPA analysis for this report.

References

Able, K.W. and M.P. Fahay. 1998. The First Year in the Life of Estuarine Fishes in the Middle Atlantic Bight. Rutgers University Press, New Brunswick, NJ.

Agnello, R. 1989. The economic value of fishing success: An application of socioeconomic survey data. *Fishery Bulletin* 87(1):223-232.

Aiken, R.A. 1985. Public Benefits of Environmental Protection in Colorado. Masters thesis, Colorado State University, Fort Collins.

Alexander, S.J. 1995. Applying Random Utility Modeling to Recreational Fishing in Oregon: Effects of Forest Management Alternatives on Steelhead Production in the Elk River Watershed. Oregon State University.

Allen, M.A. and T.J. Hassler. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) — Chinook Salmon. U.S. Fish and Wildlife Service Biological Report 82(11.49). U.S. Army Corps of Engineers TR EL-82-4. http://www.nwrc.gov/publications/specintro.htm. Accessed 7/03.

Anderson, G.D. and S.F. Edwards. 1986. Protecting Rhode Island's coastal salt ponds: An economic assessment of downzoning. *Coastal Zone Management Journal* 14(½):67-91.

Anderson, L.G. 1980. Necessary components of economic surplus in fisheries economics. *Canadian Journal of Fisheries and Aquatic Sciences* 37:858-870.

Arrow, K., R. Solow, P. Portney, E. Leamer, R. Radner, and H. Schuman. 1993. Report of the NOAA panel on contingent valuation. *Federal Register* 58(10):4602-4614.

ASMFC. 2001a. Interstate Fisheries Management Program: Atlantic Herring. Atlantic States Marine Fisheries Commission. http://www.asmfc.org/Programs/Fish%20Mgnt/AHERRING1.html. Accessed 2/12/01.

ASMFC. 2001b. Review of the Fishery Management Plan for Atlantic Menhaden. Atlantic States Marine Fisheries Commission. http://www.asmfc.org/Programs/Fish%20Mgnt/2000%20FMP%20Reviews/menhaden2000_FMP.HTM. Accessed 3/19/01.

Azevedo, C., J.A. Herriges, and C.L. Kling. 2001. Valuing Preservation and Improvements of Water Quality in Clear Lake. Staff Report 01-SR 94. Iowa State University, Center for Agricultural and Rural Development, Ames.

Bartell, S.M. and K.R. Campbell. 2000. Ecological Risk Assessment of the Effects of the Incremental Increase of Commercial Navigation Traffic (25, 50, 75, and 100 Percent Increase of 1992 Baseline Traffic) on Fish. ENV Report 16. Prepared for U.S. Army Engineer District, Rock Island. July. http://www.mvr.usace.army.mil/pdw/nav_study/env_reports/ENVRPT16.htm. Accessed 2000.

Bason, W.H. 1971. Ecology and early life history of striped bass, *Morone saxatilis*, in the Delaware Estuary. *Ichthyol. Assoc. Bulletin* 4:112. Ichthyological Associates, Middletown, DE.

Bateman, I.J. and A.P. Jones. 2003. Contrasting conventional with multi-level modeling approaches to meta-analysis: Expectation consistency in U.K. woodland recreation values. *Land Economics* 79(2):235-258.

Bateman, I.J., R.T. Carson, B. Day, M. Hanemann, N. Hanley, T. Hett, M. Jones-Lee, G. Loomes, S. Mourato, E. Ozdemiroglu, D.W. Pierce, R. Sugden, and J. Swanson. 2002. *Economic Valuation with Stated Preference Surveys: A Manual*. Edward Elgar, Northampton, MA.

BEA. 1998. Bureau of Economic Analysis National Accounts Data: Gross Product by Industry. http://www.bea.doc.gov/bea/dn2/gpoc.htm.

Beauchamp, D.A., M.F. Shepard, and G.B. Pauley. 1983. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest): Chinook Salmon. U.S. Fish and Wildlife Service FWS/OBS-82/11.6. U.S. Army Corps of Engineers TR EL-82-4.

Beck, A.D. and the Committee on Entrainment. 1978. Cumulative effects: A field assessment. In *Power Plant Entrainment: A Biological Assessment*, J.R. Schubel and B.C. Marcy, Jr. (eds.). Academic Press, New York, pp. 189-210.

Bergstrom, J.C. and P. De Civita. 1999. Status of benefits transfer in the United States and Canada: A review. *Canadian Journal of Agricultural Economics* 47(1):79-87.

Berman, M., S. Haley, and H. Kim. 1997. Estimating net benefits of reallocation: Discrete choice models of sport and commercial fishing. *Marine Resource Economics* 12:307-327.

Berrens, R.P., O. Bergland, and R.M. Adams. 1993. Valuation issues in an urban recreational fishery: Spring chinook salmon in Portland, Oregon. *Journal of Leisure Research* Vol 25.

Berrens, R.P., P. Ganderston, and C.L. Silva. 1996. Valuing the protection of minimum instream flows in New Mexico. *Journal of Agricultural and Resource Economics* 21(2):294-309.

Bert, T.M., R.E. Warner, and L.D. Kessler. 1978. The Biology and Florida Fishery of the Stone Crab, *Menippe mercenaria* (Say), with Emphasis on Southwest Florida. Technical Paper No. 9. State University System of Florida Sea College Program, Gainesville. October.

Besedin, E., M. Mazzotta, D. Cacela, and L. Tudor. 2004. Combining Ecological and Economic Analysis: An Application to Valuation of Power Plant Impacts on Great Lakes Recreational Fishing. Paper Presented at American Fisheries Society Meeting Symposium: Socio-economics and Extension: Empowering People in Fisheries Conservation. August 2004 (forthcoming).

Bielsa, L.M., W.H. Murdich, and R.F. Labisky. 1983. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida) — Pink Shrimp. U.S. Fish and Wildlife Service FWS/OBS-82/11.17. U.S. Army Corps of Engineers TR EL-82-4. http://www.nwrc.usgs.gov/wdb/pub/0098.pdf.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish and Wildlife Service Fisheries Bulletin, Volume 53. http://www.gma.org/fogm/. Accessed 8/03.

Bishop, R.C. and M.T. Holt. 2003. Estimating Post-Harvest Benefits from Increases in Commercial Fish Catches with Implications for Remediation of Impingement and Entrainment Losses at Power Plants. Staff Paper No. 458. University of Wisconsin-Madison, Department of Agricultural and Applied Economics, Madison.

Bockstael, N. and I. Strand. 1987. The effect of common sources of regression error on benefit estimates. *Land Economics* February: 11-20.

Bockstael, N.E., K.E. McConnell, and I.E. Strand. 1989. Measuring the benefits of improvements in water quality: The Chesapeake Bay. *Marine Resource Economics* 6:1-18.

Bolz, G.R., J.P. Monaghan, Jr., K.L. Lang, R.W. Gregory, and J.M. Burnett. 2000. Proceedings of the Summer Flounder Aging Workshop, 1-2 February 1999. Woods Hole, MA. http://www.nefsc.noaa.gov/nefsc/publications/tm/tm156/tm156toc.htm. Accessed 12/02.

Boreman, J. 2000. Surplus production, compensation, and impact assessments of power plants. *Environmental Science & Policy* 3:S445-S449.

Boreman, J. and C.P. Goodyear. 1981. Biases in the estimation of entrainment mortality. In *Fifth National Workshop on Entrainment and Impingement: Issues Associated with Impact Assessment*, L.D. Jensen (ed.). Ecological Analysts Inc., Sparks, MD, pp. 79-89.

Bowker, J.M. and J.R. Stoll. 1988. Use of dichotomous choice nonmarket methods to value the whooping crane resource. *American Journal of Agricultural Economics* 70(May):372-381.

Boyd, J., D. King, and L.A. Wainger. 2001. Compensation for lost ecosystem services: The need for benefit-based transfer ratios and restoration criteria. *Stanford Environmental Law Journal* 20(2):393-412.

Boyle, K.J. and J.C. Bergstrom. 1992. Benefit transfer studies: Myths, pragmatism, and idealism. *Water Resources Research* 28(3):657-664.

Boyle, K.J. and R.C. Bishop. 1987. Valuing wildlife in benefit-cost analyses: A case study involving endangered species. *Water Resources Research* 23:943-950.

Boyle, K.J., B. Roach, and D.G. Waddington. 1998. 1996 Net Economic Values for Bass, Trout and Walleye Fishing, Deer, Elk and Moose Hunting, and Wildlife Watching: Addendum to the 1996 National Survey of Fishing, Hunting and Wildlife-Associated Recreation. Report 96-2. U.S. Fish and Wildlife Service. August.
Breffle, W., E.R. Morey, R.D. Rowe, D.M. Waldman, and S.M. Wytinck. 1999. Recreational Fishing Damages from Fish Consumption Advisories in the Waters of Green Bay. Prepared by Stratus Consulting Inc., Boulder, CO, for the U.S. Fish and Wildlife Service, the U.S. Department of Justice, and the U.S. Department of Interior. November 1.

Brown, Jr., G.M. and H.O. Pollakowski. 1976. Economic valuation of shoreline. *Review of Economics and Statistics* 59:272-278.

Brown, R. and W. Kimmerer. 2002. Delta Smelt and CALFED's Environmental Water Account: A Summary of the 2002 Delta Smelt Workshop. http://calwater.ca.gov/Programs/Science/adobe_pdf/2002_Delta_Smelt_Workshop_Summary.pdf. Accessed 10/02.

Brown, T.C. 1993. Measuring Non-Use Value: A Comparison of Recent Contingent Valuation Studies. W-133 Sixth Interim Report. University of Georgia, Department of Agriculture and Applied Economics, Athens.

Buckley, J. 1989a. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic). Rainbow Smelt. U.S. Fish and Wildlife Service Biological Report 82(11.106). U.S. Army Corps of Engineers TR EL-82-4.

Cailliet, G.M. 2000. Biological Characteristics of Nearshore Fishes of California. A Review of Existing Knowledge and Proposed Additional Studies for the Pacific Ocean Interjurisdictional Fisheries Management Plan Coordination and Development Project. Submitted to Mr. Al Didier. Pacific States Marine Fisheries Commission. August 31. http://www.dfg.ca.gov/mrd/lifehistories/index.html. Accessed 11/02.

California Department of Fish and Game. 2000a. How Old Are the Fish I'm Catching? California Department of Fish and Game. http://www.dfg.ca.gov/mrd/howold.pdf. Accessed 8/03.

California Department of Fish and Game. 2000b. Striped Bass Information Page. Age Your Fish. http://www.delta.dfg.ca.gov/stripedbass/age_your_fish.asp. Accessed 6/03.

California Department of Fish and Game. 2002. Marine Sportfish Identification Pictures. http://www.dfg.ca.gov/mrd/msfindx1.html. Accessed 1/21/02.

California Department of Fish and Game. 2003. Summary of 2003 California Ocean Salmon Seasons. http://www.dfg.ca.gov/mrd/oceansalmon.html. Accessed 1/03.

Cameron, T.A. 1992. Combining contingent valuation and travel cost data for the valuation of non-market goods. *Land Economics* 68:302-307.

Cameron, T.A. and D.D. Huppert. 1989. OLS versus ML estimation of non-market resource values with payment card interval data. *Journal of Environmental Economics and Management* 17:230-246.

Cameron, T.A. and M.D. James. 1987a. Efficient estimation methods for 'closed-ended' contingent valuation surveys. *The Review of Economics and Statistics* 69(2):269-276.

Cameron, T.A. and M.D. James. 1987b. Estimating willingness to pay from survey data: An alternative pre-test-market evaluation procedure. *Journal of Marketing Research* 24(4):389-395.

Carlander, K.D. 1969. Handbook of Freshwater Fishery Biology: Life History Data on Freshwater Fishes of the United States and Canada, Exclusive of the Perciformes. Iowa State University Press, Ames.

Carlander, K.D. 1977. Handbook of Freshwater Fishery Biology, Volume 3: Life History Data on Ichthyopercid and Percid Fishes of the United States and Canada. Iowa State University Press, Ames.

