Fish and Other Aquatic Resource Trends in the United States

Andrew J. Loftus and Curtis H. Flather

A Technical Document Supporting the 2000 USDA Forest Service RPA Assessment

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Abstract

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This report documents the general trends in fisheries and aquatic resources for the nation as required by the Renewable Resources Planning Act (RPA) of 1974. The report highlights major trends in water quality, specific fish populations, resource utilization, and imperiled aquatic fauna. Relationships between land use, water quality, and aquatic species conditions are explored. An analysis is provided of a multi-state information sharing initiative (MARIS) that the Forest Service has initiated, along with recommendations for the future. The data for the report came primarily from existing state and federal agency data. The report concludes with the implications of these findings for Forest Service strategic planning.

Keywords: fish resources, national assessment, trends, aquatic species, aquatic habitats, threatened and endangered species.

The Authors

Andrew J. Loftus is a natural resources consultant at 3116 Munz Drive, Suite A, Annapolis, MD 21403, affiliated with the Conservation Management Institute, Department of Fisheries and Wildlife, Virginia Tech University, Blacksburg, Virginia.

Curtis H. Flather is a research wildlife biologist at the USDA Rocky Mountain Research Station, Fort Collins, CO.

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Andrew J. Loftus and Curtis H. Flather

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INTRODUCTION

Aquatic resources historically have been a vital component of the development of what is now the United States. Native Americans and early settlers relied on fish, water, shellfish and other aquatic resources for food and profit and as settlement progressed, these resources influenced the structure and government of a new nation. The resulting high value of fisheries often contributed to their depletion. For example, the first public schools in this country were financed in part through the sale of striped bass[1] by act of the Plymouth colony in 1670 (Setzler and others 1980). However, the pressure to harvest these resources combined with increasing land development began to take its toll on natural resources. Those same populations of striped bass that financed public education became subject to early conservation measures in the new colonies when New York and Massachusetts prohibited sales during the winter of 1776 (Setzler and others 1980). Like the effect that striped bass had on settlement in the northeastern states, every region of this country has in some way been shaped by aquatic resources. Similarly, the status of the resources has been substantially influenced by settlement.

Today, aquatic resources are no less important to economic vitality and growth than during the past 400 years of European settlement. Fish provide a source of protein and recreational opportunities for approximately one-fifth of all U.S. residents and water is vital for consumption, industry, power, and agriculture as well as for healthy aquatic ecosystems.

In balancing the uses of these resources, the vital link that aquatic species provide to the overall stability of aquatic communities and ecosystems is often overlooked. Pacific salmon, for example, play a crucial role in the mass transfer of energy and nutrients between the sea, freshwater, and terrestrial environments (Allendorf and others 1997, Cederholm and others 1999), thereby impacting terrestrial wildlife and freshwater organisms. Decisions that impact these resources have often disregarded these ecological relationships. However, the indirect benefits resulting from the ecological roles that aquatic fauna play may be greater than the direct benefits resulting from consumptive activities (Dailey 1997).

In many cases, the status of aquatic life is the best measure of success in managing the landscape, air, and water quality. A true measure of watershed and ecosystem management is reflected in how programs impact the diversity and biological integrity of aquatic populations. Some policy makers are now recognizing the interactions between landscapes and aquatic systems and incorporating them into programs. “Protection of the Chesapeake Bay starts on the land as well as the water,” noted Governor Parris Glendening of Maryland during the outbreaks of toxic dinoflagellates in portions of the Chesapeake Bay. “The crisis surrounding toxic *Pfiesteria* sharply reminded us of the link between our land and our water and the effect of water quality on our health and livelihoods.”[2] The toxic dinoflagellates that impacted portions of the Chesapeake Bay (attributed to a genus *Pfiesteria* sp.) were thought to be completing a phase of their complex life cycle that is triggered in part by heightened nutrient loads in the waters—in this case from anthropogenic sources. Agricultural practices in the surrounding watershed were initially linked to these nutrients. Governor Glendening was echoing what ecologists, scientists, naturalists and others have known for centuries: Actions on the land ultimately affect the condition of the waterways. The condition of the nation’s waterways and the aquatic fauna are in fact an indicator of the activities that take place in the surrounding watershed and airshed.

Today, many fish species and other aquatic ecosystem components face serious threats. Scientists have learned much about maintaining and restoring healthy aquatic ecosystems as sociologists, managers, and policy makers have more clearly identified the benefits that healthy ecosystems provide to people and the national economy. Restoring and maintaining healthy ecosystems requires political and economic support as well as technical knowledge. Applying these three factors to restore aquatic resources has often resulted in tremendous success as documented in several case studies presented in this report.

PURPOSE

This report is authorized under the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) as amended by the National Forest Management Act of 1976. The RPA directs the Forest Service to prepare periodic national assessments of the current and expected natural resource situation on all of the nation’s forest and range lands. Fish and other living aquatic resources, and the habitats on which they depend, are an important aspect of these resource assessments, particularly as managers move to a more holistic ecosystem approach. The RPA directs that an assessment of resources and utilization

[1] Scientific names of all species mentioned in this report are found in Appendix A.

[2] State of the State Address, January 21, 1998.

occurring on *all* lands be conducted, not just on lands managed by the USDA Forest Service. Therefore, case studies and population assessments are provided here for a variety of lands, including near-shore marine species to a limited extent.

This report is *not* a detailed accounting of the status of every aquatic resource in the United States and as such differs from some other resource assessment documents prepared for the RPA. As we discuss later, the information to make such analyses and determinations is incomplete and difficult to access. This report does focus on the general condition of aquatic habitats, species, and usage trends as reflected by the results of select surveys and data collection efforts. Supplementing this are case studies (figure 1) that provide examples of some of the impacts of an integrated approach to managing aquatic systems that encompasses management of the landscape, fish populations, and human utilization of fish stocks. We highlight successes, as well as failures, of fisheries management programs that incorporate a holistic land use component. Intertwined throughout the document and highlighted in special sections are the economic and social importance of maintaining healthy aquatic ecosystems.

FEDERAL AUTHORITIES IN RESOURCE MANAGEMENT

Federal management of aquatic species, codified in law, began to increase in the early 1900s, but it wasn't until late in the century that it began to receive significant attention from the legal community (Bean 1983). A plethora of legislation, administrative rules, and supporting judicial rulings serves to provide the legal foundation for federal interest in fishery resources. Most of this legal foundation focuses on management of habitat on federal lands or waters, endangered species, and the interstate commerce (interjurisdictional fisheries) and treaty provisions of the Constitution.

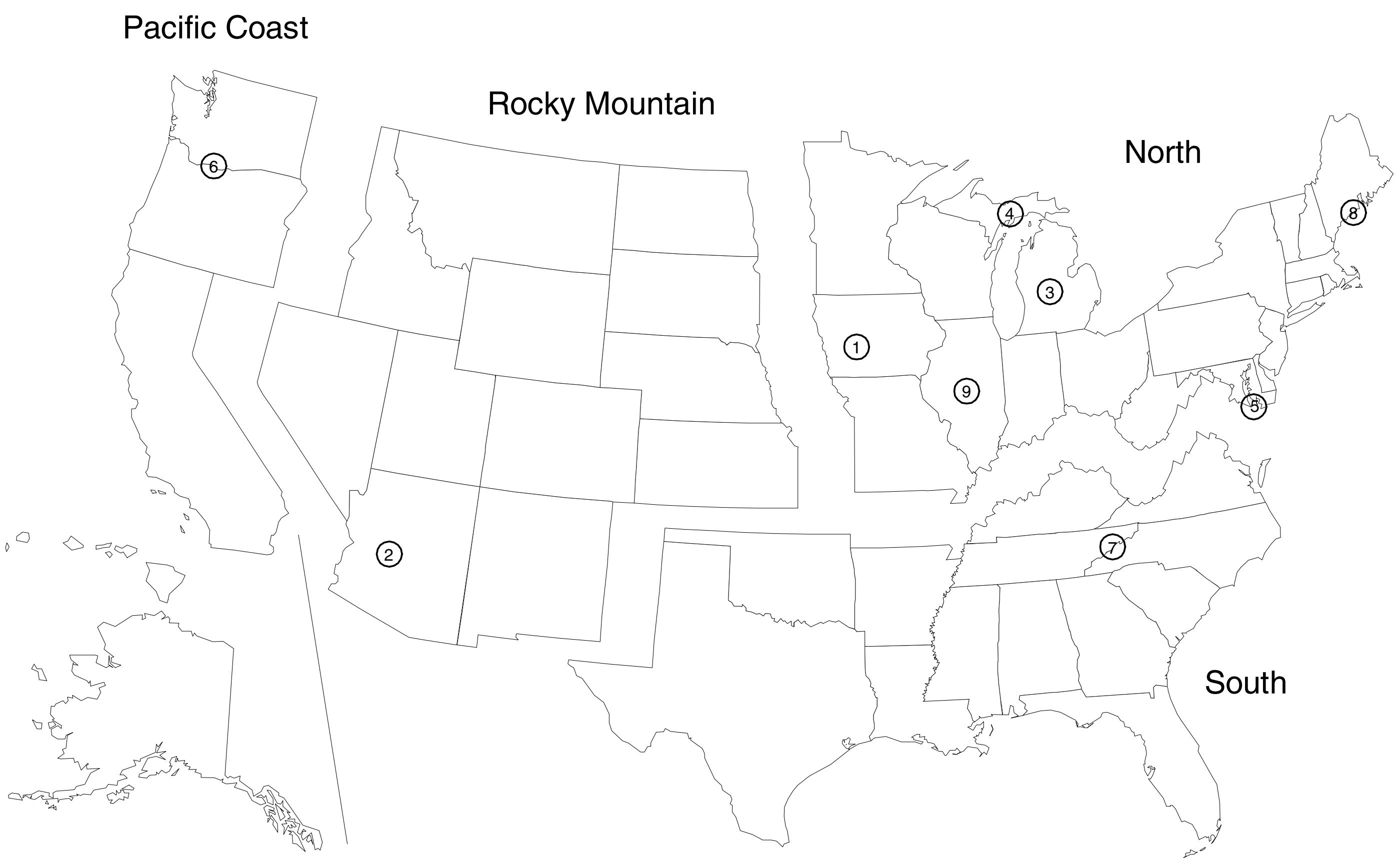


Figure 1—Location of case studies found in the RPA Fisheries Assessment. Numbers cross-reference case studies as they appear in the document. Case Study 9 actually includes the states of Illinois, Iowa, Michigan, Minnesota, Ohio, and Wisconsin.

Passage of the Lacey Act (16 U.S.C. 667e) in 1900 set the stage for cooperative federal/state management of aquatic resources and the process of defining the respective federal and state roles in management of wildlife populations (Bean 1983). While the Lacey Act enlists federal enforcement of state game laws in interstate commerce of wildlife, the states themselves retain authority over establishing those laws. The Lacey Act, as strictly interpreted, applies only to terrestrial wildlife, not to fish, and it wasn't until 1926 when Congress passed the Black Bass Act (16 U.S.C. 851-856) that the interstate transportation of fish taken in violation of state law was explicitly prohibited under federal authority. These two pieces of legislation were subsequently consolidated into a single law through the Lacey Act Amendments of 1981 (PL 97-79, 95, Stat. 1073).

Cases where a fish species migrates through two or more states constitutes interjurisdictional fisheries. To date, the federal government's role in such fisheries has been primarily to facilitate coordinated state management of these species. The Interjurisdictional Fisheries Act of 1986 (16 U.S.C. 4101; P. L. 99-659, title III, Sec. 302, Nov. 14, 1986, 100 Stat. 3732) was implemented "(1) to promote and encourage State activities in support of the management of interjurisdictional fishery resources; and (2) to promote and encourage management of interjurisdictional fishery resources throughout their range" (16 U.S.C. 4101). Passage of this legislation established a funding mechanism for states to receive support on a cost-sharing basis for activities involving cooperative interstate management of fishery resources.