Carlander, K.D. 1997. Handbook of Freshwater Fishery Biology: Life History Data on Icthyopercid and Percid Fishes of the United States and Canada. Volume 3. Iowa State University Press, Ames.

Carroll, J.C. 1982. Seasonal abundance, size composition, and growth of rock crab, *Cancer antennarius* Stimpson, off central California. *Journal of Crustacean Biology* 2(4):549-561.

Carson, R., M. Hanemann, and D. Steinberg. 1990. A discrete choice contingent valuation estimate of the values of Kenai king salmon. *Journal of Behavioral Economics* Volume 19.

Carson, R.T. and R.C. Mitchell. 1993. The value of clean water: The public's willingness to pay for boatable, fishable, and swimmable quality water. *Water Resources Research* 29(7):2445-2454.

Carson, R.T., N.E. Flores, and R.C. Mitchell. 1999. The theory and measurement of passive use value. In *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU, and Developing Countries*, I.J. Bateman and K.G. Willis (eds). Oxford University Press, New York.

Carson, R.T., T. Groves, and M.J. Machina. 2000. Incentive and Informational Properties of Preference Questions. Draft Paper. University of California, La Jolla.

Carson, R.T., N.E. Flores, K.M. Martin, and J.L. Wright. 1996. Contingent valuation and revealed preference methodologies: Comparing the estimates for quasi-public goods. *Land Economics* 72(1):80-99.

Carson, R.T., W.M. Hanemann, R.J. Kopp, J.A. Krosnick, R.C. Mitchell, S. Presser, P.A. Ruud, and V.K. Smith. 1994. Prospective Interim Lost Use Value due to DDT and PCB Contamination in the Southern California Bight. Volume 2. Prepared for the National Oceanic and Atmospheric Administration by Natural Resources Damage Assessment Inc., La Jolla, CA.

Carter, S.R. 1978. Macroinvertebrate Entrainment Study at Fort Calhoun Station. Fourth National Workshop on Entrainment and Impingement. EA Communications, Melville, NY.

CCI Environmental Services. 1996. Zooplankton Entrainment Survival Study, Anclote Power Plant, Pasco County, Florida. Prepared for Florida Power Corporation by CCI Environmental Services, Inc., Palmetto, FL.

CDWR. 1994. Effects of the Central Valley Project and State Water Project on Delta Smelt and Sacramento Splittail. Biological Assessment prepared for the U.S. Fish and Wildlife Service, Ecological Services, Sacramento Field Office by California Department of Water Resources and U.S. Bureau of Reclamation, Mid Pacific Region, August.

Clayton, G., C. Cole, S. Murawski, and J. Parrish. 1978. Common Marine Fishes of Coastal Massachusetts. Contribution No. 54 of the Massachusetts Cooperative Fishery Research Unit. University of Massachusetts, Amherst.

Cleland, C.C. and R.C. Bishop. 1984. An Assessment of the Economic Conditions of the Bay Mills Indian Community, Sault Saint Marie Tribe of Chippewa Indians, and Grand Traverse Band of Ottawa and Chippewa Indians, and a Cost-Return Analysis of Treaty Commercial Fishermen — 1981.

Clonts, H.A. and J.W. Malone. 1990. Preservation attitudes and consumer surplus in free flowing rivers. In *Social Science and Natural Resource Recreation Management*, J. Vining (ed.). Westview Press, Boulder, CO, pp. 301-317.

Cohen, M.A. 1986. The costs and benefits of oil spill prevention and enforcement. *Journal of Environmental Economics and Management* 13:167-188.

Colarusso, P. 2000. Winter Flounder Life History Information. Draft. From Phil Colarusso, EPA Region 1. Brayton Point TAC Meeting, 11/17/00.

Collins, M.R. 1985. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida): Striped Mullet. U.S. Fish and Wildlife Service Biological Report 82(11.34). U.S. Army Corps of Engineers TR EL-82-4. http://www.nwrc.gov/publications/specindex.htm. Accessed 7/03.

Costello, T.J. and D.M. Allen. 1970. Synopsis of biological data on the pink shrimp. In *Proceedings of the World Scientific Conference on the Biology and Culture of Shrimps and Prawns*. Volume IV: Species Synopses, Mexico City, June 12-21, 1967. *FAO Fisheries Report* 57(4):1499-1537.

Coutant, C.A. and M.S. Bevelhimer. 2001. Comments on Lawler, Matusky & Skelly Engineers, LLP. 1999 Draft Brayton Point Power Plant Entrainment Survival Study 1997-1998. Report for US Gen New England, Inc., Pearl River, NY. Oak Ridge National Laboratory, Oak Ridge, TN. February 12.

Croke, K., R.G. Fabian, and G. Brenniman. 1986-1987. Estimating the value of improved water quality in an urban river system. *Journal of Environmental Systems* 16(1):13-24.

Cronin, F.J. 1982. Valuing nonmarket goods through contingent markets. PNL-4255. Pacific Northwest Laboratory, Richland, WA.

Crutchfield, J.A., S. Langdon, O.A. Mathisen, and P.H. Poe. 1982. The Biological, Economic, and Social Values of a Sockeye Salmon Stream in Bristol Bay, Alaska: A Case Study of Tazimina River. Circular No. 82-2. Fisheries Research Institute, College of Fisheries, University of Washington, Seattle. October.

Cummings, R., P. Ganderton, and T. McGuckin. 1994. Substitution effects in CVM values. *Am. J. Agric. Economics* 76:205-214.

Daily, G.C. (ed.). 1997. *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, DC.

Daily, G.C., S. Alexander, P.R. Ehrlich, L. Goulder, J. Lubchenco, P.A. Matson, H.A. Mooney, S. Postel, S.H. Schneider, D. Tilman, and G.M. Woodwell. 1997. Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems. Ecological Society of America, Washington, DC.

Dalhuisen, J.M., R.J.G.M. Florax, H.L.F. de Groot, and P. Nijkamp. 2003. Price and income elasticities of residential water demand: A meta analysis. *Land Economics* 79(2):292-308.

Dalton, R.S., C.T. Bastian, and J.J. Jacobs. 1998. Estimating the economic value of improved trout fishing on Wyoming streams. *North American Journal of Fisheries Management* 18:786-797.

Dames & Moore. 1977. 316(b) Demonstration for the Cayuga and Wabash River Generating Stations.

Daniels, R.A. and P.B. Moyle. 1983. Life history of splittail (Cyprinidae: *Pogonichthys macrolepidotus*) in the Sacramento-San Joaquin Estuary. *Fishery Bulletin* 81(3):647-654.

Day Jr., J.W., C.A.S. Hall, W.M. Hall, and A. Yáñez-Arancibia. 1989. Zooplankton, the drifting consumers. In *Estuarine Ecology*. John Wiley & Sons, New York, pp. 311-337.

Deree, H.L. 1999. Age and growth, dietary habits, and parasitism of the fourbeard rockling, *Enchelyopus cimbrius*, from the Gulf of Maine. *Fishery Bulletin* 97(1):39-52. http://fishbull.noaa.gov/04dereef.pdf. Accessed 1/03.

Derickson, W.K. and K.S. Price. 1973. The fishes of the shore zone of Rehoboth and Indian River Bays, Delaware. *Trans. Amer. Fish. Soc.* 102(3):552-562.

Desvousges, W.H., F.R. Johnson, and H.S. Banzhaf. 1998. *Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method*. Edward Elgar Publishers, Northampton, MA.

Desvousges, W.H., M.C. Naughton, and G.R. Parsons. 1992. Benefit transfer: Conceptual problems in estimating water quality benefits using existing studies. *Water Resources Research* 28(3):675-683.

Desvousges, W.H., V.K. Smith, and M.P. McGivney. 1983. A Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvements. U.S. Environmental Protection Agency, Economic Analysis Division, Washington, DC.

Desvousges, W.H., V.K. Smith, D.H. Brown, and D.K. Pate. 1984. The Role of Focus Groups in Designing a contingent Valuation Survey to Measure the Benefits of Hazardous Waste Management Regulations. Research Triangle Institute, Research Triangle Park, NC.

De Zoysa, A.D.N. 1995. A Benefit Evaluation of Programs to Enhance Groundwater Quality, Surface Water Quality and Wetland Habitat in Northwest Ohio. Dissertation, Ohio State University, Columbus.

Dixon, D.A. 1999. Catalog of Assessment Methods for Evaluating the Effects of Power Plant Operations on Aquatic Communities. Final Report. Report number TR-112013. Electric Power Research Institute, Palo Alto, CA.

Drudi, D. 1998. Fishing for a living is dangerous work. *Compensation and Working Conditions* Summer:3-7.

Dryfoos, R.L. 1965. The Life History and Ecology of the Longfin Smelt in Washington. Dissertation, University of Washington. University Microfilms Inc., Ann Arbor, MI.

Duffield, J. and D. Patterson. 1992. Field Testing Existence Values: Comparison of Hypothetical and Cash Transaction Values. Benefits and Costs in Natural Resource Planning, 5th Report. W-133 Western Regional Research Publication. B. Rettig, Compiler, Department of Agricultural and Resource Economics, Oregon State University, Corvallis.

Durbin, A.G., E.G. Durbin, T.J. Smayda, and P.G. Verity. 1983. Age, size, growth, and chemical composition of Atlantic menhaden, *Brevoortia tyrannus*, from Narragansett Bay, Rhode Island. *Fishery Bulletin* 81(1):133-141.

EA Engineering, Science, and Technology. 1986. Entrainment and Impingement Studies at Oyster Creek Nuclear Generating Station 1984-1985. Prepared for GPU Nuclear Corporation by EA Engineering, Science, and Technology, Hunt Valley, MD. July.

EA Engineering, Science, and Technology. 1989. Indian Point Generating Station 1988 Entrainment Survival Study. Final. Prepared for Consolidated Edison Company of New York Inc. and New York Power Authority by EA Engineering, Science, and Technology, Hunt Valley, MD. August.

EA Engineering, Science, and Technology. 2000. Review of Entrainment Survival Studies: 1970-2000. Prepared for Electric Power Research Institute, Inc. by EA Engineering, Science, and Technology, Hunt Valley, MD.

EA Science and Technology. 1986. Indian Point Generating Station Entrainment Survival Study. 1985 Annual Report. Prepared under contract with Consolidated Edison Company of New York Inc. and New York Power Authority by EA Engineering, Science, and Technology, Hunt Valley, MD.

EA Science and Technology. 1990. Results of Entrainment and Impingement Studies Conducted at the Braidwood Nuclear Station and the Adjacent Kankakee River. Prepared for Commonwealth Edison Company by EA Engineering, Science, and Technology, Hunt Valley, MD.

Ecological Analysts Inc. 1976a. Bowline Point Generating Station Entrainment Survival and Abundance Studies, Volume I, 1975 Annual Interpretive Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts Inc. 1976b. Danskammer Point Generating Station Impingement and Entrainment Survival Studies, 1975 Annual Report. Prepared for Central Hudson Gas & Electric Corporation.

Ecological Analysts Inc. 1976c. Roseton Generating Station Impingement and Entrainment Survival Studies, 1975 Annual Report. Prepared for Central Hudson Gas & Electric Corporation.

Ecological Analysts Inc. 1977. Bowline Point Generating Station Entrainment and Impingement Studies, 1976 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts Inc. 1978a. Bowline Point Generating Station Entrainment Survival Studies, 1977 Annual Interpretive Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts Inc. 1978b. Impact of the Cooling Water Intake at the Indian River Power Plant: A 316(b) Evaluation. Prepared for Delmarva Power & Light Co. May.

Ecological Analysts Inc. 1978c. Indian Point Generating Station Entrainment Survival and Related Studies, 1977 Annual Report. Prepared for Consolidated Edison Company of New York, Inc.

Ecological Analysts Inc. 1978d. Port Jefferson Generating Station Entrainment Survival Study. Prepared for Long Island Lighting Company. December.

Ecological Analysts Inc. 1978e. Roseton Generating Station Entrainment Survival Studies, 1976 Annual Report. Prepared for Central Hudson Gas & Electric Corporation.

Ecological Analysts Inc. 1978f. Roseton Generating Station Entrainment Survival Studies, 1977 Annual Report. Prepared for Central Hudson Gas & Electric Corporation.

Ecological Analysts Inc. 1979a. An Assessment of the Potential for Ichthyoplankton Entrainment Survival at the Muskingum River Plant. Prepared for American Electric Power Service Corp.

Ecological Analysts Inc. 1979b. Bowline Point Generating Station Entrainment Abundance and Survival Studies, 1978 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts Inc. 1979c. Indian Point Generating Station Entrainment Survival and Related Studies, 1978 Annual Report. Prepared for Consolidated Edison Company of New York, Inc.

Ecological Analysts Inc. 1980a. Entrainment Survival Studies at the Cayuga Generating Plant. Prepared for Public Service of Indiana. March.

Ecological Analysts Inc. 1980b. Potrero Power Plant Cooling Water Intake Structures 316(b) Demonstration. Prepared for Pacific Gas and Electric Company. January.

Ecological Analysts Inc. 1980c. Roseton Generating Station Entrainment Survival Studies, 1978 Annual Report. Prepared for Central Hudson Gas and Electric Corporation.

Ecological Analysts Inc. 1981a. Bowline Point Generating Station Entrainment Abundance and Survival Studies, 1979 Annual Report with Overview of 1975-1979 Studies. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts Inc. 1981b. Contra Costa Power Plant Cooling Water Intake Structures 316b Demonstration. Prepared for PG&E.

Ecological Analysts Inc. 1981c. Entrainment Survival Studies. Prepared for Empire State Electric Energy Research Corporation.

Ecological Analysts Inc. 1981d. Indian Point Generating Station Entrainment Survival and Related Studies 1979 Annual Report. Prepared for Consolidated Edison Company of New York and Power Authority of the State of New York. April.

Ecological Analysts Inc. 1982a. Hunters Point Power Plant Cooling Water Intake Structures 316(b) Demonstration. Prepared for Pacific Gas and Electric Company. March.

Ecological Analysts Inc. 1982b. Indian Point Generating Station Entrainment Survival and Related Studies 1980 Annual Report. Prepared for Consolidated Edison Company of New York and Power Authority of the State of New York. January.

Ecological Analysts Inc. 1983. Roseton Generating Station Entrainment Survival Studies, 1980 Annual Report. Prepared for Central Hudson Gas and Electric Corporation.

Ehrhardt, N.M., D.J. Die, and V.R. Restrepo. 1990. Abundance and impact of fishing on a stone crab (*Menippe mercenaria*) population in Everglades National Park, Florida. *Bull. Mar. Sci.* 46(2):311-323.

ENSR and Marine Research Inc. 2000. Study of Winter Flounder Transport in Coastal Cape Cod Bay and Entrainment at Pilgrim Nuclear Power Station. Prepared for Entergy Nuclear Generation Company.

Entergy Nuclear Generation Company. 2000. Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report Number 55, January 1999-December 1999.

Farber, S. 1987. The value of coastal wetlands for protection of property against hurricane wind damage. *Journal of Environmental Economics and Management* 14:143-151.

Farber, S. and B. Griner. 2000. Valuing watershed quality improvements using conjoint analysis. *Ecological Economics* 34(1):63-76.

Feather, P.M., D. Hellerstein, and T. Thomaso. 1995. A discrete-count model of recreational demand. *Journal of Environmental Economics and Management* 29:214-227.

Federal Register. 1999. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for Sacramento Splittail. U.S. Department of the Interior, Fish and Wildlife Service. Final Rule 64(25):5963-5981.

Feinerman, E. and K. Knapp. 1983. Benefits from groundwater management: Magnitude, sensitivity, and distribution. *American Journal of Agricultural Economics* 65(4):703-710.

Finkel, A.M. 1990. Confronting Uncertainty in Risk Management. Center for Risk Management, Resources for the Future, Washington, DC.

Fischman, R.L. 2001. The EPA's NEPA duties and ecosystem services. *Stanford Environmental Law Journal* 20(2):497-536.

Fish, M.P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie, and its tributary waters. *Bulletin of the Bureau of Fisheries* 47:293-398.

Fisher, A. and R. Raucher. 1984. Intrinsic benefits of improved water quality: Conceptual and empirical perspectives. *Advances in Applied Micro-Economics* 3:37-66.

Florida Fish and Wildlife Conservation Commission. 2001. Fishing Lines Fish Identification Section. http://marinefisheries.org/fishinglines/fish_id2.pdf. Accessed 12/12/01.

Freeman III, A.M. 1993. Non-use values in natural resource damage assessment. In *Valuing Natural Assets*, R.J. Kopp and V. Kerry Smith (eds). Resources for the Future, Washington, DC.

Freeman III, A.M. 2003. The Measurement of Environmental and Resource Values: Theory and Methods. Resources for the Future, Washington, DC.

Froese, R. and C. Binohlan. 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Fishbase. http://filaman.uni-kiel.de/Download/index.htm. Accessed 12/17/02.

Froese, R. and D. Pauly (eds). 2000. FishBase 2000. International Center for Living Aquatic Resources Management, Los Baños, Laguna, Phillippines.

Froese, R. and D. Pauly (eds.). 2001. FishBase. http://www.fishbase.org. Accessed 10/01.

Froese, R. and D. Pauly (eds.). 2002. FishBase. http://www.fishbase.org, Accessed 11/02.

Froese, R. and D. Pauly (eds.). 2003. FishBase. http://www.fishbase.org. Accessed 1/03.

Fuchs, E.H. 1967. Life history of the emerald shiner, *Notropis atherinoides*, in Lewis and Clark Lake, South Dakota. *Transactions of the American Fisheries Society* 96:247-256.

Garwood, G.P. 1968. Notes on the life histories of the silversides, *Menidia beryllina* (Cope) and *Membras martinica* (Valenciennes) in Mississippi Sound and adjacent water. *Proceedings of the Southeastern Association of Game and Fish Commissioners* 21:314-323.

Gautam, A. and S. Steinback. 1998. Valuation of recreational fisheries in the north-east U.S. Striped Bass: a case study. Chapter 23 in *Recreational Fisheries: Social, Economic and Management Aspects*, P. Hickley and H. Tompkins (eds.). Fishing News Books, Oxford.

Geo-Marine, Inc. 1978. 316(b) Demonstration for the W.H. Sammis Generating Station. Prepared for Ohio Edison Company. Plano, TX. September 8.

Gilbert, D.J. 1988. Use of a simple age-structured bioeconomic model to estimate optimal long-run surpluses. *Marine Resource Economics* 5:23-42.

Glass, G.V. 1976. Primary, secondary, and meta-analysis of research. *Educational Researcher* 5(10):3-8.

Goldstein, H. 1995. *Multilevel Statistical Models*. 2nd ed. Edward Arnold, London, UK.

Goodyear, C.P. 1978. Entrainment Impact Estimates Using the Equivalent Adult Approach. FWS/OBS - 78/65. U.S. Department of the Interior, Fish & Wildlife Service, Washington, DC. July.

Great Lakes Fishery Commission. 2003. Great Lakes Fishery Commission. Protecting Our Fishery. http://www.glfc.org/pubs/fact_10.pdf. Accessed 2/03.

Griffiths, C. undated. The Use of Benefit-Cost Analysis in Environmental Policy Making. Working Paper. National Center for Environmental Economics, U.S. Environmental Protection Agency, Washington, DC.

Grigalunas, T.A., J.J. Opaluch, D. French, and M. Reed. 1988. Measuring damages to marine natural resources from pollution incidents under CERCLA: Applications of an integrated ocean systems/economic model. *Marine Resources Economics* 5:1-21.

Grimes, B.H., M.T. Huish, J.H. Kerby, and D. Moran. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic) Summer and Winter Flounder. U.S. Fish and Wildlife Service Biological Report 82(11.112). U.S. Army Corps of Engineers TR EL-82-4.

Hadderingh, R.H. 1978. Mortality of young fish in the cooling water system of Bergum power station. *Proceedings International Association of Theoretical and Applied Limnology* 20:347-352.

Hagen, D., J. Vincent, and P. Welle. 1992. Benefits of preserving old growth forests and the spotted owl. *Contemporary Policy Issues* 10:13-25.

Hanemann, M., J. Loomis, and B. Kanninen. 1991. Statistical efficiency of double-bounded dichotomous choice contingent valuation. *American Journal of Agricultural Economics* 73(4):1255-1263.

Harpman, D.A., M.P. Welsh, and R.C. Bishop. 1993. Nonuse economic value: Emerging policy analysis tool. *Rivers* 4(4):280-291.

Hartman, K.J. 1993. Striped Bass, Bluefish, and Weakfish in the Chesapeake Bay: Energetics, Trophic Linkages, and Bioenergenics Model Applications. Dissertation, University of Maryland, College Park.

Hayes, K.M., T.J. Tyrell, and G. Anderson. 1992. Estimating the benefits of water quality improvements in the upper Narragansett Bay. *Marine Resource Economics* 7:75-85.

Hazleton Environmental Science Corporation. 1978. The Survival of Entrained Icthyoplankton at Quad-Cities Station 1978. Prepared for Commonwealth Edison Company, Chicago, IL.

Heal, G., G.C. Daily, P.R. Ehrlich, J. Salzman, C. Boggs, J. Hellmann, J. Hughes, C. Kremen, and T. Ricketts. 2001. Protecting natural capital through ecosystem service districts. *Stanford Environmental Law Journal* 20(2):333-364.

Hendrickson, L. 2000. Windowpane Flounder. NOAA. http://www.nefsc.nmfs.gov/sos/spsyn/fldrs/window. Accessed 2/1/02.

Herman, J.S., D.C. Culver, and J. Salzman. 2001. Groundwater ecosystems and the service of water. *Stanford Environmental Law Journal* 20(2):479-496.

Herriges, J.A. and J.F. Shogren. 1996. Starting point bias in dichotomous choice valuation with follow-up questioning. *Journal of Environmental Economics and Management* 30(1):112-131.

Hicks, R. 2002. Stated Preference Methods for Environmental Management: Recreational Summer Flounder Angling in the Northeastern United States. Final report prepared for Fisheries Statistics and Economics Division, Office of Science and Technology, National Marine Fisheries Service. Requisition Request # NFFKS-18. March.

Hicks, R., S. Steinback, A. Gautam, and E. Thunberg. 1999. Volume II: The Economic Value of New England and Mid-Atlantic Sportfishing in 1994. NOAA Technical Memorandum NMFS-F/SPO-38. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Hilborn, R. and C.J. Walters. 1992. *Quantitative Fisheries Stock Assessment, Choice, Dynamics and Uncertainty*. Chapman and Hall, London and New York.

Hildebrand, S.F. 1922. Notes on habits and development of eggs and larvae of the silversides *Menidia menidia* and *Menidia beryllina*. *Fishery Bulletin* 38:113-120.

Holmlund, C.M. and M. Hammer. 1999. Ecosystem services generated by fish populations. *Ecological Economics* 29:253-268.

Holt, M.T. and R.C. Bishop. 2002. A semiflexible normalized quadratic inverse demand system: An application to the price formation of fish. *Empirical Economics* 27(1):23-48.

Horseman, L.O. and C.A. Shirey. 1974. Age, growth, and distribution of white perch in the Chesapeake and Delaware Canal. In: Anonymous. Ecological Studies in the Vicinity of the Proposed Summit Power Station, January through December 1973. Vol. I, Part B.

Horst, T.J. 1975. The assessment of impact due to entrainment of ichthyoplankton. In *Fisheries and Energy Production*, S.B. Saila (ed.). D.C. Heath, Lexington, MA, pp. 107-118.

Houde, E.D., W.J. Richards, and V.P. Saksena. 1974. Description of eggs and larvae of scaled sardine, *Harengula jaguana*. *Fishery Bulletin* 72(4):1106-1122.

Huang, J-C., T.C. Haab, and J.C. Whitehead. 1997. Willingness to pay for quality improvements: Should revealed and stated preference data be combined? *Journal of Environmental Economics and Management* 34(3):240-255.