In most cases, federal legislation works with state programs using incentives to facilitate interstate management of fisheries. The Atlantic Striped Bass Conservation Act of 1984 (PL 98-613) combines incentives with a mandate that the Atlantic coastal states implement the conservation and management provisions of the interstate fishery management plan for striped bass. Although this plan was developed by the states in 1981 under the auspices of the Atlantic States Marine Fisheries Commission (ASMFC), full implementation of the plan had not been achieved prior to passage of this Act. Following passage of this Act (which provides for a federally imposed and enforced moratorium on fishing for, or harvesting, striped bass in jurisdictional marine waters of a state that is not in compliance with the plan), full implementation was quickly achieved and maintained. The results of this successful interstate management and habitat restoration on striped bass populations are detailed in a later case study.

Based on the success of the Atlantic Striped Bass Conservation Act, in 1993 the Atlantic Coast Cooperative Fishery Management Act (16 U.S.C. 5101) was enacted into law. This is similar to the striped bass legislation but applies to any species for which the states, under the auspices of the ASMFC, have developed a fishery management plan. Any state that is found out of compliance by the ASMFC is referred to the Secretary of Commerce, who then begins proceedings for imposing a federal moratorium on fishing for that particular species in that state's waters.

The history of the federal role in managing aquatic species on federal land is founded in the same laws as wildlife law. Various legislation such as the Sikes Act (16 U.S.C. 670a-670f) and Sikes Act Extension (16 U.S.C. 670g-670o) for military lands, Classification and Multiple Use Act of 1964 (16 U.S.C. 1411-1418 for Bureau of Land Management), National Environmental Policy Act of 1969 (42 U.S.C. 4321-4361), and the National Wildlife Refuge Administration Act of 1966 (16 U.S.C. 668dd - 668ee) clearly establish the interest of managing resources on various federal lands. Significantly, for the USDA Forest Service, 16 U.S.C. 694 (Fish and Game Sanctuaries on National Forests) provides for the establishment of preserves "devoted to the increase" of populations of "fish of all kinds" on Forest Service property, but only upon the approval of the legislature in the state in which that forest is located.

Federally controlled waters (exclusive of those designated as National Parks, preserves, sanctuaries, or other special classifications) generally extend from three miles offshore to a distance of 200 miles offshore. The Magnuson Fishery Conservation Management Act of 1976 (16 U.S.C. 1801–1882) claims these waters and the ocean bottom as part of the U.S. Territorial Sea. The Magnuson-Stevens Act (as amended in 1996) provides for federal management of fisheries occurring predominantly in these waters and throughout the range of the fish species. The 1996 amendments to this law greatly expand federal responsibility in habitat issues that are essential to the life cycle of these fish. Federal interest in restoring and enhancing habitat of the nation's coastal waters is also embodied in the Coastal Zone Management Act of 1972 (16 U.S.C. 1451-1464), which is designed to "preserve, protect, develop and where possible, restore or enhance the resources of the nation's coastal zone for this and succeeding generations."

The authority for entering into treaties with foreign governments is preserved with the federal government through Article II and Article III of the U.S. Constitution. Many fishery resources migrate through the jurisdictions of foreign nations. These species include Pacific salmon, Atlantic salmon, and numerous highly migratory pelagic species (tunas, billfishes) among others. Achieving coordinated management of these species often requires entering into agreements with foreign nations. The International Commission for the Conservation for Atlantic Tunas, the North Atlantic Salmon Conservation Organization, and the U.N. Law of the Sea are just a few of such agreements. Additionally, as Native American nations are considered sovereign entities, the U.S. government retains the authority to enter into treaties for the management of aquatic species that transcend reservation boundaries.

TRENDS AND IMPACTS OF AQUATIC HABITAT

Status

Although ecologists have long known that aquatic systems can be impacted by forces originating far from the habitat where organisms live, only recently has the term "ecosystem management" been applied to their management. Trends in both habitat and the broader ecosystem provide the most accurate depiction of the status of aquatic systems. Since wetland and terrestrial habitat trends are discussed in a companion report (Flather and others 1999), the following discussion will detail more of the broad aquatic habitat and ecosystem conditions.

While no national survey accurately depicts the true condition of the nation's waterways, analysis of a variety of attributes provides a status of water resources and in some cases can provide an indication of how water resources have changed over time. In the United States, there are 3.5 million miles of streams (approximately two-thirds perennial), 41 million acres of lakes and reservoirs, 34,400 square miles of estuaries (excluding Alaska),and approximately 300 million acres of wetlands (170–200 million acres of those in Alaska) (Environmental Protection Agency 1996). The 191 million acres of National Forest System lands contain 128,000 miles of fishable streams and rivers, over 2.2 million acres of lakes, ponds and reservoirs, and 12,500 miles of coast and shoreline. Similarly, the USDI Bureau of Land Management manages over 168,000 miles of streams and more than 2.5 million acres of lakes and reservoirs. Other federal agencies manage lesser amounts of waters (table 1).

In terms of water quality, 70% of the nation's assessed river miles, lake acres, and estuarine area (square miles) can support the "aquatic life use" designated under the Clean Water Act (EPA 1996). However, significant physical alterations in water bodies and watercourses including construction of new reservoirs have greatly altered aquatic habitat availability and water quality since European settlement. An indication of how six commonly used indices of surface water quality have changed during the decade of 1980–1989 is provided in figure 2. An upward trend for dissolved oxygen is typically a sign of improving water quality while an upward trend in the other constituents is typically a sign of degrading water quality. In five of the six parameters (dissolved solids, fecal coliform, suspended sediment, and the nutrients of phosphorous and nitrates), a greater percentage of sites exhibited trends in conditions typically indicative of "improved water quality" (declining concentrations of these constituents) than those showing degraded conditions. The same trend is true for dissolved oxygen, where a greater

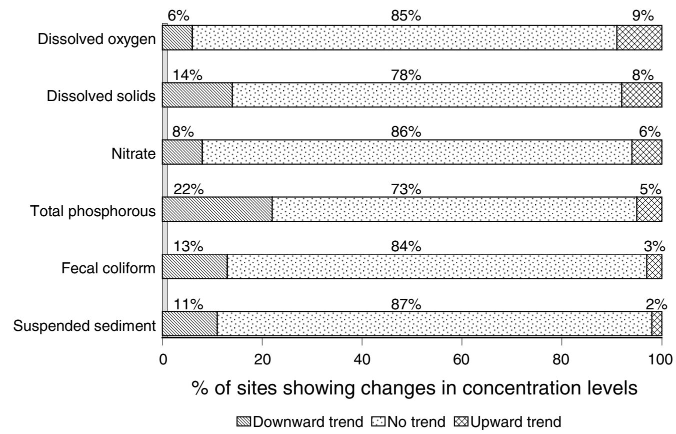


Figure 2—Trends in surface water pollutants in the United States, 1980–1989. Note that an upward trend indicates an increase in the concentration while a downward trend indicates a decrease in the concentration. An upward trend in dissolved oxygen is typically an indicator of improving water quality while an upward trend in other variables is typically an indicator of degrading water quality (Environmental Protection Agency 1996).

portion of the sites exhibited trends typically associated with higher water quality (i.e., higher dissolved oxygen) than sites that exhibited reduced water quality (lower dissolved oxygen).

Land and Water Impacts on Aquatic Habitats

Many of the changes in the waterways of this nation have come through alterations of free flowing rivers, either through channelization, damming, diversions, or dewatering. Of the more than three million miles of streams in the lower 48 states, only 2% remain in the condition that qualify them for potential designation as wild and scenic (Wilcove and Bean 1994, Benke 1990); the remaining 98% have dams, water diversions, or significant development (Wilcove and Bean 1994, Benke 1990, Noss and Peters 1995), thereby significantly altering those ecosystems from historical conditions.

One of the most significant threats to the quality of aquatic habitat for supporting fish and other aquatic life is increased turbidity (Judy and others 1982), most often caused by increases in sediment input. Siltation is the primary pollution problem threatening U.S. waterways (Southern Appalachian Man and the Biosphere [SAMAB] 1996). While siltation is a natural physical process and a certain amount of sediment from natural erosion is

Table 1—Aquatic resources, recreational angling use and associated economic impact on select federal lands. Estimates of Forest Service "Angler Use" and "Angler Economic Impact" cannot be compared to other agencies' estimates for these categories due to differences in methodology.

Agency (year of estimate)	Streams	Lakes/ponds/ reservoirs	Coastal	Angler use[a]	Angler economic impact
Bureau of Land Management (1990)[b]	168,697 miles	2.4 million acres of natural lakes; 172,746 acres of reservoirs		7.2 million angler use days	$220.9 million expenditures; 342.4 million output; 7,125 jobs
National Park Service (1989)[9]	33 National Parks, 18 Recreation Areas, 14 Seashores, 14 Wild & Scenic Rivers with fishing.			7.5 million angler use days	$231.2 million expenditures; $358.3 million output; 7,458 jobs
Fish & Wildlife Service (1986-87)[b]	2 million acres with recreational fishing opportunities			5.4 million angler use days	$137.2 million expenditures; $212.5 million output; 4,425 jobs
Bureau of Reclamation (1990)[b]		1.69 million acres of reservoirs	13,054 shoreline habitat	27.1 million angler use days	$836.3 million expenditures; $1.3 billion output; 26,979 jobs.
Bureau of Indian Affairs (1991)[b]	15,154 perennial streams	985,591 acres of natural lakes/ ponds		15 million angler use days	$462.4 million expenditures; $716.7 million output; 14,912 jobs
Forest Service (1996)[c]	128,000 miles	2.2 million acres	12,500 shoreline miles	46.8 million freshwater fishing days	$2.9 billion expenditures; $8.5 billion output; 95,718 FTE jobs.

[a] Angler use day=4 hours. Freshwater fishing day is any portion of a day spent fishing.
[b] Sport Fishing Institute 1993*a*.
[c] Maharaj and Carpenter 1999.

normal, accelerated sediment runoff caused by human activities can cause severe negative impacts to aquatic life. Land use activities that increase soil erosion will increase sedimentation in the waterways and exacerbate negative impacts on the aquatic system (see accompanying Case Study 1). Between 675 million and one billion tons of eroded agricultural soils are deposited in waterways each year, causing water damages estimated as high as $16 billion annually; agriculture is the single largest source of this nonpoint pollution in the United States (National Biological Survey 1995). There is some indication that the sedimentation is improving, however. In nationwide sampling, the percentage of sites showing reduced sedimentation (11%) during the 1980s exceeded the number of sites exhibiting worsening sediment conditions (2%), although the vast majority (87%) still showed no change (figure 2).

Sediment inputs degrade water quality for both fish (Karr 1981) and invertebrates (Penrose and others 1980, Lenat and Crawford 1993). Impacts to aquatic habitat and biota include excessive siltation on spawning substrate, increased water temperatures, nuisance vegetation, low dissolved oxygen levels, and unstable stream flows (Pajak 1990, National Biological Survey 1995).

One of the principal negative factors related to sediment deposition is nutrient loading, especially nitrogen and phosphorous, contained in surface waters via runoff (National Biological Survey 1995). Runoff from agricul-

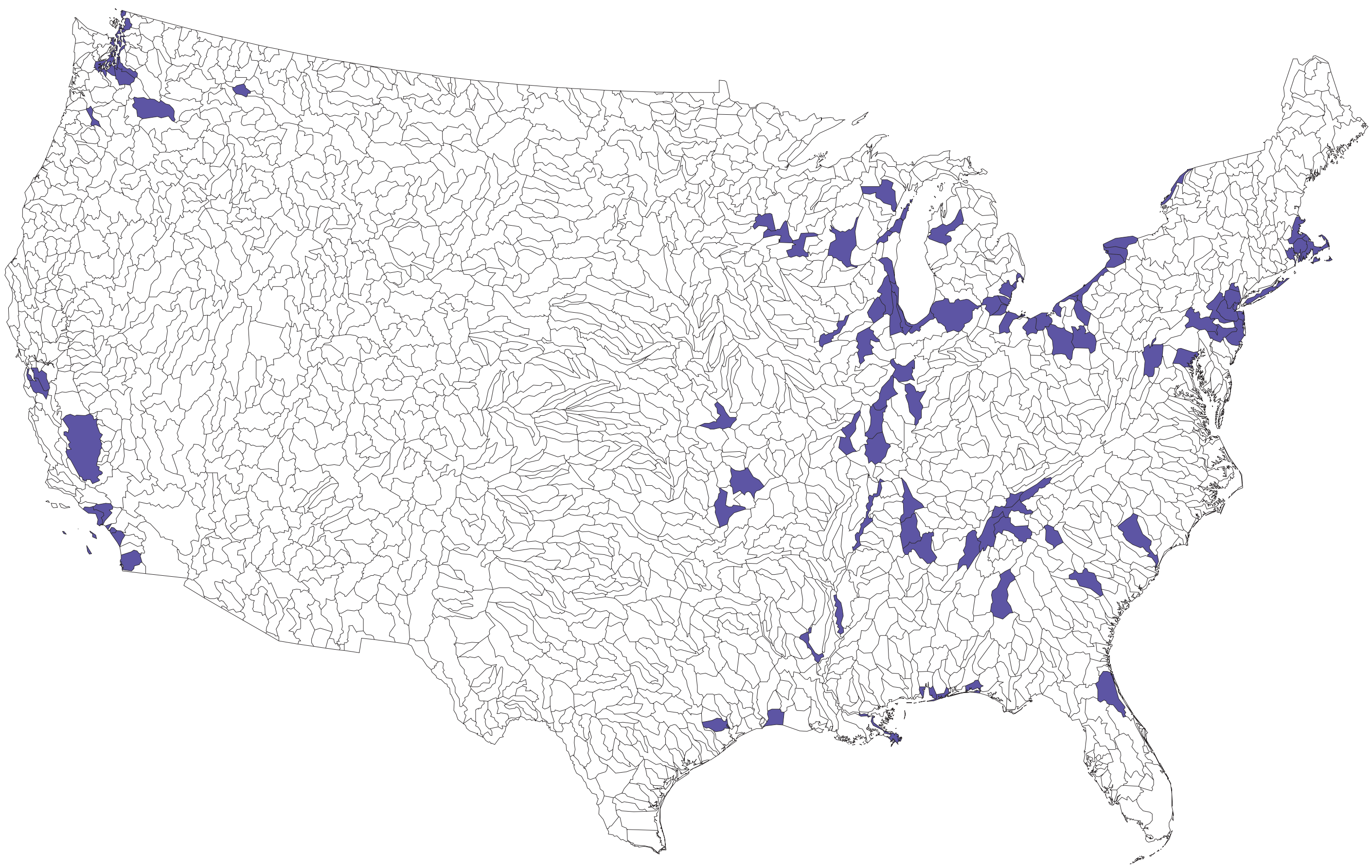


Figure 3—Watersheds of "probable concern" (Environmental Protection Agency 1998).

ture, urban areas, timber-related activities, construction, and road building may cause enrichment of waterways through the addition of nutrients and sediment within this runoff (Klein 1985, Lenat and Crawford 1994). Both sediment and nutrient (nitrogen and phosphorous) indices indicated a greater percentage of sites with improving conditions than deteriorating conditions during the 1980s although the majority have remained unchanged (figure 2).

Some land management activities can be implemented to reduce both sediment (see Case Study 2) and nutrient input into aquatic systems. Studies have shown that riparian "filter strips" reduce nutrients, such as nitrogen and phosphorus, in agricultural runoff by up to 80% (National Biological Survey 1995). The effect of this on fish populations can be quite dramatic. The addition of filter strips on agricultural lands surrounding waterways in Wisconsin has the potential to increase the amount of habitat suitable for brook trout by 68%, northern pike by 174%, and smallmouth bass by 30% (Pajak 1990, National Biological Survey 1995).

Sediment input and runoff can carry with it contaminants from the surrounding watershed that can remain trapped in sediments indefinitely, particularly in closed lentic systems. The EPA (1998) found that sediment contamination exists in every region and every state of the country. More than two-thirds of the 1,363 watersheds surveyed have fish consumption advisories and approximately 10% of the sediment underlying U.S. surface waters poses potential risks to fish consuming wildlife (including humans). Many of these contaminants were introduced years ago and persist in the environment today. Seven percent (96) of the watersheds surveyed by the EPA were classified as "areas of probable concern" (figure 3). Such a designation indicates that 10 or more sites within the watershed had contaminant levels where adverse environmental or health effects "are probable" based on a weight-of-evidence approach.

In addition to degradation of waterways through sedimentation, a variety of other human-induced factors degrade the quality of aquatic systems. Among land-based activities leading to long recovery times for depleted aquatic organisms are channelization, forest spraying, mining activity, and timber harvesting activity within watersheds (Niemi and others 1990). After an evaluation of numerous studies, Niemi and others (1990) concluded that some fish populations still had not recovered from declines in over 52 years. The channelization of waterways for purposes such as navigation, flood control, or land drainage contributed to the longest of these recovery times and also resulted in increased sedimentation, increased variability in flows, and subsequently altered habitat conditions precluding restoration of aquatic life.

Contaminant Advisories

In some ways, the quality of waters can be reflected in the safety for human consumption of the fish coming from those waters. The cleaner the waters become, the fewer advisories we would expect to see and conversely, the more polluted waters become, the more fish consumption guidelines we would expect. However, several problems confound this interpretation of fish consumption advisories. The lack of uniform criteria for establishing advisories hinders the comparison of information from various state, tribal, and federal agencies, making information difficult, if not impossible, to compare. Second, as technology advances and the ability to detect smaller levels of contaminants increases, we may expect scientists to begin to detect pollutants that have existed undetected in those waters for decades if not centuries. In addition, some states are being extremely protective of public health by erring on the side of safety and issuing advisories where they had not in the past, often as an effort to minimize potential litigation. All of these factors, if not accounted for in the interpretation of advisory trends, may lead to erroneous conclusions regarding the actual trends in the quality of our waters.

The U.S. Environmental Protection Agency has taken initial steps to catalog and track the number of fish consumption advisories that are issued by state and federal agencies each year. The number of water bodies currently under an advisory represents 15% of the nation's total lake acres and 5% of the nation's total river miles. In addition, 100% of the Great Lakes and connecting waters have advisories for some type of contaminant. In 1996, the number of advisories increased from the previous year for four of 37 contaminants: PCBs, chlordane, mercury, and DDT, although this *may* only indicate an increase in the incidence of detection rather than an increase in contamination. Ninety-six percent of the advisories were for mercury contamination (EPA 1996).

Wetland Habitats

Wetlands form a critical link in the life stages of numerous fish. Functions of wetlands include spawning habitat for fish, refuge areas and nursery areas for young fish, production of food as a basis for aquatic food chains (zooplankton, etc.), flood control, recharging aquifers, erosion control, habitat for birds and other animals, and filters for sediments, nutrients, and contaminants. The timing of inundation is also very important for the survival of particular fish species. To some species, such as the northern pike, wetlands serve as spawning and nursery areas for a short period of time in the early spring. The absence of water from these ephemerally flooded lands in other periods of the year does not lessen the usefulness of these wetlands to the survival of the species. Furthermore, wetlands fulfill similar vital roles in the life history of most fish species in near-shore marine environments. It is estimated that 75% of all estuarine finfish and shellfish species of recreational and commercial value depend on tidal marshes for food and habitat (Chambers 1992, Scodari 1997). Among regions, the value of wetlands to these species may vary, with 18 to 94% relying on wetland habitats (table 2; Chambers 1992). Nationwide, the EPA's Environmental Monitoring and Assessment Program (EMAP), which sampled 50% of the nation's coastal estuaries, found that 74% of the estuaries sampled have "healthy" aquatic communities (Environmental Protection Agency 1996).

Table 2—Percent of commercial marine fish species occurring in various geographic areas that depend on estuarine habitats (Chambers 1992).

Northeast	41	Southwest	18
Chesapeake Bay	78	Northwest	52
Southeast	94	Alaska	76
Gulf of Mexico	98		

However, more than one-half of the 221 million acres of wetlands that existed in the contiguous United States prior to European colonization have disappeared with slightly more than 100 million acres remaining today (USGS 1997[3]). As is documented in a companion report (Flather and others 1999), the rate of wetland loss has declined overall and the principal activities contributing to wetland loss has shifted from agriculture to urbanization. The majority (85%) of the losses were freshwater (palustrine) wetlands.

While the economic benefits of wetlands are not easily measured, it is certain that they play a major role in the economy of the nation. On the west coast of Florida, each additional acre of wetland produced a value of $79.60 for the recreational fishery based on a willingness to pay model (Bell 1989). Raphael and Jaworski (1979) rated the net value of habitat such as wetlands for sport fishing

[3] USGS. 1997. National water summary on wetland resources. USGS Water Supply Paper 2425 (http://water.usgs.gov/).

along the Michigan coast as $286/acre. Studies in the Chesapeake Bay rated the economic loss that would result from an 80% reduction in areas of submerged aquatic vegetation at over $8 million (Kahn and Kemp, 1985).

Although federal programs historically promoted the filling or draining of wetlands (Scodari 1997) for the purposes of agriculture, settlement, and other human activities, much has changed in current day legislation. Many federal activities are now attempting to reduce the loss of wetlands. Major legislation such as Swampbuster, the Clean Water Act (and revisions), the Federal Aid in Sport Fish Restoration Act, the Coastal Barrier Resource Act, and the Coastal Zone Management Act that contain components designed to prevent the destruction of wetlands or assist states in implementing programs to prevent the destruction of wetlands and restore degraded wetlands. Federal agencies are now spending considerable funds to reestablish and protect these lands. In 1992, 18 federal agencies were conducting wetlands research with expenditures totaling approximately $63 million (see footnote 3). Since revisions to the Federal Aid in Sport Fish Restoration Act were implemented in 1992, grants have been made available through the Coastal Wetlands Conservation Grant Program to states to implement wetlands conservation and restoration projects. Twenty-four states have received funding between 1992 and 1997 for a total of 96 projects which directly affect nearly 52,000 acres. Of this total, 42,000 acres have been acquired for protection against activities that might degrade them. (USDI Fish and Wildlife Service 1997).

TRENDS IN POPULATIONS

Inland and Freshwater Species

There are approximately 800 freshwater fish species in the United states (Southern Appalachian Man and the Biosphere 1996). While we know that some species such as Atlantic and northwest Pacific salmon, paddlefish, and sturgeon (Atlantic, shortnose, and lake) have declined, we cannot describe beyond select case-by-case scenarios the status of the majority of most species. Simply counting the number of species, or observing fish assemblages, will not necessarily reflect the integrity of ecosystems. There are more fish species in the Colorado River today than before European settlement due to introductions of nonnative species (Wilcove and Bean, 1990), but this does not necessarily indicate a greater biodiversity or ecosystem stability.

Direct measurements allowing the analysis of trends in aquatic species populations on a nationwide, or regionwide, basis are generally not available. This is particularly true in freshwater fisheries. Data on aquatic species are generally collected as needed for management purposes and long-term data sets, particularly as they relate to quantitative status and trends, are rare. Additionally, state agencies typically collect the majority of fish population information and each state's data collection, analysis, and management are tailored to their needs. Therefore, data may not be compatible with other agencies. Even within states, a data system is often not established for the purpose of compiling data over larger geographic areas. Commonly, trend information is not collected until species are in need of conservation (which therefore tends to focus on species in decline) or in cases where the attempted restoration of populations is occurring. These situations can often provide valuable insight into aquatic species' conditions and the potential (or lack thereof in some cases) for restoring specific stocks in contemporary aquatic environments (Case Study 3). In select cases of inland waters where coordinated management (such as recovery efforts) has occurred, better information may exist. In the Great Lakes, for example, where lake trout restoration has been a cooperative effort between the states, Native American tribes, and the U.S. and Canadian governments, population trends can be documented (Case Study 4).

Marine and Estuarine Species

Since this report focuses on species that may be directly impacted by land use activities, an in-depth analysis of the status of marine fisheries is not provided. However, certain life stages of many marine fish species (particularly those occurring near-shore) and all anadromous species can be impacted by land use and therefore, will be addressed briefly.