Huppert, D.D. 1989. Measuring the value of fish to anglers: Application to Central California anadromous species. *Marine Resource Economics* 6(2): 89-107.

Huppert, D.D. and D. Squires. 1987. Potential economic benefits and optimum fleet size in the Pacific Coast trawl fleet. *Marine Resource Economics* 3(4):297-318.

Hushak, L.J., J.M. Winslow, and N. Dutta. 1988. Economic value of Great Lakes sportfishing: The case of private-boat fishing in Ohio's Lake Erie. *Transactions of the American Fisheries Society* 117:363-373.

Isaacson, P.A. 1964. Length-weight relationship of the white croaker. *Transactions of the American Fisheries Society* 93:302-303.

Jenkins, R.E. and N.M. Burkhead. 1993. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, MD.

Jinks, S.M., G.J. Lauer, and M.E. Loftus. 1981. Advances in techniques for assessment of ichthyoplankton entrainment survival. In *Fifth National Workshop on Entrainment and Impingement: Issues Associated with Impact Assessment,* L.D. Jensen (ed.). Ecological Analysts Inc., Sparks, MD, pp. 91-110.

Johnson, D.M. 1989. Economic Benefits of Alternative Fishery Management Programs. Colorado State University, Dissertation.

Johnson, D.M., R.J. Behnke, D.A. Harpman, and R.G. Walsh. 1995. Economic benefits and costs of stocking catchable rainbow trout: A synthesis of economic analysis in Colorado. *North American Journal of Fisheries Management* 15(1): 26–32.

Johnson, D.R. and W. Seaman. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida): Spotted Seatrout. U.S. Fish and Wildlife Service Biological Report 82(11.43). U.S. Army Corps of Engineers TR EL-82-4. http://www.nwrc.gov/wdb/pub/0139.pdf.

Johnson, N.S. and R.M. Adams. 1989. On the marginal value of a fish: Some evidence from the steelhead fishery. *Marine Resource Economics* 6(1): 43-55.

Johnston, R.J., E.Y. Besedin, and R.F. Wardwell. 2003. Modeling relationships between use and nonuse values for surface water quality: A meta-analysis. *Water Resources Research* 39(12): 1363-1372.

Johnston, R.J., T.F. Weaver, L.A. Smith, and S.K. Swallow. 1995. Contingent valuation focus groups: Insights from ethnographic interview techniques. *Agricultural and Resource Economics Review* 24(1):56-69.

Jones and Stokes Associates. 1987. Juneau Area Sport Fishing Economic Study. Jones & Stokes Associates, Inc., Robert D. Niehaus, Inc. Prepared for Alaska Department of Fish and Game, Sport Fish Division. Anchorage. Study Report AK 99518-1599. October.

Jude, D.J., F.J. Tesar, S.F. Deboe, and T.J. Miller. 1987. Diet and selection of major prey species by Lake Michigan salmonines, 1973-1982. *Transactions of the American Fisheries Society* 116(5):677-691.

Kaoru, Y. 1993. Differentiating use and nonuse values for coastal pond water quality improvements. *Environmental and Resource Economics* 3:487-494.

Karpoff, J.M. 1985. Non-pecuniary benefits in commercial fishing: Empirical findings from the Alaska salmon fisheries. *Economic Inquiry* 23:159-174.

Kelso, J.R.M. and G.S. Milburn. 1979. Entrainment and impingement of fish by power plants in the Great Lakes which use the once-through cooling process. *Journal of Great Lakes Research* 5:182-194.

King, D.M. and V.G. Flagg. 1984. The Economic Structure of California's Commercial Fisheries 1982. Working Paper No. P-T-32. California Sea Grant College Program, La Jolla.

King, D.M. and M. Mazzotta. 2002. Ecosystem Valuation. Methods, Section 6: Contingent Valuation Method. http://www.cbl.umces.edu/~dkingweb/contingent_valuation.htm. Accessed 4/2/02.

Kirkley, J.E., N.E. Bockstael, K.E. McConnell, and I.E. Strand. 1999. The Economic Value of Saltwater Angling in Virginia. Virginia Marine Resource Report No. 99-2, VSG-99-02, January.

Kleinholz, C.W. 2000. Species Profile: Bigmouth Buffalo. SRAC Publication No. 723. Southern Regional Aquaculture Center, Stoneville, MS. June.

Kotchen, M.J. and S.D. Reiling. 2000. Environmental attitudes, motivations, and contingent valuation of nonuse values: A case study involving endangered species. *Ecological Economics* 32:93-107.

Krentz, S. 1997. 1997 Summary Report of Work Conducted by the Missouri River FWMAO on Missouri and Yellowstone Rivers - Pallid Sturgeon. Report #MRFAO97-03. U.S. Fish and Wildlife Service, Bismarck, ND.

Krinsky, I. and A.L. Robb. 1986. Approximating the statistical properties of elasticities. *Review of Economics and Statistics* 68(4):715-719.

Kucas, S.T. and T.J. Hassler. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) — California Halibut. U.S. Fish and Wildlife Service Mol. Report 82t11.44. U.S. Army Corps of Engineers TR EL-82-4.

Lant, C.L. and R.S. Roberts. 1990. Greenbelts in the cornbelt: Riparian wetlands, intrinsic values, and market failure. *Environment and Planning* 22:1375-1388.

Larkin, S.L., C.M. Adams, and D.J. Lee. 2000. Reported trip costs, gross revenues, and net returns for U.S. Atlantic pelagic longline vessels. *Marine Fisheries Review* 62(2):49-60.

Lassuy, D.R. 1989. Species Profile: Life History and Environmental Requirements of Coastal Fishes: Pacific Herring. U.S. Fish and Wildlife Service Biological Report 82(11.126). U.S. Army Corps of Engineers TR EL-82-4. http://www.nwrc.usgs.gov/wdb/pub/0151.pdf. Accessed 7/3/01.

Lauer, G.J., W.T. Waller, D.W. Bath, W. Meeks, D. Heffner, T. Ginn, L. Zubarik, P. Bibko, and P.C. Storm. 1974. Entrainment studies on Hudson River organisms. In *Proceedings of the Second Workshop on Entrainment and Intake screening*. Report. 15. EPRI, Palo Alto, CA, pp. 37-82.

Lawler, Matusky & Skelly Engineers. 1985. 2.0 entrainment survival studies. In *Quad Cities Aquatic Program 1984 Annual Report*. Prepared for Commonwealth Edison, Chicago, IL, by Lawler, Matusky & Skelly Engineers, Pearl River, NY.

Lawler, Matusky & Skelly Engineers. 1999. Brayton Point Power Station Entrainment Survival Study, 1997-1998. Draft. Prepared for USGen New England, Inc., Brayton Point Station, Somerset, MA, by Lawler Matusky & Skelly Engineers, Pearl River, NY.

Layton, D. and G. Brown. 1998. Heterogenous Preferences Regarding Global Climate Change. Presented at NOAA Applications of Stated Preference Methods to Resource Compensation Workshop, Washington, DC.

Leak, J.C. and E.D. Houde. 1987. Cohort growth and survival of bay anchovy, *Anchoa mitchilli*, larvae in Biscayne Bay, Florida. *Marine Ecology Progress Series* 37:109-122.

Leard, R., R. Matheson, K. Meador, W. Keithly, C. Luquet, M. Van Hoose, C. Dyer, S. Gordon, J. Robertson, D. Horn, and R. Scheffler. 1993. The black drum fishery of the Gulf of Mexico, United States: A regional management plan. Gulf States Marine Fisheries Commission Report Number 28, Ocean Springs, MS.

Lee, S.T. 1996. The Economics of Recreational Fishing. Dissertation, University of Washington.

Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson (eds). 2001. California's Living Marine Resources: A Status Report. California Department of Fish and Game. December. http://www.dfg.ca.gov/mrd/status/.

Light, P.R. and K.W. Able. 2003. Juvenile Atlantic menhaden (*Brevoortia tyrannus*) in Delaware Bay, USA are the result of local and long-distance recruitment. *Estuarine, Coastal and Shelf Science* 57:1007-1014.

Lindberg, W.J. and M.J. Marshall. 1984. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida) — Stone Crab. U.S. Fish and Wildlife Service FWS/OBS-82/11.21. U.S. Army Corps of Engineers TR EL-82-4.

Loomis, J. and E. Ekstrand. 1997. Economic benefits of critical habitat for the Mexican spotted owl: A scope test using a multiple bounded contingent valuation survey. *Journal of Agricultural and Resource Economics* 22(2):356-366.

Loomis, J., P. Kent, E.M. Strange, K. Fausch, and A. Covich. 2000. Measuring the total economic value of restoring ecosystem services in an impaired river basin: Results from a contingent valuation survey. *Ecological Economics* 33:103-117.

Loomis, J.B. 1988. The bioeconomic effects of timber harvesting on recreational and commercial salmon and steelhead fishing: A case study of the Siuslaw National Forest. *Marine Resource Economics* Volume 5.

Loomis, J.B. 1996. How large is the extent of the market for public goods: Evidence from a nation wide contingent valuation survey. *Applied Economics* 28(7):779-782.

Loomis, J.B. and D.M. Larson. 1994. Total economic values of increasing gray whale populations: Results from a contingent valuation survey of visitors and households. *Marine Resource Economics* 9:275-286.

Loomis, J.B. and D.S. White. 1996. Economic benefits of rare and endangered species: Summary and meta-analysis. *Ecological Economics* 18:197-206.

Lupi, F. and J.P. Hoehn. 1998. A Partial Benefit-Cost Analysis of Sea Lamprey Treatment on the St. Marys River. Michigan State University.

Lupi, F., J. Hoehn, H. Chen, and T. Tomasi. 1997. The Michigan Recreational Angling Demand Model. Michigan State University and the Michigan Department of Natural Resources and Department of Environmental Quality.

Lyke, A.J. 1993. Discrete Choice Models to Value Changes in Environmental Quality: A Great Lakes Case Study. Dissertation, University of Wisconsin, Madison.

Magat, W.A., J. Huber, K.W. Viscusi, and J. Bell. 2000. An iterative choice approach to valuing clean lakes, rivers, and streams. *Journal of Risk and Uncertainty* 21(1):7-43.

MaineToday.com. 2003. 2003 Saltwater Fishing Regulations. http://outdoors.mainetoday.com/fishing/bruce/bassreg.shtml.

Marcy, B.C., Jr. 1971. Survival of young fish in the discharge canal of a nuclear power plant. *Journal Fisheries Research Board of Canada* 28:1057-1060.

Marcy, B.C., Jr. 1973. Vulnerability and survival of young Connecticut River fish entrained at a nuclear power plant. *Journal Fisheries Research Board of Canada* 30:1195-1203.

Marcy, B.C., Jr. 1975. Entrainment of organisms at power plants, with emphasis on fishes – an overview. In *Fisheries and Energy Production*, S.B. Sailia (ed.). D.C. Heath and Company, Lexington, MA, pp. 89-106.

Marcy, B.C., A.D. Beck, and R.E. Ulanowicz. 1978. Effects and impacts of physical stress on entrained organisms. In *Power Plant Entrainment: A Biological Assessment*. Academic Press, New York, pp. 136-188.

Marine Recreational Fisheries Statistics (Southeast, Northeast, Pacific West). Year? http://www.st.nmfs.gov/recreational/the_mrfss.html.

Masnik, M.T. and J.H. Wilson. 1980. Assessment of the Impacts of the Salem and Hope Creek Stations on Shortnose Sturgeon, *Acipenser brevirostrum LeSueur*. Prepared by the U.S. Nuclear Regulatory Commission, Washington, DC. April.

Matthews, L.G., F.R. Homans, and K.W. Easter. 1999. Reducing Phosphorous Pollution in the Minnesota River: How Much is it Worth? Staff Paper. Department of Applied Economics, University of Minnesota, St. Paul.

Mayo, R. and L. O'Brien. 2000. Atlantic cod. In *Status of Fishery Resources off Northeastern United States*. http://www.wh.whoi.edu/sos/spsyn/pg/cod/. Accessed 1/03.

McConnell, K. and I. Strand. 1994. The Economic Value of Mid and South Atlantic Sportfishing: Volume 2. Cooperative Agreement #CR-811043-01-0 between the University of Maryland at College Park, the U.S. Environmental Protection Agency, the National Marine Fisheries Service, and the National Oceanic and Atmospheric Administration.

McDermot, D. and K.A. Rose. 2000. An individual-based model of lake fish communities: Application to piscivore stocking in Lake Mendota. *Ecological Modelling* 125:67-102.

McLaren, J.B., T.H. Peck, W.P. Dey, and M. Gardinier. 1988. Biology of Atlantic tomcod in the Hudson River Estuary. In *Science, Law, and Hudson River Power: A Case Study in Environmental Impact Assessment*, L.W. Barnthouse, R.J. Klanda, D.S. Vaughn, and R.L. Kendall (eds.). American Fisheries Society Monograph No. 4. American Fisheries Society, Bethesda, MD.

McLean, R.I. and J.J. Dieter. 2002. State of Maryland Comments on Proposed Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities; Proposed Rule, Published Federal Register, April 9, 2002. To Proposed Rule Comment Clerk W-00-32, dated August 5, 2002.

MDNR. 2002. Data from the 2001 Recreational Angler Survey. Charlevoix Fisheries Research Station. Michigan Department of Natural Resources. Received from David Clapp, Charlevoix Great Lakes Research Station, Charlevoix, MI.

Meffe, G.K. 1992. Techno-arrogance and halfway technologies: Salmon hatcheries on the Pacific Coast of North America. *Conservation Biology* 6:350-354.

Meredith, W.H. and V.A. Lotrich. 1979. Production dynamics of tidal creek population of *Fundulus heteroclitus* (linnaeus). *Estuaries and Coastal Marine Science* 8:99-118.

Miller, E.E. 1966. Channel catfish. In *Inland Fisheries Management*. California Department of Fish and Game, Sacramento, pp. 440-463.

Miller, R.R. 1960. Systematics and biology of the gizzard shad (*Dorosoma cepedianum*) and related fishes. *Fishery Bulletin* 60:371-392.

Milliman, S.R., B.L. Johnson, R.C. Bishop, and K.J. Boyle. 1992. The bioeconomics of resource rehabilitation: A commercial-sport analysis for a Great Lakes fishery. *Land Economics* 68(2):191-210.

Mitchell, R.C. and R.T. Carson. 1981. An experiment in determining willingness to pay for national water quality improvements. Preliminary Draft of a Report to the U.S. Environmental Protection Agency. Resources for the Future, Inc., Washington, DC.

Mitchell, R.C. and R.T. Carson. 1986. The Use of Contingent Valuation Data for Benefit/Cost Analysis of Water Pollution Control. Resources for the Future, Washington, DC. September.

Mitchell, R.C. and R.T. Carson. 1989. Using Surveys to Value Public Goods: The Contingent Valuation Method. Resources for the Future, Washington, DC.

Montana Fish, Wildlife & Parks. 2004. Animal Field Guide: Pallid Sturgeon. http://fwp.state.mt.us/fieldguide/detail_AFCAA02010.aspx. Accessed October 18, 2004.

Monterey Bay Aquarium. 1999. White Sturgeon. http://www.mbayaq.org/efc/living_species/default.asp?hOri=1&inhab=498.

Morey, E.R., R.D. Rowe, and M. Watson. 1993. A repeated nested-logit model of Atlantic salmon fishing. *American Journal of Agricultural Economics* August, pp. 578-592.

Morey, E., W.D. Shaw, and R.D. Rowe. 1991. A discrete-choice model of recreational participation, site choice, and activity valuation when complete trip data are not available. *Journal of Environmental Economics and Management* 20:181-201.

Morey, E.R., W.S. Breffle, R.D. Rowe, and D.M. Waldman. 2002. Estimating recreational trout fishing damages in Montana's Clark Fork River basin: Summary of a natural resource damage assessment. *Journal of Environmental Management* 66(2):159-170.

Morgan, II, R.P. 1980. Biocides and fish behavior. *Power Plants: Effects on Fish and Shellfish Behavior*, C.H. Hocutt, J.R. Stauffer, Jr., J.E. Edinger, L.W. Hall, Jr., and R.P. Morgan, II (eds.). Academic Press, New York, pp. 75-102.

Morgan, II, R.P. and E.J. Carpenter. 1978. Biocides. *Power Plant Entrainment: A Biological Assessment*, J.R. Schubel and B.C. Marcy, Jr. (eds.). Academic Press, New York, pp. 95-134.

Moyle, P.B., B. Herbold, D.E Stevens, and L.W. Miller. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. *Transactions of the American Fisheries Society* 121:67-77.

Muncy, R.J. 1984. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Gulf of Mexico): Pinfish. U.S. Fish and Wildlife Service FWS/OBS-82/11.26. U.S. Army Corps of Engineers TR EL-82-4. http://www.nwrc.gov/wdb/pub/0166.pdf.

Murdock, J. 2001. Valuing Recreational Fishing Opportunities While Catching Unobserved Characteristics. Yale University.

Murphy, M.D. and T.C. MacDonald. 2000. An Assessment of the Status of Sheepshead in Florida Waters through 1999. Florida Marine Research Institute, St. Petersburg.

Murphy, M.D. and R.G. Taylor. 1989. Reproduction and growth of black drum, *Pogonias cromis*, in northeast Florida. *Northeast Gulf Science* 10:127-137.

Murphy, M.D. and R.G. Taylor. 1994. Age, growth, and mortality of spotted seatrout in Florida waters. *Transactions of the American Fisheries Society* 123:482-497.

Murphy, M.D., G.A. Nelson, and R.G. Muller. 2000. Florida's Inshore and Nearshore Species: 2000 Status and Trends Report. http://floridamarine.org.

NatureServe. 2002. Natural Heritage Central Databases. NatureServe, Arlington, VA.

Nelson, G.A. 1998. Abundance, growth, and mortality of young-of-the-year pinfish, *Lagodon rhomboides*, in three estuaries along the Gulf Coast of Florida. *Fishery Bulletin* 96:315-328.

NEP. 2004. National Estuary Program Extramural Funding, FY 1998-FY 2003. National Estuary Program. Received from Greg Colianni, U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Oceans and Coastal Protection Division. July 1.

New England Power Company and Marine Research Inc. 1995. Brayton Point Station Annual Biological and Hydrological Report, January-December 1994. August.

New Jersey Division of Fish and Wildlife. 2002. New Jersey Division of Fish and Wildlife. http://www.state.nj.us/dep/fgw/ensphome.htm. Accessed 3/3/99.

Newman, M.C. 1995. *Quantitative Methods in Aquatic Ecotoxicology*. Lewis Publishers, Boca Raton, FL.

Nitschke, P., R. Brown, and L. Hendrickson. 2000. Winter flounder. In *Status of the Fishery Resources off the Northeastern United States*. NOAA, Northeast Fisheries Science Center. http://www.nefsc.nmfs.gov/sos/spsyn/fldrs/winter/. Accessed 1/03.

NMFS. 1999a. Our Living Oceans. Report on the Status of US Living Marine Resources. NMFS-F/SPO-41. NOAA Technical Memorandum. National Marine Fisheries Service.

NMFS. 1999b. Recovery Planning for West Coast Salmon. National Marine Fisheries Service. http://www.nwr.noaa.gov/1salmon/salmesa/pubs/recovsum.pdf. Accessed 1/03.

NMFS. 2001a. Report to Congress: Status of Fisheries of the United States 2001. Prepared by National Marine Fisheries Service, Silver Spring, MD. January.

NMFS. 2001b. Sea Turtle Protection and Conservation. National Marine Fisheries Service, Office of Protected Resources. http://www.nmfs.noaa.gov/prot_res/PR3/Turtles/turtles.html.

NMFS. 2002a. Annual Report to Congress on the Status of U.S. Fisheries — 2001. U.S. Department of Commerce, NOAA, National Marine Fisheries Service, Silver Spring, MD.

NMFS. 2002b. Commercial Landings Data Caveats. National Marine Fisheries Service. http://www.st.nmfs.gov/commercial/landings/caveat.html. Accessed 11/4/02.

NMFS. 2002c. Fishery Management Councils. National Marine Fisheries Service. http://www.nmfs.noaa.gov/councils/. Accessed 12/9/02.

NMFS. 2002d. Marine Recreational Fisheries Statistics Survey (MRFSS), Snapshot Query. National Marine Fisheries Service. http://www.st.nmfs.gov/recreational/queries/catch/snapshot.html.

NMFS. 2002e. Sustainable Fisheries Act. http://www.nmfs.noaa.gov/sfa/. Accessed 12/9/02.

NMFS. 2003a. Annual Commercial Landing Statistics website. National Marine Fisheries Service. http://www.st.nmfs.gov/st1/commercial/. Accessed 8/03.

NMFS. 2003b. Annual Report to Congress on the Status of U.S. Fisheries – 2002. U.S. Dept. Commerce, NOAA, National Marine Fisheries Service, Silver Spring, MD.

NMFS. 2003c. Marine Recreational Fisheries Statistics Intercept Survey. National Marine Fisheries Service. http://www.st.nmfs.gov/recreational/the_mrfss.html.

NOAA. 1993. Status of the Fishery Resources off the Northeastern United States for 1993. NOAA Technical Memorandum NMFS-F/NEC 101. National Oceanic and Atmospheric Administration. National Marine Fisheries Service, Silver Spring, MD.

NOAA. 2001a. Chesapeake Bay Office Species Information. National Oceanic and Atmospheric Administration. http://noaa.chesapeakebay.net/fisheries/species.htm. Accessed 12/01.

NOAA. 2001b. Status of the Fishery Resources off the Northeastern United States. National Oceanic and Atmospheric Administration. http://www.nefsc.nmfs.gov/sos/. Accessed 11/01.

NOAA Fisheries. 2004. Shortnose Sturgeon (*Acipenser brevirostrum*). http://www.nmfs.noaa.gov/prot_res/species/fish/Shortnose_sturgeon.html. Accessed October 14, 2004.

Northeast Midwest Institute. 2004. Large-scale Ecosystem Restoration Initiatives, Protecting and Restoring the Upper Mississippi River. Available at http://www.nemw.org/uppermiss_restoration.htm. Accessed June 23, 2004.

Norton, V., T. Smith, and I.E. Strand (eds.). 1983. Stripers: The Economic Value of the Atlantic Coast Commercial and Recreational Striped Bass Fisheries. UM-SG-TS-83-12. Maryland Sea Grant Publication, College Park.

NY State Department of Environmental Conservation. 2003. Lake Sturgeon Fact Sheet. http://www.dec.state.ny.us/website/dfwmr/wildlife/endspec/lakestur.html.

O'Brien, L. 2000. American Plaice. http://www.nefsc.nmfs.gov/sos/spsyn/fldrs/plaice/. Accessed 6/30/01.

O'Connell, C. 1953. Life History of the Cabezon *Scorpaenichthys marmoratus* (Ayres). State of California Department of Fish and Game Marine Fisheries Branch Fish Bulletin No. 93.

Ohio Department of Natural Resources. 2003. Life History Notes: Bluntnose Minnow. http://www.dnr.state.oh.us/wildlife/Fishing/aquanotes-fishid/bluntnose.htm. Accessed 1/03.

Olsen, D., J. Richards, and D.R. Scott. 1991. Existence and sport values for doubling the size of Columbia River Basin salmon and steelhead runs. *Rivers* 2(1):44-56.

Overholtz, W. 2002a. Northeast Fisheries Science Center. Status of the Fishery Resources off the Northeastern United States. Atlantic Herring. http://www.nefsc.nmfs.gov/sos/spsyn/pp/herring/. Accessed 1/11/02.

Overholtz, W. 2002b. Northeast Fisheries Science Center. Status of the Fishery Resources off the Northeastern United States. Atlantic Mackerel. http://www.nefsc.nmfs.gov/sos/spsyn/pp/mackerel/. Accessed 1/03.