Although some marine fish stocks (mostly high profile or popular species) have been studied extensively and much is known about their populations, generally quantitative population information on marine fisheries is lacking or poor. The National Marine Fisheries Service and the regional fishery management councils established under the Magnuson Act have begun to conduct better assessments and analyses to rectify this. In general, of the 163 U.S. marine fisheries whose biological status could be assessed, 40% were classified as over utilized and 43% were fully utilized (USDC 1996) in 1993. Table 3 provides

Table 3—Status of select Atlantic fishery resources (USDC 1998*a*).

Species	Stock status
Striped Bass	Recovered
Summer Flounder	Overfished
Winter Flounder	Overfished
Weakfish	Overfished
Bluefish	Overfished
Scup	Overfished
Black Sea Bass	Overfished
Atlantic Croaker	Overfished
Red Snapper	Overfished
Spiny Dogfish	Overfished
Gulf of Maine Cod	Overfished

the status of some of the high- profile near-shore species occurring in the mid-Atlantic.

Management agencies have begun to realize the benefits of cooperatively managing interjurisdictional species (see Case Study 5) and in coordinating data collection and data management efforts. Additionally, the implementation of federal legislation, particularly on the Atlantic coast, along with cooperative data sharing programs between states on the Pacific and Gulf coasts, has fostered cooperative management. Recent amendments to the Magnuson Act (now referred to as the Magnuson-Stevens Act) have spurred cooperation between federal and state agencies by emphasizing the need for information on the "essential fish habitat" parameters for each fish species and requiring that these be incorporated into management plans. Each of these efforts will lead to improved refinement of knowledge on the status and trends of marine fisheries in general and the factors behind the trends.

The status of Pacific salmonids has perhaps received more attention, and dedicated fiscal resources, than any anadromous fisheries issue in the United States. The range of the five species of Pacific salmon that spawn in the United States extends from San Francisco Bay, California, northward along the Oregon, Washington, British Columbia, and Alaska coastlines, and southward into the coastal waters of Japan and Korea in the western Pacific (Groot and Margolis 1991). Pacific salmon in the northwest states of the contiguous United States are declining and are highlighted in Case Study 6. Fifteen distinct population segments of Pacific salmon and anadromous trout in the Pacific northwest region are listed as either threatened or endangered under the Endangered Species Act of 1973 (table 4; Dandelski and Buck 1998). However, Baker and others (1996) noted that the condition of stocks of Pacific salmon in southeast Alaska is generally perceived to be "good." Even in this area, the lack of data presents obstacles to evaluating salmon, with only 10% of the "spawning aggregates" in southeast Alaska having sufficient data to

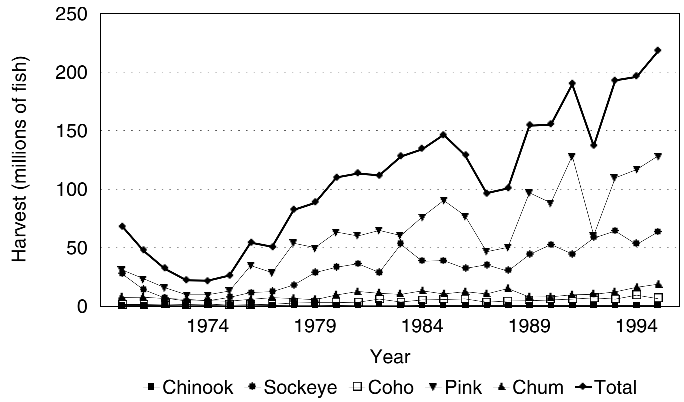


Figure 4—Harvest of Pacific salmon from Alaska waters (Alaska Department of Fish and Game. Alaska Commercial Salmon Harvest 1970–2995. http://state.ak.us/local/akpages/fish.game/adfgame).

allow status evaluation using escapement (total number of salmon returning to spawning areas) indices (Baker and others 1996). If we accept the evaluations of 10% of the stocks as being a representative sample of the entire salmon stocks in this region of Alaska, then several inferences can be made.

Alaskan salmon are currently experiencing high levels of productivity and abundance. Since the 1970s, salmon harvests in Alaska have greatly increased (figure 4; Baker and others 1996). Only two out of 2,296 spawning aggregates surveyed in southeast Alaska were rated as at a "high risk of extinction" compared to 146 out of 201 aggregates evaluated in the Pacific northwest (Baker and others 1996). Using the Washington State Salmon and Steelhead Inventory to allow comparable estimates between Alaska and Washington, less than 1% of the identifiable salmon stocks in southeast Alaska were at high or moderate risk of extinction as compared to 15% of the total stocks in Washington (Baker and others 1996).

The relatively favorable status of salmon stocks in southeast Alaska is primarily attributable to: 1) relatively pristine and undeveloped habitats; 2) habitat and salmon management policies in Alaska; 3) enhancement by hatcheries; 4) favorable environmental conditions in the streams; and 5) favorable marine conditions that have contributed to higher survival rates (Baker and others 1996). Alaska's constitution mandates that a sustainable yield of fish be maintained, providing somewhat more definitive management authority for closing or restricting a fishery when biologists determine this is needed (Baker 1995). At present, the most immediate threat to salmon productivity in southeast Alaska is the loss of spawning and rearing habitat in natal streams. The activity posing the greatest threat to this habitat is logging, although urbanization and mining also are having an impact (Baker and others 1996).

Table 4—Status of spawning populations of six species of Pacific northwest salmonids (Dandelski and Buck 1998).

Species	Population (ESU[a])	Status (E-Endangered; T-Threatened)	FR citation	Pending actions
Coho salmon (*Oncorhynchus kisutch*)	1. Central CA	Threatened	1. 61 FR 56138 Oct. 31, 1996	➢ Complete final critical habitat designations for listed ESUs by October 1998
	2. Southern OR/Northern CA Coasts	Threatened	2. 62 FR 24588.May 6, 1997	
	3. Oregon Coast	Threatened	3. 63 FR 42587 Aug. 10, 1998	
	4. Puget Sound/Strait of Georgia	Candidate	4. 60 FR 38001 July 25, 1995	➢ Complete listing assessments for candidate ESUs by December 1998
	5. Southwest WA/Lower Columbia River	Candidate	5. 60 FR 38001 July 25, 1995	
Chinook salmon (*Oncorhynchus tshawytscha*)	1. Sacramento River Winter-run	Endangered	1. 55 FR 12832 April 6, 1990 55 FR 49623 Nov. 30, 1990 59 FR 13836 March 23, 1994	
	2. Snake River Fall-run	Threatened	2. 57 FR 14653 Apr. 22, 1992	
	3. Snake River Fall-run to include the Deschutes River populations	Proposed (T)	3. 63 FR 11481 March 9, 1998	➢ NMFS issued a proposal to redefine the Snake River fall-run to include the fall Deschutes River populations
	4. Snake River spring/summer-run	Threatened	4. 57 FR 14653 Apr. 22, 1992 59 FR 13836 March 23, 1994	
	5. Central Valley spring-run	Proposed (E)	5. 63 FR 11481 March 9, 1998	➢ Complete final listing determinations and critical habitat designations for proposed ESUs by March 1999
	6. Upper Columbia River spring-run	Proposed (E)	6. 63 FR 11481 March 9, 1998	
	7. California Central Valley fall-run	Proposed (T)	7. 63 FR 11481 March 9, 1998	
	8. Southern Oregon/Northern CA coasts	Proposed (T)	8. 63 FR 11481 March 9, 1998	
	9. Puget Sound	Proposed (T)	9. 63 FR 11481 March 9, 1998	
	10. Lower Columbia River	Proposed (T)	10. 63 FR 11481 March 9, 1998	
	11. Upper Willamette River	Proposed (T)	11. 63 FR 11481 March 9, 1998	
Chum salmon (*Oncorhynchus keta*)	1. Hood Canal summer-run	Proposed (T)	1. 63 FR 11773 March 10, 1998	➢ Complete final listing determinations and critical habitat designations for proposed ESUs by March 1999
	2. Columbia RiverProposed (T)	Proposed (T)	2. 63 FR 11773 March 10, 1998	
Sockeye salmon (*Oncorhynchus nerka*)	1. Snake River	Endangered	1. 56 FR 58619 Nov. 20, 1991	➢ Complete final listing determination and critical habitat designation for Ozette Lake ESU by March 1999
	2. Ozette Lake	Proposed (T)	2. 63 FR 11750 March 10, 1998	
	3. Baker River	Candidate	3. 63 FR 11750 March 10, 1998	➢ Complete listing assessments for candidate ESU by March 1999
Steelhead trout (*Oncorhynchus mykiss*)	1. Southern California	Endangered	1. 62 FR 43937 Aug. 18, 1997	➢ Complete final critical habitat designations for listed ESUs by March 1999
	2. South-Central California Coast	Threatened	2. 62 FR 43937 Aug. 18. 1997	
	3. Central California Coast	Threatened	3. 62 FR 43937 Aug. 18. 1997	
	4. Upper Columbia River	Endangered	4. 62 FR 43937 Aug. 18. 1997	
	5. Snake River Basin	Threatened	5. 62 FR 43937 Aug. 18. 1997	
	6. Lower Columbia River	Threatened	6. 63 FR 13347 Mar. 19, 1998	
	7. Central Valley	Threatened	7. 63 FR 13347 Mar.19, 1998	
	8. Upper Willamette River	Proposed(T)	8. 63 FR 11797 Mar. 10, 1998	
	9. Middle Columbia River	Proposed(T)	9. 63 FR 11797 Mar. 10, 1998	
	10. Northern California	Candidate	10. 63 FR 13347 Mar.19, 1998	➢ Complete listing assessment for candidate ESUs by March 1999
	11. Klamath Mountains Province	Candidate	11. 63 FR 13347 Mar.19, 1998	
	12. Oregon Coast	Candidate	12. 63 FR 13347 Mar. 19, 1998	
Sea-run cutthroat trout (*Oncorhynchus clarki clarki*)	1. Umpqua River (Oregon)	Endangered	1. 61 FR 41514 August 9, 1996	➢ Re-assess listing status of Umpqua ESU by August 1998 ➢ Complete initial listing determinations for other West Coast populations by December 1998

[a] ESU: Evolutionary Significant Unit

Imperiled Fish and Other Aquatic Species

As is documented in Flather and others (1998), fish and aquatic species now dominate the list of threatened and endangered animal species in the United States. Over the last two decades, fish have been listed on the Threatened and Endangered Species list at a rate twice that of other vertebrate species while other aquatic species such as mussels are imperiled in a greater proportion relative to terrestrial species.

Although there are 111 fish taxa officially listed as threatened and endangered under the Endangered Species Act (ESA), far more are considered imperiled (should be listed under ESA) by the American Fisheries Society (AFS) (Williams and others 1989). Between 1979 and 1989, none of the 251 North American fish species identified by the AFS as warranting protection because of low populations were removed from their list because of recovery. Ten became extinct, and 16 were removed because of better information. According to the AFS list, a total of 364 fish taxa that warrant protection because of their rarity were listed in 1989, with 70% (254) of those coming from the United States. One hundred thirty-nine new taxa were added to the AFS list during that time frame, although 41% of those were Mexican fishes that were added because new information became available and their habitat continued to decline. Of the fish taxa that changed status in the 1979–1989 time period, seven improved and 24 declined (table 5). An additional 18 were reclassified (but remained on the list) due to new information, not because of a change in their condition (Williams and others 1989).

The Nature Conservancy recognized 55% of North America's mussels as extinct or imperiled as compared to only 7% of the continent's bird or mammal species (Williams and others 1993, Master 1990). Two hundred ninety-seven freshwater mussel species are native to the United States and Canada. Of these, 213 are considered endangered, threatened, or of special concern and only 70 are listed as currently stable (Williams and others 1993). Twenty-one distinct taxa of mussels are now considered to be extinct. The primary factor contributing to the decline of mussels is habitat destruction and degradation (Williams and others 1993), although other factors such as exploitation may have played a role. Dams are a significant factor in altering habitat and changing the physical, chemical, and biological environment of streams. Approximately 30 to 60% of the mussel fauna is destroyed upstream and downstream of dams (Williams and others 1993, Layzer and others 1993). Erosion caused by deforestation, poor agricultural practices, and destruction of riparian habitat leads to increased siltation, reducing and eliminating suitable habitat for mussels and other bivalves. Additionally, the introduction of nonindigenous species such as zebra mussel and Asian clam also negatively impact native mussel fauna. The Asian clam was first introduced in the United States in the 1930s and is now the most widespread nonindigenous bivalve mollusk in the nation. It settles in densities of thousands per square meter (Williams and others 1993), thereby crowding out native mussel fauna.

Table 5—Changes in the status of species identified as endangered, threatened, or of special concern by the American Fisheries Society from 1979 to 1989. List does not include species whose status did not change (Williams and others 1989).

Taxon	Change
Improved	
Fish Creek Springs tui chub (*Gila bicolor euchila*)	E to T
Yaqui chub (*Gila purpurea*)	E to T
Zuni bluehead sucker (*Catostomus discobolus yarrowi*)	T to SC
Devils hole pupfish (*Cyprinodon diabolis*)	E to T
Gila topminnow (*Poeciliopsis occidentalis*)	T to SC
Spring pygmy sunfish (*Elassoma sp.*)	E to T
Sharphead darter (*Etheostoma acuticeps*)	T to SC
Declined	
Pallid sturgeon (*Acipenser brevirostrum*)	T to E
Least chub (*Iotichthys phlegethontis*)	T to E
White River spine dace (*Lepidomeda albivalls*)	T to E
Cape Fear shiner (*Notropis mekistocholas*)	SC to E
Blackmouth shiner (*Notropis melanostomus*)	SC to T
Oregon chub (*Oregonichthys crameri*)	SC to T
Mountain blackside dace (*Phoxinus cumberlandensis*)	T to E
Loach minnow (*Tiaroga cobitis*)	SC to T
White River sucker (*Catostomus clarki intermedius*)	T to E
Shortnose sucker (*Chasmistes brevirostris*)	T to E
June sucker (*Chasmistes liorus mictus*)	SC to E
Lost River sucker (*Deltistes luxatus*)	SC to E
Razorback sucker (*Xyrauchen texanus*)	T to E
Pygmy madtom (*Noturus stanauli*)	T to E
Alabama cavefish (*Speoplatyrhinus poulsoni*)	T to E
Preston springfish (*Crenichthys baileyi albivallis*)	T to E
White River springfish (*Crenichthys baileyi baileyi*)	T to E
Moorman springfish (Crenichthys baileyi thermophilus)	SC to T
Railroad Valley springfish (*Crenichthys nevadae*)	SC to T
Desert pupfish (*Cyprinodon macularius*)	T to E
Striped goodeid (*Ataeniobius toweri*)	T to E
Rainbow characodon (*Characodon laterilis*)	T to E
Amber darter (*Percina antesella*)	T to E
Shoshone sculpin (*Cottus greenei*)	SC to T

SC: Special Concern
T: Threatened
E: Endangered

The geographic distribution of threatened and endangered aquatic species is not uniform across the United States. Rather, endangered aquatic species are concentrated in distinct geographic regions (figure 5*a*). Geographic areas with a concentration of endangered aquatic species were identified using the criteria specified in Prendergast and others (1993), namely, an arbitrarily defined upper percentile of sample units ranked by species counts. To account for the disparity in county area across the United States, counties were partitioned into "large-area" and "small-area" sets at a threshold of about 910,000 acres. This was done because the alternative, a simple conversion to county density (e.g., number of endangered species per unit area), produced an eastern bias and concealed known concentrations of endangered species in the arid southwest (Hallock 1991). Within each large and small area set, counties were ranked according to the number of threatened and endangered species that occurred within their boundaries. Areas of endangered species concentration were initially identified by mapping the top 5% in each of the large-and small-area county sets (i.e., those counties where the greatest number of listed species were found). Since "endangerment regions" likely do not follow county borders, the areal extent of each region of concentration was further defined by mapping the top 20% of counties in each of the small-county and large-county sets. Counties in this mapping that were contiguous to, or formed distinct physiographic clusters with, those counties in the top 5% formed the region of endangered species concentration (see Flather and others 1998 for details).

The incidence of endangered fish (figure 5*b*) and other aquatic taxa (figure 5*c*) is geographically similar to concentrations of all aquatic species (figure 5*a*) in the arid southwest and the southern Appalachian mountains (see Case Study 7). Within these two areas, the current distribution of listed species is often restricted to that area, making them endemic to that region. These regional endemics are often fish. For example, of the total number of listed species occurring in the Southern Appalachians that are endemic to that region (see Flather and others 1998), 27% were fish. Similarly, in the Sonoran Basin, 24% of the listed endemic species were also fish. Because of the prevalence of endemism in these regions, conservation of aquatic diversity will require land management activities to address those local factors that have contributed to species endangerment.

The ecological impact from the loss of aquatic biota can be enormous. For example, Chesapeake Bay oyster populations are at less than 1% of their historical abundance. Historical oyster populations in the Bay (pre 1870s) could filter a volume of water equal to the entire Bay every few days whereas today's level of oyster populations takes more than a year to filter the same volume of water (Horton and Eichbaum 1991). This filtering capability plays an integral role in the cycling of nutrients, balance of the planktonic community, and water quality attributes such as clarity, nutrient levels, and others.

Causes and Economic Effects of Species Declines

In addition to the ecological significance of declining species, there is also a significant economic impact. Freshwater mussels once provided an important source of commerce for the United States. In the early 1900s, there were more than 2,000 mussel harvesters on the Illinois river, whereas there are none today (Wilcove and Bean, 1990). Unfortunately, high prices for clam shells on the Asian market have increased commercial harvesting pressure on already stressed mussel stocks in other areas (Williams and others 1993). In Washington and northern Oregon, the declining Pacific salmon stocks resulted in the closure of the commercial salmon fishery completely in 1994 and restrictions on recreational fisheries, creating significant economic impacts (see Case Study 6). On the Atlantic coast, the near-collapse of the striped bass stocks resulted in complete five-year closures of the recreational, charter, and commercial fisheries in Maryland and Delaware and a one-year closure in Virginia. Most notably in recent years, the collapse of New England groundfish stocks and subsequent closures have had significant economic consequences for that region.

There is generally more than a single causative factor behind the decline of aquatic species (Wilcove and Bean 1994, see Case Study 8). In an examination of 40 taxa of North American fishes, Miller and others (1989) determined the most common contributing factors for extinctions are habitat loss (73% of the cases), effects of introduced species (68% of the cases), chemical alteration or pollution (38% of the cases), and over harvesting (15% of the cases). Causes behind the species declines may vary by region, but in the southern Appalachians, contamination and modification of aquatic environments from mining, reservoir construction, and farming affected at least 50% of all listed species in this region (Flather and others 1998). An aquatic taxon that is particularly susceptible to these factors is freshwater mussels. Over 50% of the mussel fauna in the southern Appalachians are classified by the U.S. Fish and Wildlife Service as threatened, endangered, or of special concern or are considered by state agencies as being "at risk" (Southern Appalachian Man and the Biosphere 1996). Furthermore, Flather and others (1998) found that nearly 40% of all the endangered species in the southern Appalachian region are clams.

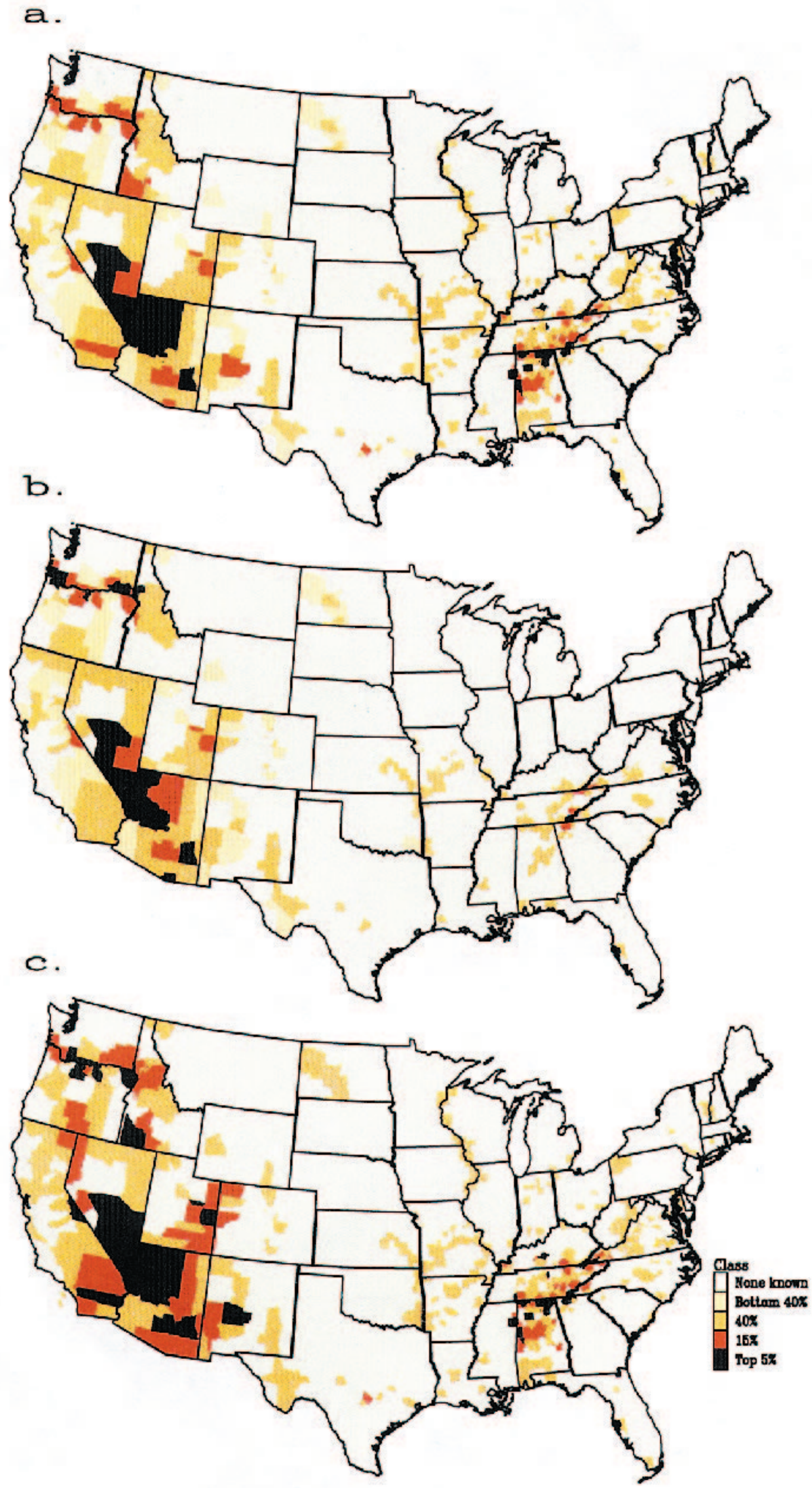


Figure 5—The geographic distribution of threatened and endangered aquatic species. All maps show counties in percentile classes after ranking both large- and small-area counties (to account for differential county area) according to the number of threatened and endangered species that occurred within their boundaries (see text for details). Map (a) depicts all aquatic species (fish and non-fish); map (b) depicts only fish; map (c) depicts only non-fish aquatic species.

CASE STUDY 1:
MIDWEST CRAPPIE PRODUCTION IN IMPOUNDMENTS

Background

Crappie populations in Midwest impoundments support some of the most popular sport fisheries in this region (Mitzner 1991, USDI Fish and Wildlife Service and Bureau of Census 1998). Environmental factors that effect crappie populations are of significant interest to fisheries managers and the general public.

Rathbun Lake in south-central Iowa is one such system. This 11,000 acre impoundment was created in 1969–70 on the Chariton River. Crappie typically composes 80% to 90% of the angler creel in Lake Rathbun and harvests of 100,000 or more fish were recorded in nine out of 14 survey years (Mitzner 1991).

Issue

Between 1980 and 1983, the Iowa Department of Natural Resources investigated the relationships between abundance of juvenile crappie and five environmental variables to determine what factors controlled population growth and subsequent angling success. Factors of water storage, turbidity, wind, temperature, and substrate were investigated in relationship to crappie reproduction.