Overholtz, W.J., R.S. Armstrong, D.G. Mountain, and M. Tercerio. 1991. Factors Influencing Spring Distribution, Availability, and Recreational Catch of Atlantic Mackerel (*Scomber scombrus*) in the Middle Atlantic and Southern New England Regions. NOAA Technical Memorandum NMFS-F/NEC-85.

Packer, D.B., S.J. Griesbach, P.L. Berrien, C.A. Zetlin, D.L. Johnson, and W.W. Morse. 1999. Essential Fish Habitat Source Document: Summer Flounder, *Paralichtyus dentatus*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-151. September. http://www.nefsc.nmfs.gov/nefsc/publications/.

Pate, J. and J. Loomis. 1997. The effect of distance on willingness-to-pay values: A case study of wetlands and salmon in California. *Ecological Economics* 20:199-207.

Pattillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco. 1997. Distribution and Abundance of Fishes and Invertebrates in Gulf of Mexico Estuaries, Volume II: Species Life History Summaries. ELMR Report No.11. NOAA/NOS Strategic Environmental Assessments Division, Silver Spring, MD.

Pauly, D. and V. Christensen. 1995. Primary production required to sustain global fisheries. *Nature* 374:255-257.

Pauley, G.B., D.A. Armstrong, R. Van Citter, and G.L. Thomas. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) — Dungeness Crab. U.S. Fish and Wildlife Service Biological Report 82(11.121). U.S. Army Corps of Engineers TR EL-82-4.

Pendleton, L.H. and R. Mendelsohn. 1998. Estimating the economic impact of climate change on the freshwater sportfisheries of the Northeast United States. *Land Economics* 74:483-496.

Pennsylvania. 1999. Rules and Regulations: Title 58-Recreation, Fish and Boat Commission [58 PA. Code CHS. 61 and 65]. http://www.pabulletin.com/secure/data/vol29/29-28/29_28_rr.pdf. Accessed 11/01.

Pennsylvania Department of Conservation and Natural Resources. 2002. Pennsylvania Department of Conservation and Natural Resources. http://www.dcnr.state.pa.us/wrcf/franda.htm. Accessed 3/3/02.

Pepin P., J.F. Dower, J.A. Helbig, and W.C. Leggett. 2002. Estimating the relative roles of dispersion and predation in generating regional differences in mortality rates of larval radiated shanny (*Ulvaria subbifurcata*). *Can. J. Fish. Aquat. Sci.* 59:105-114.

Peterson, C.H. and J. Lubchenco. 1997. Marine ecosystem services. In *Nature's Services, Societal Dependence on Natural Ecosystems*, G.C. Daily (ed.). Island Press, Washington, DC, pp. 177-194.

PFMC. 1998. Fishery Management Plan: Coastal Pelagic Species. Appendix A: Description of the Coastal Pelagics Fishery. December. Pacific Fishery Management Council. http://www.pcouncil.org/cps/cpsfmp.html. Accessed 2/03.

PFMC. 2003a. Background: Coastal Pelagic Species. Pacific Fishery Management Council. http://www.pcouncil.org/cps/cpsback.html#fishery. Accessed 2/03.

PFMC. 2003b. Pacific Fishery Management Council. http://www.pcouncil.org. Accessed 2/03.

PFMC. 2003c. Pacific Fishery Management Council Information Sheet: Groundfish. Pacific Fishery Management Council. http://www.pcouncil.org/facts/groundfish.pdf. Accessed 2/03.

PG&E National Energy Group. 2001. Brayton Point Station Permit Renewal Application, NPDES Permit No. MA0003654. 316(a) and (b) Demonstration. Executive Summary and Appendices. PG&E National Energy Group, San Francisco, CA. November.

Pierce, D.J., B. Mahmoudi, and R.R. Wilson, Jr. 2001. Age and growth of the scaled Herring, *Harengula jaguana*, from Florida waters, as indicated by microstructure of the sagittae. *Fish. Bull.* 99:202-209. http://fishbull.noaa.gov/991/18.pdf. Accessed 12/13/01.

Poe, G.L., K.J. Boyle, and J.C. Bergstrom. 2001. A preliminary meta analysis of contingent values for ground water quality revisited. In *The Economic Value of Water Quality*, J.C. Bergstrom, K.J. Boyle and G.L. Poe (eds.). Edward Elgar Publishers, Northampton, MA.

Polgar, T.T., J.K. Summers, and M.S. Haire. 1979. Evaluation of the Effects of the Morgantown SES Cooling System on Spawning and Nursery Areas of Representative Important Species. Prepared by Martin Marietta Environmental Center.

Poole, C. and S. Greenland. 1999. Random-effects meta-analyses are not always conservative. *American Journal of Epidemiology* 150(5):469-474.

Postel, S. and S. Carpenter. 1997. Freshwater ecosystem services. In *Nature's Services, Societal Dependence on Natural Ecosystems*, G.C. Daily (ed.). Island Press, Washington, DC, pp. 195-214.

PSE&G. 1984. Spot (*Leiostomus xanthurus*): A Synthesis of Information on Natural History, with Reference to Occurrence in the Delaware River and Estuary and Involvement with the Salem Generating Station. Appendix VII. Salem Generating Station 316(b) Demonstration. Public Service Electric & Gas Company, Newark, NY.

PSE&G. 1999. Permit Renewal Application NJPDES Permit No. NJ0005622. Public Service Electric and Gas Company Salem Generating Station. Public Service Electric & Gas Co., Newark, NJ.

Quinn II, T.J. and R.B. Deriso. 1999. *Quantitative Fish Dynamics*. Oxford University Press, Oxford, UK, and New York.

Rago, P.J. 1984. Production forgone: An alternative method for assessing the consequences of fish entrainment and impingement losses at power plants and other water intakes. *Ecological Modelling* 24:79-111.

Responsive Management. 1992. Responsive Management Report: Focus on Focus Groups. Responsive Management, Tallahassee, FL.

Rettig, R. and B. McCarl. 1985. Potential and actual benefits from commercial fishing activities. In Making Information More Useful for Salmon and Steelhead Production Decisions. NOAA Technical Memorandum NMFS F/NWR-8. National Marine Fisheries Service, Portland, OR.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. *Fisheries Research Board of Canada, Bulletin* 191.

Roberts, L.A. and J.A. Leitch. 1997. Economic Valuation of Some Wetland Outputs of Mud Lake. Agricultural Economics Report No. 381. Department of Agricultural Economics, North Dakota Agricultural Experiment Station, North Dakota State University, Fargo.

Rosenberger, R.S. and J.B. Loomis. 2000a. Panel stratification in meta-analysis of economic studies: An investigation of its effects in the recreation valuation literature. *Journal of Agricultural and Applied Economics* 32(3): 459-470.

Rosenberger, R.S. and J.B. Loomis. 2000b. Using meta-analysis for benefit transfer: In-sample convergent validity tests of an outdoor recreation database. *Water Resources Research* 36(4): 1097-1107.

Rowe, R.D., W.D. Shaw, and W. Schulze. 1992. Nestucca oil spill. In *Natural Resource Damages*, K. Ward and J. Duffield (eds). Wiley and Sons, New York.

Rowe, R.D., E.R. Morey, A.D. Ross, and W.D. Shaw. 1985. Valuing Marine Recreational Fishing on the Pacific Coast. Energy and Resource Consultants Inc. Report prepared for the National Marine Fisheries Service, National Oceanic and Atmospheric Administration. Report LJ-85-18C. March.

Rowe, R.D., W.D. Schulze, B. Hurd, and D. Orr. 1985. Economic Assessment of Damage Related to the Eagle Mine Facility. Energy and Resource Consultants, Inc., Boulder, CO.

Ruhl, J.B. and R.J. Gregg. 2001. Integrating ecosystem services into environmental law: A case study of wetlands mitigation banking. *Stanford Environmental Law Journal* 20(2):365-392.

Ruppert, D., R.L. Reish, R.B. Deriso, and R.J. Carroll. 1985. A stochastic population model for managing the Atlantic menhaden (*Brevoortia tyrannus*) fishery and assessing managerial risks. *Canadian Journal of Fisheries and Aquatic Sciences* 42:1371-1379.

Russell, B. and C.H. Hanson. 1990. Assessment of Entrainment Impacts to Rockfish at the Diablo Canyon Power Plant. Prepared for Pacific Gas and Electric Company by Tenera Environmental Services, Lafayette, CA. May 2.

Saila, S.B., E. Lorda, J.D. Miller, R.A. Sher, and W.H. Howell. 1997. Equivalent adult estimates for losses of fish eggs, larvae, and juveniles at Seabrook Station with use of fuzzy logic to represent parametric uncertainty. *North American Journal of Fisheries Management* 17:811-825.

Salzman, J., B.H. Thompson, Jr., and G.C. Daily. 2001. Protecting ecosystem services: Science, economics, and law. *Stanford Environmental Law Journal* 20(2):309-332.

Samples, K. and R. Bishop. 1985. Estimating the value of variations in anglers' success rates: An application of the multiple-site travel cost method. *Marine Resource Economics* 2(1):55-74.

Sanders, L.D., R.G. Walsh, and J.B. Loomis. 1990. Toward empirical estimation of the total value of protecting rivers. *Water Resources Research* 26(7):1345-1357.

Santos, J.M.L. 1998. *The Economic Valuation of Landscape Change*. Edward Elgar, Cheltenham, UK.

Schorfhaar, R.G. and P.J. Schneeberger. 1997. Commercial and Sport Fisheries for Lake Whitefish in Michigan Waters of Lake Superior, 1983-96. State of Michigan Department of Natural Resources, Fisheries Division Research Report Number 2034. June 30. http://www.dnr.state.mi.us/www/ifr/ifrlibra/research/reports/2034rr.pdf.

Schram, S.T., T.N. Halpern, and T.B. Johnson. 1998. Ecology of burbot in western Lake Superior. In *Biology and Management of Burbot*, V. Paragamian and D. MacKinlay (eds). International Congress on the Biology of Fish, Baltimore, MD, July 27-30. http://www-heb.pac.dfo-mpo.gc.ca/congress/Burbot.pdf.

Schubel, J.R., C.C. Coutant, and P.M.J. Woodhead. 1978. Thermal effects of entrainment. In *Power Plant Entrainment: A Biological Assessment*, J.R. Schubel and B.C. Marcy (eds.). Academic Press, New York, pp. 20-93.

Schuhmann, P.W. 1996. A Welfare Analysis of Commercial Fishery Harvest Restrictions: A Bioeconomic Model of Red Drum Stock Dynamics and Recreation Demand. Dissertation, North Carolina State University.

Schuhmann, P.W. 1997. Deriving species-specific benefits measures for expected catch improvements in a random utility framework. *Marine Resource Economics* 13:1-21.

Schultz, K. 2000. *Ken Schultz's Fishing Encyclopedia: Worldwide Angling Guide*. IDG Books Worldwide, New York.

Schulze, W.D., R.D. Rowe, W.S. Breffle, R.R. Boyce, and G.H. McClelland. 1995. Contingent Valuation of Natural Resource Damages due to Injuries to the Upper Clark Fork River Basin. State of Montana Natural Resource Damage Litigation Program. Prepared by RCG/Hagler Bailly, Boulder, CO.

Schwartz, F.J., P. Perschbacher, M. McAdams, L. Davidson, K. Sandoy, C. Simpson, J. Duncan, and D. Mason. 1979. Summary Report for 1973-77, an Ecological Study of Fishes and Invertebrate Macrofauna Utilizing the Cape Fear River Estuary, Carolina Beach Inlet, and Adjacent Atlantic Ocean. Vol. XIV. Report to Carolina Power Light Co., Raleigh, NC.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. *Fisheries Research Board of Canada Bulletin* 184.

Scott, W.B. and E.J. Crossman. 1998. Freshwater fishes of Canada. *Fisheries Research Board of Canada Bulletin* 184. Galt House, Oakville, Ontario, Canada.

Scott, W.B. and M.G. Scott. 1988. Atlantic fishes of Canada. *Can. Bull. Fish. Aquat. Sci.* 219.

Serchuk, F. and C. Cole. 1974. Age and growth of the cunner, *Tautogolabrus adspersus* (Waldbaum), Pisces (Labridae), in the Weweantic River Estuary, Massachusetts. *Chesapeake Science* 15(4):205-213.

Setzler, E.M., W.R. Boynton, K.V. Wood, H.H. Zion, L. Lubbers, N.K. Mountford, P. Frere, L. Tucker, and J.A. Mihursky. 1980. Synopsis of Biological Data on Striped Bass, *Morone saxatilis* (Walbaum). NOAA Technical Report NMFS Circular 433. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, June.

Shafer, E.L., R. Carline, R.W. Guldin, and H.K. Cordell. 1993. Economic amenity values of wildlife: Six case studies of Pennsylvania. *Environmental Management* 17(2): 669-682.

Shirey, C.A., C.C. Martin, and E.J. Stetzar. 1997. Abundance of Sub-adult Atlantic Sturgeon and Areas of Concentration within the Lower Delaware River. Final Report, Grant No. NA66FG0326. Prepared for the Delaware Division of Fish and Wildlife, Dover.

Siegfried, C.A. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest) — Crangonid Shrimp. U.S. Fish and Wildlife Service Biological Report 82(11.125). U.S. Army Corps of Engineers TR EL-82-4.

Silberman, J., D.A. Gerlowski, and N.A. Williams. 1992. Estimating existence value for users and nonusers of New Jersey beaches. *Land Economics* 68(2):225-236.

Singer, J.D. 1998. Using SAS PROC MIXED to fit multilevel models, hierarchical models, and individual growth models. *Journal of Educational and Behavioral Statistics* 23(4):323-355.

Smith, C.L. 1981. Satisfaction bonus from salmon fishing: Implications for economic evaluation. *Land Economics* 57(2):181-196.

Smith, C.L. 1985. The inland fishes of New York State. ISBN 0-9615433-0-2. The New York State Department of Environmental Conservation, Albany.

Smith, V.K. and L. Osborne. 1996. Do contingent valuation estimates pass the scope test? A meta analysis. *Journal of Environmental Economics and Management* 31(3):287-301.

Smith, V.K., G. Van Houtven, and S.K. Pattanayak. 2002. Benefit transfer via preference calibration: “Prudential algebra” for policy. *Land Economics* 78(1):132-152.

Snyder, D.E. 1998. Burbot — larval evidence for more than one North American species? In *Biology and Management of Burbot*, V. Paragamian and D. MacKinlay (eds). International Congress on the Biology of Fish, Baltimore, MD, July 27-30. http://www-heb.pac.dfo-mpo.gc.ca/congress/Burbot.pdf.

Southern Energy Delta, LLC. 2000. Multispecies Habitat Conservation Plan, Pittsburg and Contra Costa Power Plants. Draft-Revision 5, June 30, 2000. Prepared for the U.S. Fish & Wildlife Service, Sacramento, CA, and the National Marine Fisheries Service, Santa Rosa, CA.

Spigarelli, S.A., A.J. Jensen, and M.M. Thommes. 1981. An Assessment of the Impacts of Water Intakes on Alewife, Rainbow Smelt, and Yellow Perch Populations in Lake Michigan. EPA-905/3-81-001. ANL/ES-109. Prepared by Argonne National Laboratory and U.S. EPA. March.

Stanley, J.G. and D.S. Danie. 1983. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic): White Perch. U.S. Fish and Wildlife Service Biological Services Report FWS/OBS-82/11.7. U.S. Army Corps of Engineers TR EL-82-4.

State of New York, Department of Environmental Conservation. 2001. State of New York, Department of Environmental Conservation. List of Endangered, Threatened and Special Concern Fish & Wildlife Species of New York State. http://www.dec.state.ny.us/website/dfwmr/wildlife/endspec/etsclist.html. Accessed 3/3/01.

Stauffer, Jr., J.R. 1980. Influence of temperature on fish behavior. In *Power Plants: Effects on Fish and Shellfish Behavior*, C.H. Hocutt, J.R. Stauffer, Jr., J.E. Edinger, L.W. Hall, Jr., R.P. Morgan, II (eds.). Academic Press, New York, pp. 103-141.

Stevens, D.E. and B.J. Finlayson. 1978. Mortality of Young Striped Bass Entrained at Two Power Plants in Sacramento–San Joaquin Delta, California. Fourth National Workshop on Entrainment and Impingement. EA Communications, Melville NY, pp. 57-69.

Stevens, T.H., M.K. Field, T.A. More, and R.J. Glass. 1994. Contingent Valuation of Rare and Endangered Species: An Assessment. W-133 Benefits and Cost Transfer in Resource Planning.

Stevens, T.H., J. Echeverria, R.J. Glass, T. Hager, and T.A. More. 1991. Measuring the existence value of wildlife: What do CVM estimates really show? *Land Economics* 67:390-400.

Stewart, L.L. and P.J. Auster. 1987. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic) Atlantic Tomcod. U.S. Fish and Wildlife Service Biological Report 82(11.78). U.S. Army Corps of Engineers TR EL-82-4. http://www.nwrc.gov/wdb/pub/1043.pdf. Accessed 6/03.

Stokes, M. 2002. The Economic Value of Viewing Lake Sturgeon (*Acipenser fulvescens*) in Wisconsin. Presented at the 2004 Joint Meeting of the Wisconsin and Michigan Chapters of the American Fisheries Society. January 20-22, 2004.

Stone & Webster Engineering Corporation. 1977. Supplemental Assessment in Support of the 316 Demonstration, Pilgrim Nuclear Power Station Units 1 and 2, Boston Edison Company. Stone & Webster Engineering Corporation, Boston, MA.

Stone & Webster Engineering Corporation. 1980. 316(a) and (b) Demonstration Big Bend Station — Unit 4. Volume I and Volume II, Appendices. Prepared for Tampa Electric Company by Stone & Webster Engineering Corporation, Boston, MA. August 1.

Studholme, A.L., D.B. Packer, P.L. Berrien, D.L. Johnson, C.A. Zetlin, and W.W. Morse. 1999. Essential Fish Habitat Document: Atlantic Mackerel, *Scomber scombrus*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-141.

Stumborg, B.E., K.A. Baerenklau, and R.C.. Bishop. 2001. Nonpoint source pollution and present values: A contingent valuation of Lake Mendota. *Review of Agricultural Economics* 23(1): 120-132.

Sullivan, J.R. 1979. The Stone Crab, *Menippe mercenaria*, in the Southwest Florida Fishery. Florida Marine Research Publications Number 36. Florida Department of Natural Resources Marine Research Laboratory, St. Petersburg.

Summers, J.K. 1989. Simulating the indirect effects of power plant entrainment losses on an estuarine ecosystem. *Ecological Modelling* 49: 31-47.

Sutherland, R.J. and R.G. Walsh. 1985. Effect of distance on the preservation value of water quality. *Land Economics* 61(3):282-291.

Sutter, F.C., R.S. Waller, and T.D. McIlwain. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fisheries and Invertebrates (Gulf of Mexico)-Black Drum. U.S. Fish and Wildlife Service Biological Report 82(11.51). U.S. Army Corps of Engineers TR LE-82-4.

Swanson, C. 1993. Economics of Non-Game Management: Bald Eagles on the Skagit River Bald Eagle Natural Area, Washington. Dissertation, Department of Agricultural Economics, Ohio State University, Columbus.

Talhelm, D.R. 1988. Economics of Great Lakes Fisheries: A 1985 Assessment. Great Lakes Fishery Commission Technical Report No. 54. Great Lakes Fishery Commission, Ann Arbor, MI. November.

TBNEP. 1992. Synthesis of Basic Life Histories of Tampa Bay Species. TBNEP Technical Publication #10-92. Tampa Bay National Estuary Program, St. Petersburg, FL.

Tenera Environmental Services. 1988. Diablo Canyon Power Plant Cooling Water Intake Structure 316(b) Demonstration. Prepared for Pacific Gas and Electric Company. April 28.

Tenera Environmental Services. 2000a. Diablo Canyon Power Plant 316(b) Demonstration Report and Appendices. Prepared for Pacific Gas and Electric Company. March 1.

Tenera Environmental Services. 2000b. Moss Landing Power Plant Modernization Project 316(b) Resource Assessment. Prepared for Duke Energy Moss Landing, LLC. April 28.

Tenera Environmental Services. 2001. Morro Bay Power Plant Modernization Project: 316(b) Resource Assessment. Prepared for Duke Energy Morro Bay, LLC, Oakland, CA. July 10.

The Upper Mississippi River Basin Association. 2004. Basin Facts. Available at http://www.umrba.org/basinfacts.htm. Accessed 6/23/04.

Thomas, D.A. 2002. Memo to docket, RE: Observations of foam in discharge canals of 2 power plants. December 30, 2002.

Thomas, D.L. 1971. An Ecological Study of the Delaware River in the Vicinity of Artificial Island. Progress Report for the Period January-December 1970, Part III: The Early Life History and Ecology of Six Species of Drum (Sciaenidae) in the Lower Delaware River, a Brackish Tidal Estuary.

Thomas, M.V. and R.C. Haas. 2000. Status of Yellow Perch and Walleye Populations in Michigan Waters of Lake Erie, 1994-98. Fisheries Research Report 2054. Michigan Department of Natural Resources, Fisheries Division, Lansing. August.

Townsend, R.E. 1985. The right to fish as an external benefit of open access. *Canadian Journal of Fisheries and Aquatic Sciences* 42:2050-2053.

TPWD. 2003. Marine Sport-Harvest Monitoring Program, Annual Effort, Landings, and CPUE Estimates. Texas Parks and Wildlife Department. Coastal Fisheries Division. Received from Mark Fisher, August 6.

Trautman, M.B. 1981. *The Fishes of Ohio, with Illustrated Keys*. Revised ed. Ohio State University Press, Columbus.

Ulanowicz, R.E. and B. Kinsman. 1978. Purgatorio–two rather different views of the same event. In *Power Plant Entrainment: A Biological Assessment*, J.R. Schubel and B.C. Marcy, Jr. (eds.). Academic Press, New York, pp. 245-253.

University of Washington. 2000. Invertebrates in the Plankton: Arthropoda. http://depts.washington.edu/fhl/zoo432/plankton/plarthropoda/plarthropoda.html. Accessed 11/19/2002.

U.S. Bureau of Labor Statistics. 2002. Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, 2002-03 Edition, Fishers and Fishing Vessel Operators. http://www.bls.gov/oco/ocos177.htm. Accessed 2002.

U.S. Bureau of Labor Statistics. 2004. Consumer Price Index (CPI) data: U.S. Bureau of Labor Statistics, Division of Consumer Prices and Price Indexes. CPI-U, Not Seasonally Adjusted. http://www.bls.gov/cpi/home.htm. Accessed 5/04.

U.S. Census Bureau. 2002. 2000 Census, Summary File 3: United States. Prepared by the U.S. Census Bureau, Washington, DC.

U.S. DOI. 1997. 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of the Census. U.S. Government Printing Office, Washington, DC.

U.S. DOI. 2004. Fisheries: Aquatic and Endangered Resources. U.S. Geological Survey, Great Lakes Science Center. U.S. Department of the Interior. http://www.glsc.usgs.gov/main.php?content=research_risk&title=Species%20at%20Risk0&menu=research. Accessed 6/23/04.

U.S. DOI and U.S. DOC. 2002. 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, U.S. Census Bureau. U.S. Government Printing Office, Washington, DC. October. http://fa.r9.fws.gov/surveys/surveys.html#survey_reports.

U.S. EPA. 1972. Dr. Clarence Tarzwell. Pollution of the Interstate Waters of Mount Hope Bay and its Tributaries in the States of Massachusetts and Rhode Island. Conference Proceedings, Providence, RI, January 6, 1972. Volume 2. NTIS No. PB 230 572. U.S. Environmental Protection Agency, Washington, DC, pp. 591-623.

U.S. EPA. 1977. (Draft) Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 1997. Guiding Principles for Monte Carlo Analysis. EPA/630/R-97/001. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

U.S. EPA. 1998. Product Performance Test Guidelines OPPT 810.3500 Premises Treatments. EPA-712-C-98-413. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA. 2000a. Guidelines for Preparing Economic Analyses. EPA 240-R-00-003. U.S. Environmental Protection Agency, Washington, DC. September.