Results

The amount of water in the system (flood water storage) was the largest influence on larval crappie abundance, with higher volumes (more water) producing higher numbers of juvenile crappie (figure 6). Water storage reservoirs such as Rathbun Lake often fluctuate year to year (and also within season). The amount of available water impacts many physical characteristics of the habitat of larval fish in a particular year, including physical habitat availability, water temperature, and water clarity. However, apart from flood water storage, turbidity in the reservoir played the dominant role. In several years of high water volume (when high numbers of juvenile crappie would be expected) accompanied by high turbidity, low numbers of juvenile crappie were measured. Removing these years from the analysis doubled the strength of the relationship (as measured by r^2) between water volume and crappie production (Mitzner 1995). Forty-nine percent of the variability in crappie abundance was accounted for by variations in turbidity during 1980 and 1982 (Mitzner 1991). At the extreme, no crappie were present in locations in Lake Rathbun with high turbidity (Secchi depths less than 2 inches). Crappie abundance increased at a geometric rate as water clarity increased to values above 25 inches of Secchi disk depth (Mitzner, 1995).

Turbidity in Rathbun originates from three main sources: wave action on the shoreline, suspension of bottom sediments, and runoff from the watershed. Of these factors, turbidity was more a function of inflow of silt from the watershed than bank sloughing by wind and molar action (Mitzner 1987). Correspondingly, a principal factor related to turbidity was the inflow of water from the surrounding water basin. An estimated 321,000 tons of sediment are delivered to the lake annually from 173,760 acres of cropland in the watershed, according to the water quality management plan for Rathbun Lake. Of these croplands, 90,000 acres were classed as critical erosion areas and recommended for priority soil conservation practices (Mitzner 1987).

Related studies in other watersheds have shown that water quality indices were adversely impacted by watershed size and larger ratios between watershed size and

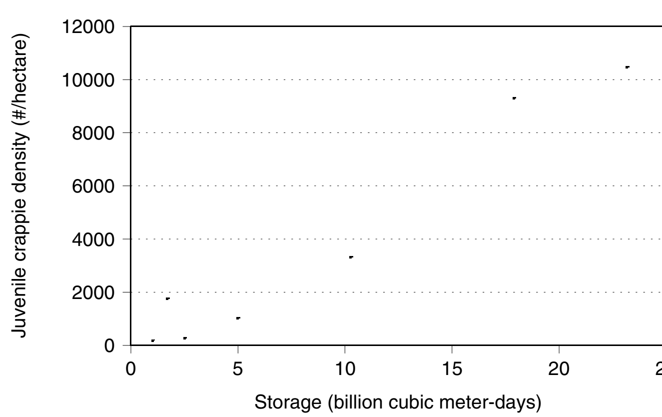


Figure 6—Relationship between reservoir flood storage levels and juvenile crappie abundance. Points indicate measurements taken in individual years 1972–1979 (Mitzner 1981).

lake surface area (Mitzner 1995) that impacted fish populations. Larger ratios (larger watersheds in relation to the size of the lake) in conjunction with shallower depth and less steep slopes of the lakes produced poorer bluegill populations as measured by a “well-being” index (developed through a composite of growth rate, body condition, and size structure of the population). Subsequently, higher bluegill and crappie harvests were associated with higher well-being indices. Additionally, agricultural nonpoint source pollution modeling has demonstrated that sediment and nutrient loadings are important to the well-being indices of panfish populations. Lower sediment and nutrient runoff from the watershed produced better panfish populations and angling opportunities. Recommendations from Rathbun Lake and other studies concluded that lakes that have already been constructed can benefit from deepening and reduction in soil and nutrient erosion in the watershed (Mitzner 1995).

The Future

These studies have shown that crappie populations in at least one Midwest impoundment are impacted by the runoff from the surrounding watershed. Poor land use practices in the watershed that contribute to excess soil runoff contribute to heavy sediment loads. At the same time, improved land use practices that reduce the amount of sediments and other runoff into reservoirs create improved habitat conditions for fish populations. These problems in the water can only be rectified through appropriate action on the surrounding watershed.

CASE STUDY 2:

WATERSHED IMPACTS ON COLD WATER HABITAT IN CANYON CREEK, ARIZONA

Background

Canyon Creek, Arizona, is a tributary to the Salt River. Base flows originate in natural springs and the total drainage area is relatively small, encompassing approximately 325 square miles (Morgensen 1986). The soils of this region are highly erodible with a high silt content, making the activities on watershed extremely influential to the water quality of the stream. Predominant land use practices at the outset of the rehabilitation initiative in 1986 consisted of logging, livestock grazing, and heavy recreational use (including camping, fishing, and off-road vehicle use). Native fish in Canyon Creek include speckled dace and desert sucker. Catchable rainbow trout and brown trout were stocked beginning in 1948 and sustained a catch-and-release fishery only, with no natural reproduction before restoration efforts began in 1986.

As a result of the conditions created by year-long cattle grazing in the watershed, wildlife and fish resources suffered. Grazing reduced streamside vegetation, particularly the cottonwood and willow that stabilize the banks and provide shade to the stream, thereby reducing the water temperature. The primary impact from timber harvesting activity on water resources was from the construction of haul roads and skid trails, resulting in large sediment input. With the exception of water temperature and siltation loads, all water quality parameters were in the acceptable range for sustaining coldwater fish populations. This indicated that watershed activities which exacerbated these two factors were the primary agents responsible for degraded habitat suitability and trout reproduction prior to the implementation of a riparian and in-stream habitat improvement initiative in 1986 (Morgensen, 1986).

Responses and Results

In 1986, the Canyon Creek Aquatic Habitat Improvement Plan was developed by a team of state, federal, and private partners with goals of establishing a quality brown trout fishery with a native fish forage base and providing a rainbow trout fishery. Management of the creek would principally be through riparian management, restrictive regulations, and substantially reduced stocking. Since the major factors limiting fish growth and reproduction were high temperatures due to the lack of shade, high siltation

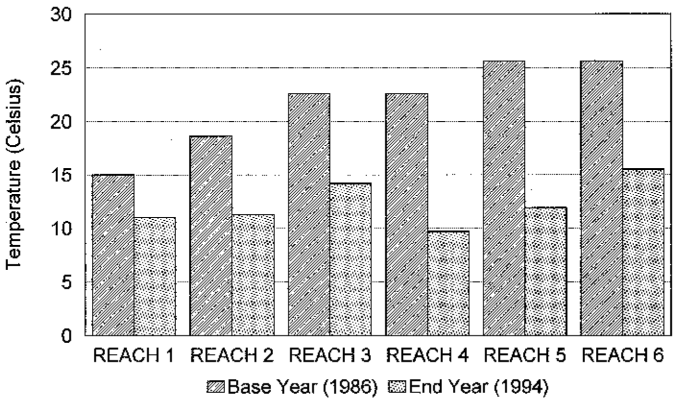


Figure 7—Water temperature change due to habitat improvement, Canyon Creek, Arizona (Warnecke and others 1996) .

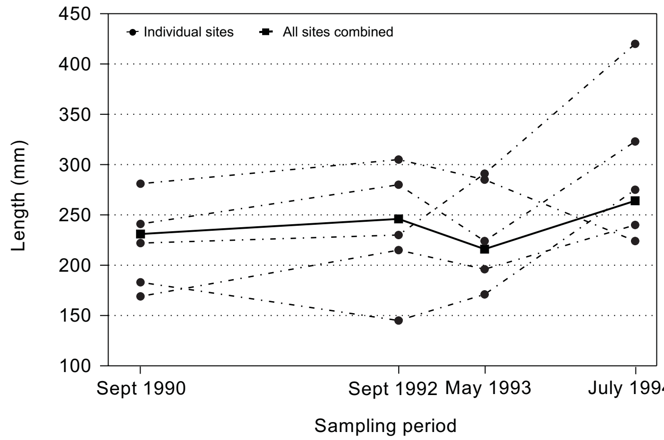


Figure 8—Change in brown trout size in Canyon Creek, Arizona, following watershed and in-stream improvements (Warnecke and others 1996).

from erosion, and lack of pools with adequate depth and substrate due to stream scouring (Morgensen 1986, Warnecke and others 1996), these factors were targeted for improvement. Following a habitat survey in 1986, improvements were made to the stream and riparian corridor including reestablishing native vegetation on the banks, improving in-stream habitat, and removing cattle from the stream and adjacent riparian areas.

Following these modifications, between 1986 and 1994 the average water temperature was reduced by 9.4° C, dropping from an average of 21.7° C in 1986 to 12.3° C in 1994 (figure 7). Bank stability, which effects sediment loads, markedly improved in four of seven areas, slightly improved in two areas, and declined in one area. The average stream depth increased in all areas and the average rating of pool habitat quality increased in five of the areas while remaining unchanged in the remaining two sites. Fish population surveys from 1990–94 indicated that brown trout size likely responded to these changes in four of five sites (figure 8) and slightly in terms of fish density. Natural reproduction became sufficient to maintain a catch-and-release fishery, and over 10% of the population grew to a "trophy" size. Except for a single small stocking in 1993, all introductions of hatchery brown trout were discontinued. Populations of native desert sucker and speckled dace also appeared to increase to higher levels although future monitoring is needed to confirm this (figure 9).

In August 1992 and January 1993, substantial flooding occurred in this watershed, creating the potential to reduce the gains that had been made in this stream system. Although the floods had a profound effect on the riparian corridor, much of the new bank vegetation, primarily willows, withstood and contained the scouring action of the flood waters and, as evidenced by the data, appeared to have limited impact on the trout populations (Warnecke and others 1996).

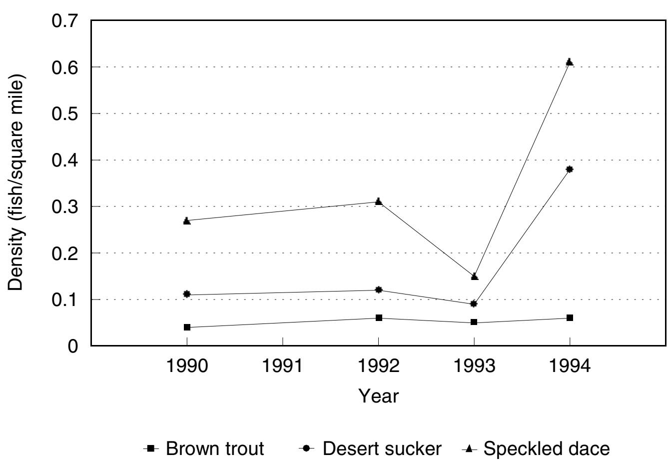


Figure 9—Changes in native and non-native fish populations in Canyon Creek, Arizona, following watershed and in-stream improvements (Warnecke and others 1996).

The Future

Canyon Creek, a stream once negatively impacted by the effects of poor land use practices in the watershed and unable to sustain wild coldwater species, has benefitted from a comprehensive management prescription. Natural reproduction of coldwater fish, which had not been possible for over 40 years, is now sustaining a fishery (brown trout) and populations of native fish continue to do well. Long-term costs of maintaining a trophy brown trout fishery without the need for hatchery production likely will be lower than if habitat improvements in the watershed and riparian areas had not been made. While maintaining the habitat improvements, a self-sustaining brown trout population, and a stable native forage fish population are of paramount importance, public demand is also calling for a greater increase in the stocked rainbow trout fishery. Future management is likely to emphasize a diversified fishery where all of these objectives and user demands can be accommodated.

CASE STUDY 3:

MICHIGAN GRAYLING RESTORATION: A LOST OPPORTUNITY?

Background

Arctic grayling were native to the northern lower and upper peninsulas of Michigan. Historically, most populations in Michigan were stream dwelling (Nuhfer 1992). By the late 1930s, grayling stocks in Michigan had been extirpated (Hubbs and Lagler 1958). Principal reasons for the decline of these stocks were identified as angler harvest, introduction of non-native salmonids, and destruction of spawning habitat by extensive logging (Hubbs and Lagler 1958, Nuhfer 1992) and the associated log drives in streams which lasted until 1972 (Kelso and others 1996). Several attempts to reestablish grayling in various Michigan waters by transplanting stocks thought to be genetically similar to the original Michigan population failed (Nuhfer 1992).

Response

From 1987 to 1990, the Michigan Department of Natural Resources studied the linkages between grayling growth, survival, and reproduction to physical, chemical, and biotic factors, and assessed the feasibility of restoring self-sustaining populations. A total of 145,000 grayling (principally one-year-old fish) were stocked into 13 lakes and seven river systems in the grayling's historic range in Michigan. Stocked waters were chosen based on their favorable physical, chemical, and biological conditions for maximizing the survivability of these fish. Selected lakes had sustained other coldwater fish (trout), were remote, and contained few other fish species (Nuhfer 1992). Since Michigan strains had been extirpated, eggs from a lake population of grayling in Montana and a river population in Northwest Territories, Canada, were hatched and raised in Michigan hatcheries before stocking.

Results

In most lakes, arctic grayling grew well during the first season and even into the second season in certain situations. First year survival was best in lakes where few other fish species were present and was lowest in lakes containing larger piscivorus fish such as largemouth bass and non-native brown trout. Survival after the third year was only observed in lakes that were closed to fishing (although grayling harvest was prohibited in all lakes) and with no competition from other species. There was no evidence of reproduction in any of the systems although suitable spawning habitat, based on known spawning requirements, was available in some systems.

In the seven river systems, most Arctic grayling disappeared within six months. Angler-reported catches indicated a movement of fish away from the original stocking sites. Nuhfer (1992) hypothesized that some movement may have been induced by higher water temperatures compared to historical conditions and resulted in movement of the grayling into areas with higher predator densities. There was no indication that competition or predation at the stocking sites contributed to the low survival in streams. In several rivers, obstructions such as dams blocked upstream migration that may have provided more suitable habitat conditions. Higher temperatures in today's contemporary rivers may provide a competitive advantage to salmonids over grayling (Nuhfer 1992). Additionally, there were some indications that grayling in some of the lakes may be susceptible to the more acidic conditions characterizing today's waters, This acidity is exacerbated through input of low pH precipitation in poorly buffered soils of the northern lower and upper peninsulas of Michigan.

The Future

The original strain of Arctic grayling that inhabited Michigan waterways has been extirpated and can never be reestablished. The unique genetic characteristics that adapted this strain to the conditions of the lakes and streams of that region is lost. At the same time, however, the landscape and water quality conditions to which that genetic make-up was adapted no longer exist. The results of this and other studies conclude that river strains of Arctic grayling that currently survive in conditions similar to historical Michigan conditions are unlikely to “either survive well, or reproduce, in contemporary Michigan rivers” (Nuhfer 1992). River strains of Arctic grayling often undertake long seasonal migrations and therefore need large, cold, non-fragmented rivers with few competing fish species, particularly salmonids, or predatorysized non-salmonids. These conditions are rare in today’s streams. Future management, restoration, and rehabilitation of large river systems may provide opportunities to recreate these environmental conditions more suitable to the survival of arctic grayling.

Although grayling survived and grew in lake systems, no natural reproduction occurred. Thus, self-sustaining populations of this native species may not be possible under current environmental conditions. Since grayling do not survive well in the presence of non-native predators (such as certain species of salmonids), current management regimes may need to be modified in appropriately suited lakes if the establishment of a hatcherybased grayling fishery is desired.

CASE STUDY 4:
RESTORING A DECLINING LAKE SUPERIOR LAKE TROUT FISHERY

Background

The fish communities in Lake Superior have undergone dramatic changes during the past 200 years. These changes have been attributed to alterations in land use, intentional and unintentional introductions of exotic species, contamination by toxic chemicals, and other factors (Kelso and others 1996). Lake trout, which once existed as the top predator in this system, were decimated by the introduction of the parasitic sea lamprey through the Welland canal, overfishing, pollution (particularly DDT), and degradation of their spawning habitat due in part to siltation resulting from extensive logging activities in the 19th and 20th centuries (Schreiner and Schram 1997, Hile and others 1951, Scott and Crossman 1973). Although native lake trout were extirpated in the lower Great Lakes, remnant populations have survived in off shore areas (primarily three shoals) of Lake Superior (Schreiner and Schram, 1997, Hansen 1996). Full restoration of the Lake Superior lake trout population has been a goal of managers since stocks were decimated in the 1950s.

In 1956, the governments of the United States and Canada formed the Great Lakes Fishery Commission (GLFC) to develop control techniques for sea lamprey and to share information to better manage the Great Lakes fisheries. Development of the chemical lampricide “TFM” in the 1950s opened the door for sea lamprey control and the beginning of rebuilding fish populations in the lakes (Smith and others 1974). To successfully restore lake trout populations, managers focused on three primary areas: reducing sea lamprey populations, reducing fishing harvest (the commercial fishery was closed 1962-70), and restoring spawning habitat. Even though over-fishing and sea lamprey are considered the primary causes of lake trout declines, spawning habitat restoration and improved water quality were considered critical to lake trout rehabilitation and the establishment of a wild, selfsustaining stock (Schreiner and Schram 1997). Although watershed alterations continue to occur, pollution from watershed activities has declined, channelization and new harbor development is decreasing, and hydroelectric facility construction has abated overall in the Great Lakes (Kelso and others 1996).

Results

When these rehabilitation efforts and extensive stocking programs began in the early 1960s, wild lake trout abundance steadily increased. By 1994, more than 90% of lake trout caught in surveys in the Michigan waters of Lake Superior were of wild (non-hatchery) origin. Eightyfive percent of the lake trout produced in eastern Wisconsin and 50 to 90% of the lake trout in Ontario waters of Lake Superior were of wild origin. Since the early 1970s,

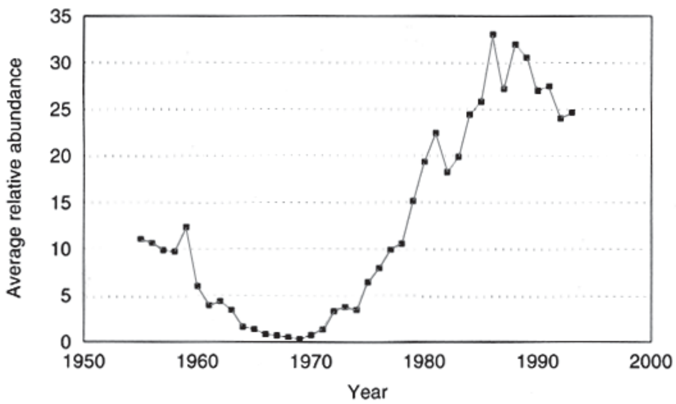


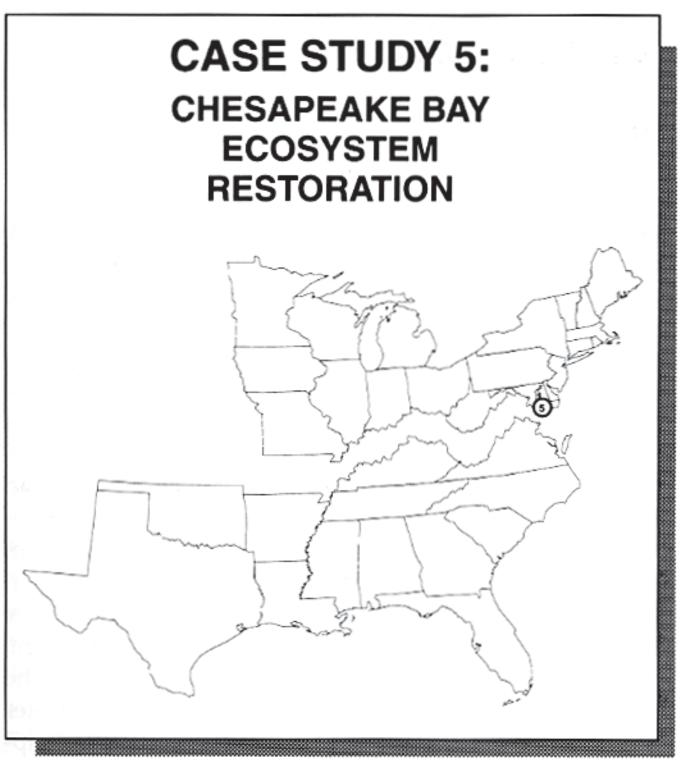
Figure 10—Wild lake trout abundance (sites combined) in Michigan waters of Lake Superior using unweighted averages of catch-per-unit effort. (MA Hansen, pers. comm., College of Natural Resources, University of Wisconsin, Stevens Point 1998; Hansen and others 1996).

natural production of lake trout consistently increased through the mid 1980s (figure 10). Only areas in the extreme western portion of the lake are lagging in natural reproduction (Schreiner and Schram 1997). Michigan now proposes to cut all stocking of hatchery fish; Wisconsin proposes to stop stocking in eastern waters of their state; and Minnesota will decrease stocking by 30%. Additionally, contaminant levels continue to decline in lake trout (DeVault and others 1994). Although populations of wild fish are not yet at pre-1940s levels, when the fishery sustained a commercial harvest averaging two million kilograms annually (Hansen 1996), they have recovered to where stock supplementation can be reduced or eliminated.

The Future

Environmental management problems still exist and continue to impact the ecosystem, including chlorine from paper mills, municipal sewage overflows, heavy metals from mining activities, atmospheric deposition of contaminants (Schreiner and Schram, 1997), continuing introductions of exotic species, and persistent toxins (Kelso and others 1996). However, the use of large mesh gill nets in commercial fisheries has been reduced in Michigan and Wisconsin, which may improve survival of large (age 7+) mature lake trout (Hansen and others 1996).

Lake trout in Lake Superior are showing signs of restoration through an integrated management process involving improved environmental conditions and reduced fishing mortality. While the scenario for the other Great Lakes differ significantly in some respects, the Lake Superior lake trout restoration provides encouraging evidence that long-lived species in large systems can successfully be restored using a holistic approach to management.



by Andrew J. Loftus, Loftus and Associates,
Curtis H. Flather, Rocky Mountain Research Station,
and Marjorie S. Adkins, Chesapeake Regional Information Service Director, Alliance for the Chesapeake Bay[4]

Background

The Chesapeake Bay is the largest estuary in the United States. While the shoreline stretches 195 miles through Maryland and Virginia, the Bay's watershed extends from its northernmost tip in Cooperstown, New York, to its southern reach in the Tidewater area of Virginia (Horton and Eichbaum. 1991). This watershed encompasses over 64,000 square miles and is shared by six states and the District of Columbia (figure 11). The relative shallowness of the Bay (average depth less than 22 feet) combined with the large watershed area create a very large watershed to volume ratio (2,743 square km/m3 of water), making the Bay very susceptible to influences from the landscape

[4] Current address: Loftus Consulting, 3116 Munz Drive, Suite A, Annapolis, MD 21403