U.S. EPA. 2000b. Section 316(b) Industry Survey. Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures and Industry Short Technical Questionnaire: Phase II Cooling Water Intake Structures, January 2000 (OMB Control Number 2040-0213). Industry Screener Questionnaire: Phase I Cooling Water Intake Structures, January, 1999 (OMB Control Number 2040-0203).

U.S. EPA. 2002. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. Fifth Edition. Section 11, Acute Toxicity Analysis. EPA-821-R-02-012. U.S. Environmental Protection Agency, Washington, DC, pp. 71-108.

U.S. EPA. 2004a. Chapter B4: RUM Analysis. Section 316(b) Phase II Final Rule – Regional Studies, Part B: California. U.S. EPA.

U.S. EPA. 2004b. Chapter D4: RUM Analysis. Section 316(b) Phase II Final Rule – Regional Studies, Part D: Mid-Atlantic. U.S. EPA.

U.S. EPA. 2004c. Chapter E4: RUM Analysis. Section 316(b) Phase II Final Rule – Regional Studies, Part E: South-Atlantic. U.S. EPA.

U.S. EPA. 2004d. Chapter F4: RUM Analysis. Section 316(b) Phase II Final Rule – Regional Studies, Part F: Gulf of Mexico. U.S. EPA.

U.S. EPA. 2004e. Economic Analysis for the Proposed Section 316(b) Phase III Rule. U.S. Environmental Protection Agency, Office of Water, Engineering and Analysis Division. EPA-XXX-X-XX-XX. November X.

U.S. EPA. 2004f. Great Lakes Program Funding, Mining Ideas 2: A Report on 106 Great Lakes Ecological Protection and Restoration Projects. http://www.epa.gov/glnpo/fund/mining/II/index.html. Accessed 6/23/04.

U.S. EPA. 2004g. National Estuary Program, Which Estuaries are in the NEP? http://www.epa.gov/owow/estuaries/find.htm. Accessed 6/23/04.

U.S. EPA. 2004h. National Estuary Program, Why isn't the Chesapeake Bay in the National Estuary Program? http://www.epa.gov/owow/estuaries/about2.htm#chesapeake. Accessed 8/10/04.

U.S. EPA. 2004i. Regional Analysis Document for the Final Section 316(b) Phase II Existing Facilities Rule. U.S. Environmental Protection Agency, Office of Science and Technology, Engineering and Analysis Division. EPA-821-R-02-003. February 12.

U.S. EPA. 2004j. Technical Development Document for the Proposed Section 316(b) Phase III Rule. U.S. Environmental Protection Agency, Office of Water, EPA-XXX-X-XX-XX. November X.

USFWS. 1978. Development of Fishes of the Mid-Atlantic Bight. An Atlas of Egg, Larval and Juvenile Stages. FWS/OBS-78/12. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

USFWS. 1996a. The Endangered Species Act of 1973. A Summary of the ESA and Implementation Activities. Updated October 1996. U.S. Fish and Wildlife Service. http://endangered.fws.gov/esasum.html. Accessed 10/10/00.

USFWS. 1996b. Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes. U.S. Fish and Wildlife Service, Portland, OR.

USFWS. 2004a. The Endangered Species Program. U.S. Fish and Wildlife Service. http://endangered.fws.gov/index.html. Accessed 6/04.

USFWS. 2004b. Native Species Restoration. USFWS Fisheries, Great Lakes - Big Rivers. http://midwest.fws.gov/Fisheries/topic-nativespecies.htm. 6/23/04.

USFWS. 2004c. Upper Mississippi River Nine-Foot Channel Project: Operation and Maintenance Section 7 Consultation: Pallid Sturgeon. http://midwest.fws.gov/endangered/section7/pallid.pdf. Accessed October 19, 2004.

USFWS. 2004d. Feature Series. The Pallid Sturgeon, a Missouri River 'Dinosaur'. http://www.r6.fws.gov/feature/sturgeon.html. Accessed October 18, 2004.

USFWS and NMFS. 2000. Habitat Conservation Planning and Incidental Take Permit Processing Handbook. U.S. Fish and Wildlife Service and National Marine Fisheries Service. http://endangered.fws.gov/hcp/hcpbook.html. Accessed 3/6/00.

USGen New England. 2001. Variance Request Application and Partial Demonstration Under the Clean Water Act, Section 316(a) and (b) in Support of Renewal of NPDES Permit No. MA 000 3654 for USGen New England, Inc.'s Brayton Point Station. May 24.

Usher, A.J. 1987. Ontario Lake of the woods fishery: Economic and social analysis. *Transactions of the American Fisheries Society* 116:352-366.

U.S. Ocean Commission. 2002. Developing a National Ocean Policy: Mid-term Report of the U.S. Commission on Ocean Policy. September. Available at http://oceancommission.gov/documents/midterm_report/midterm_report.html.

Valiela, I. 1995. Spatial structure: Patchiness. In *Marine Ecological Processes*. Springer, New York, pp. 325-353.

Van den Avyle, M.J. and D.L. Fowler. 1984. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Atlantic) — Blue Crab. U.S. Fish and Wildlife Service Biological Report USFWS/OBS-82/11. U.S. Army Corps of Engineers TR EL-82-4.

Vandenberg, T.P., G.L. Poe, and J.R. Powell. 2001. Assessing the accuracy of benefits transfers: Evidence from a multi-site contingent valuation study of ground water quality. In *The Economic Value of Water Quality*, J.C. Bergstrom, K.J. Boyle, and G.L. Poe (eds.). Edward Elgar Publishers, Northampton, MA.

Van Oosten, J. 1942. The age and growth of the Lake Erie white bass, *Lepibema chrysops* (Refinesque). *Papers of the Michigan Academy of Science Arts and Letters* 27: 307-334.

Varian, H.R. 1992. *Microeconomic Analysis*. 3rd Edition. W.W. Norton, New York.

Vaughan, W.J. and C.S. Russell. 1982. Valuing a fishing day: An application of a systematic varying parameter model. *Land Economics* 58(4):450-463.

Vetter, E.F. 1988. Estimation of natural mortality in fish stocks: A review. *Fishery Bulletin* 86 (1):25-43.

Virginia Tech. 1998. Marine and Coastal Species Information System. Fish and Wildlife Information Exchange. http://fwie.fw.vt.edu/WWW/macsis/index.htm.

Wainger, L.A., D. King, J. Salzman, and J. Boyd. 2001. Wetland value indicators for scoring mitigation trades. *Stanford Environmental Law Journal* 20(2):413-478.

Wallus, R., B.L. Yeager, and T.P. Simon. 1990. Reproductive Biology and Early Life History of Fishes in the Ohio River Drainage, Volume I: Acipenseridae through Esocidae. Tennessee Valley Authority, Chattanooga.

Walsh, R., R.D. Bjonback, T.D. Rosenthal, and R. Aiken. 1985. Public Benefits of Programs to Protect Endangered Wildlife in Colorado. Symposium on Issues and Technology in the Management of Impacted Western Wildlife. Thorne Ecological Institute, Glenwood Springs, CO.

Walsh, R.G., D.M. Johnson, and J.R. McKean. 1990. Nonmarket values from two decades of research on recreation demand. In *Advances in Applied Micro-Economics*, V.K. Smith and A.N. Link (eds.). JAI Press, Greenwich, CT.

Walsh, R.G., J.B. Loomis, and R.A. Gillman. 1984. Valuing option, existence, and bequest demands for wilderness. *Land Economics* 60(1):14-29.

Walsh, R.G., D.A. Greenley, R.A. Young, J.R. McKean, and A.A. Prato. 1978. Option Values, Preservation Values and Recreational Benefits of Improved Water Quality: A Case Study of the South Platte River Basin, Colorado. EPA 600/5 78 001. Socioeconomic Environmental Studies Series, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories. Prepared by the California Dept. of Water Resources, the California Dept. of Fish and Game, the U.S. Bureau of Reclamation, and the U.S. Fish and Wildlife Service. Technical Report 9 (FS/B10-4ATR 86-9). Prepared for the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. January. http://elib.cs.berkeley.edu/kopec/tr9/html/home.html. Accessed 11/01.

Wang, J.C.S. and R.J. Kernehan. 1979. Fishes of the Delaware Estuaries: A Guide to Early Life Histories. E.A. Communication. Ecological Analysts, Inc., Towson, MD.

Wapora. 1979. Impingement and Entrainment Assessment Using the Production Foregone Analysis at J.R. Whiting Plant During 1978. Prepared for Consumers Power Company. October.

Warlen, S.M., A.J. Chester, and M.T. Boyd. 1980. Growth of larval/early juvenile spot, *Leiostomus xanthurus*, in North Carolina. In Anonymous. Annual report of the Southeast Fish Cent. Beaufort Lab., Beaufort, NC, to U.S. Dep. Energy, July 1, pp. 456-472.

Washington Department of Fish and Wildlife. 1997. Washington State Forage Fish. Pacific Herring. http://www.wa.gov/wdfw/fish/forage/herring.htm.

Water Quality Act of 1987. (P.L. 100-4), §317(a)(1)(A) and(B) adding §320 to the CWA, 33, US.C. §1330.

Welle, P.G. 1986. Potential Economic Impacts of Acid Deposition: A Contingent Valuation Study of Minnesota. Dissertation, University of Wisconsin-Madison.

Wey, K.A. 1990. Social Welfare Analysis of Congestion and Water Quality of Great Salt Pond, Block Island, Rhode Island. Dissertation, University of Rhode Island, Kingston.

Whitehead, J.C. and R. Aiken. 2000. An Analysis of Trends in Net Economic Values for Bass Fishing from the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. East Carolina University, Department of Economics, Greenville, NC. April.

Whitehead, J.C. and G.C. Blomquist. 1991a. A link between behavior, information, and existence value. *Leisure Sciences* 13:97-109.

Whitehead, J.C. and G.C. Blomquist. 1991b. Measuring contingent values for wetlands: Effects of information about related environmental goods. *Water Resources Research* 27(10):2523-2531.

Whitehead, J.C. and G.C. Blomquist. 1992. Ex ante willingness to pay with supply and demand uncertainty: Implications for valuing a sea turtle protection programme. *Applied Economics* 24:981-988.

Whitehead, J.C. and P.A. Groothuis. 1992. Economic benefits of improved water quality: A case study of North Carolina's Tar-Pamlico River. *Rivers* 3:170-178.

Whitehead, J.C. and T.C. Haab. 1999. Southeast marine recreational fishery statistical survey: Distance and catch based choice sets. *Marine Resource Economics* 14(4): 283-298.

Whitehead, J.C., G.C. Blomquist, T.J. Hoban, and W.B. Clifford. 1995. Assessing the validity and reliability of contingent values: A comparison of on-site users, off-site users, and non-users. *Journal of Environmental Economics and Management* 29(2):238-251.

Whittington, D., G. Cassidy, D. Amaral, E. McClelland, H. Wang, and C. Poulos. 1994. The Economic Value of Improving the Environmental Quality of Galveston Bay. GBNEP-38, 6/94. Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill.

Wild, P.W. and R.N. Tasto (eds.). 1983. Life History, Environment, and Mariculture Studies of the Dungeness Crab, *Cancer magister*, with Emphasis on the Central California Fishery Resource. Fish Bulletin 172. California Department of Fish and Game.

Williams, J.S. and P.W. Bettoli. 2003. Net Value of Trout Fishing Opportunities in Tennessee Tailwaters. Fisheries Report 03-21. Final Report Submitted to the Tennessee Wildlife Resource Agency.

Wilson, M.A. and S.R. Carpenter. 1999. Economic valuation of freshwater ecosystem services in the United States: 1971-1997. *Ecological Applications* 9(3):772-783.

Wisconsin DNR. 2003. Adrift on the sea of life. *Wisconsin Natural Resources* June:17-21.

Woodward, R.T. and Y.S. Wui. 2001. The economic value of wetland services: A meta-analysis. *Ecological Economics* 37:257-270.