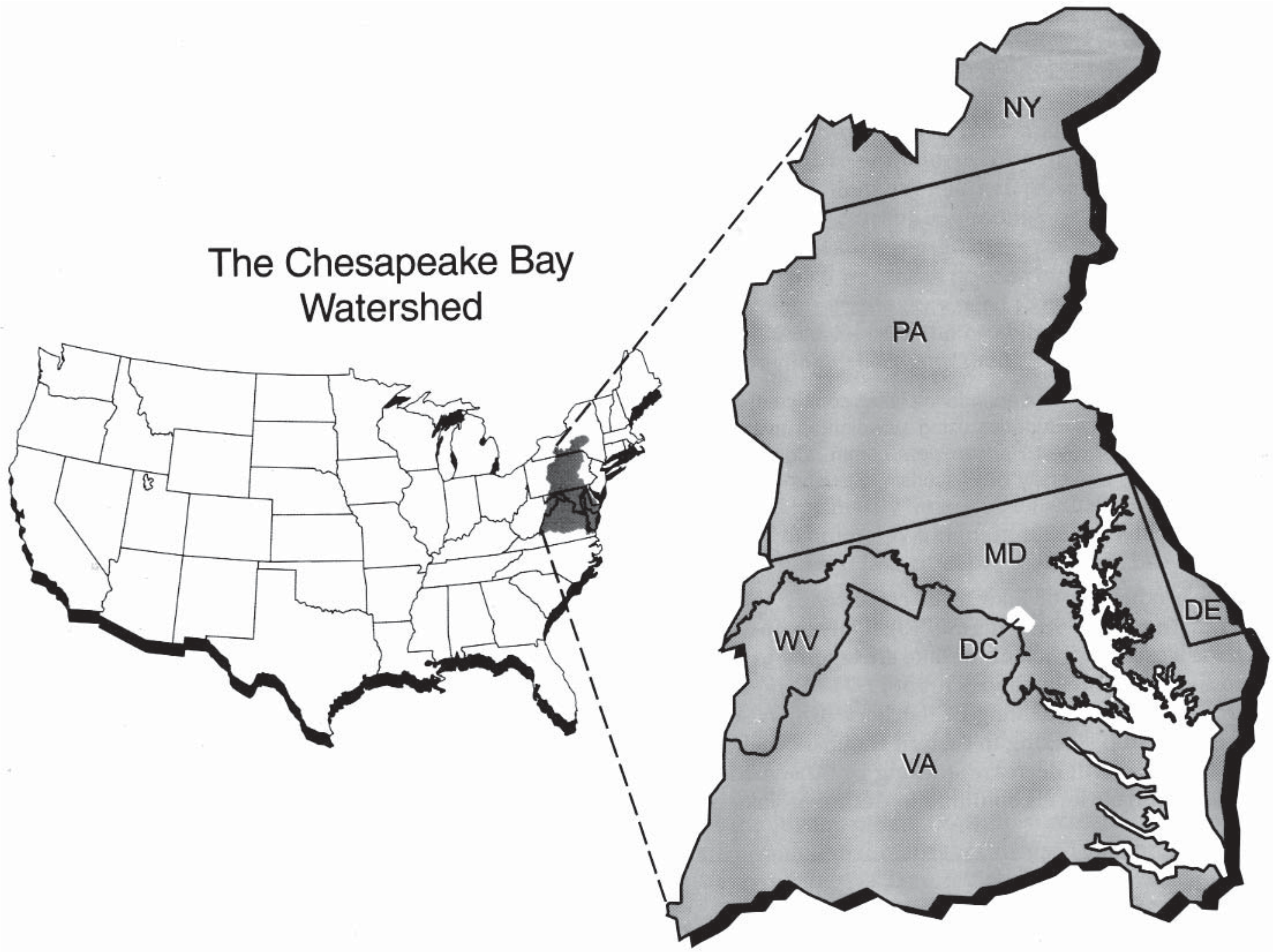


Figure 11—The Chesapeake Bay watershed.

(Horton and Eichbaum 1991). The flora and fauna of the Chesapeake Bay system are ecologically diverse, with more than 2,000 plants and animals having been identified from the Chesapeake Bay region (Lippson and Lippson 1984)

Despite the political complexity of managing the Bay as an ecosystem, the Chesapeake Bay states recognized in the early 1980s that this was the only effective way to manage such a large system. The enormous task of managing the Bay as an ecosystem not only involves multiple state, federal, and municipal governments, but requires the general support and participation by the 15 million residents of the Bay region.

Problem and Response

The Chesapeake Bay has been a center of commerce and an area of high human growth since its exploration by Captain John Smith nearly four centuries ago. With its abundant fish and shellfish resources, easy accessibility by water, proximity to important political seats of power, and natural ports for shipping, human settlement in the region has been steady. By the mid 1900s, the impact of four centuries of intense human habitation and industrialization on the Bay's living resources were beginning to be recognized. Prior to European colonization, nearly all of the watershed was forested as compared to less than 60% today. Peak storm flows from the surrounding watershed into the Bay prior to deforestation, agriculture, development, and urbanization were likely 25 to 30% lower than today (Horton and Eichbaum 1991). By the 1970s, when agencies such as the Environmental Protection Agency began to focus research efforts on this as an ecosystem, impacts were already at critical stages. Nearly all of the historical oyster reefs (which not only provided oyster habitat but also were important fish habitat) had disappeared due to intense harvesting. Anoxic conditions in many parts of the estuary, fueled by high nutrient loads, impeded aquatic life and toxic chemicals were still being released into the Bay's waters. The effects of these factors were manifested in the living resources of the Bay in many ways: submerged aquatic vegetation (SAV) had been depleted, striped bass populations had declined dramatically, spawning runs of migratory American shad had disappeared from some river systems, and oysters had dropped to a fraction of their historical levels.

No single cause was to blame for these trends, so there was no single solution to the problems. The landmark 1987 Chesapeake Bay Agreement between Maryland, Virginia, Pennsylvania, the District of Columbia, the EPA, and the Chesapeake Bay Commission (a tri-state legislative advisory commission) focused on eight primary goals embracing an ecosystem approach to management:

1) Provide for the restoration and protection of the living resources, their habitats, and their ecological relationships.
2) Reduce and control point and non-point sources of pollution to attain the water quality condition necessary to support the living resources of the Bay.
3) Plan for and manage the adverse environmental effects of human population growth and land development in the Chesapeake Bay watershed.
4) Promote greater understanding among citizens about the Chesapeake Bay system, the problems facing it, and policies and programs designed to help it; and to foster individual responsibility and stewardship of the Bay's resources.
5) Provide increased opportunities for citizens to participate in decisions and programs affecting the Bay.
6) Promote increased opportunities for public appreciation and enjoyment of the Bay and its tributaries.
7) Support and enhance the present comprehensive, cooperative, and coordinated approach toward management of the Chesapeake Bay system.
8) Provide for continuity of management efforts and perpetuation of commitments necessary to ensure long term results.

In 1987, the signatories of the Chesapeake Bay agreement identified excess nutrients as the root of many of the problems. These nutrients were fueling excessive growth of algae, which was thought to be blocking sunlight and inhibiting the growth of submerged aquatic vegetation. When the algae died, it sank to the bottom and its decomposition contributed to anoxic conditions in parts of the Bay bottom. To address this problem, the partners in the agreement established a numerical goal for reducing the levels of nitrogen and phosphorous in the Bay's main stem by 40% by the year 2000. Subsequent amendments to this agreement extended these reduction targets to the tributaries.

Results

Within a decade, 90 of 315 significant municipal plants had installed (or were installing) biological nutrient removal to remove not only phosphorous but also nitrogen, effectively applying advanced nutrient removal to 59% of municipal sewage flow by the year 2003 at the time of full implementation. Best Management Practices (BMP's) on agricultural lands were implemented on 1.6 million acres between 1985 and 1996, representing 22% of the agricultural land in the three Bay states. Urban runoff was curbed by implementing innovative landscape and construction technologies developed cooperatively by government agencies, citizen's groups, landscapers, and the development community. In 1997 the state of Maryland, under the umbrella of the "Smart Growth Initiative" and "Rural Legacy Program," passed what is perhaps the most aggressive package of legislation for "open" land preservation in this region to date. This was designed to direct land use patterns in the state through programs of financial and political incentives as opposed to regulatory actions.

Because many of the fish stocks in the Chesapeake Bay migrate to Atlantic coastal waters, successful restoration and management of these species must be done in concert with other states. The 13 Atlantic states and the District of Columbia have joined under an interstate compact to form the Atlantic States Marine Fisheries Commission (ASMFC) to develop cooperative fishery and habitat management plans and share data. Until 1984, implementation of fishery management plans developed through the ASMFC was voluntary and only marginally successful. In 1984, the Atlantic Striped Bass Conservation Act was signed into law, which required states to implement and enforce the cooperative Atlantic Striped Bass Management Plan.

Together, the Chesapeake Bay Agreement and the cooperative ASMFC management have had measurable and substantial results on the ecosystem. Overall, the levels of phosphorous in the Chesapeake Bay declined 16% between 1985 and 1992 and are on target for meeting the 40% reduction goal in 2000. Although it is questionable whether the 40% nitrogen reduction goal will be met in the time frame specified, levels of nitrogen are declining in the major tributaries to the Bay and have stabilized in the main portion of the Bay; they are expected to continue to decline as additional nutrient reduction actions are implemented. In some areas, submerged aquatic vegetation beds have rebounded 70% since their low levels in 1984. By providing fish passage facilities or redesigning artificial obstructions to fish migration, over 330 miles of historical habitat have been reopened to migratory fish, with plans to open 1,357 miles by the year 2003. The goal of reducing chemical releases from Chesapeake Bay industries by 65% before the year 2000 was achieved in 1995, a full five years ahead of schedule. Industry releases of specific toxins of concern have been reduced 22% between 1988 and 1997 with a goal to further reduce releases and transfers of these materials by 75% by the year 2000.

The combined effects of interstate management and a cooperative Chesapeake Bay ecosystem restoration program are seen most dramatically with striped bass. Since the Chesapeake Bay historically produced 90% of the striped bass on the Atlantic coast, the restoration and maintenance of healthy spawning and nursery habitat in the Bay is of vital importance. Actions of the Chesapeake Bay states will be reflected in the status of the striped bass population along the entire Atlantic coast. In the 15-year period between 1982 and 1997, the Atlantic coast striped bass population has rebounded nearly 800% (figure 12). Juvenile production has steadily increased with the highest recorded indices of reproduction in 1993 and 1996 in over 40 years of surveys. The number of age classes in the spawning stock has increased from 2–3 in the early 1980s to 3–6 in 1997. Likewise, other fisheries have begun to rebound, such as American shad (figure 13). The Susquehanna River stock of American shad had declined to fewer than 6,000 fish but by 1997 had rebounded to more than 200,000. This occurred because of an ongoing moratorium on shad fisheries in most of the Chesapeake Bay combined with improved fish passage and habitat improvements.

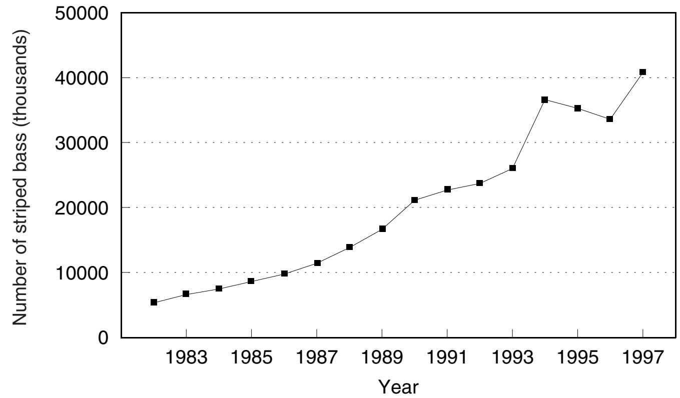


Figure 12—Estimated total population size of Atlantic coast striped bass (USDC 1998*b*).

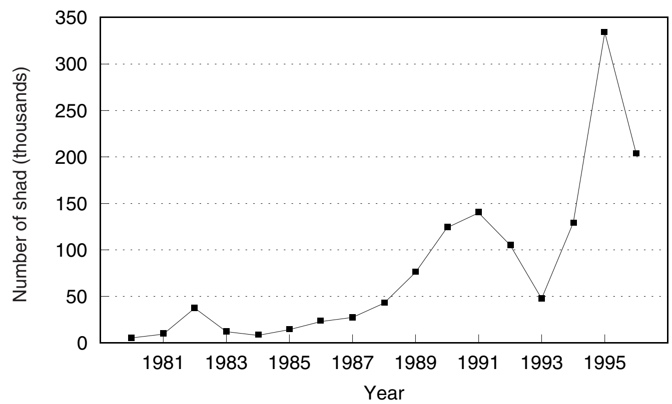


Figure 13—Estimated population of American shad in the upper Chesapeake Bay (C. Markham, pers. comm., Maryland Department of Natural Resources-Fisheries, 580 Taylor Avenue, Annapolis, MD 21401 1997).

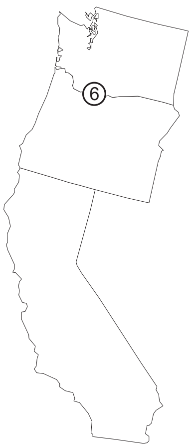
The Future

The Bay jurisdictions and federal partners continue to commit large amounts of fiscal resources to address the Chesapeake Bay's problems on an ecosystem basis. Many of the relatively inexpensive actions have been completed, however, and jurisdictions will be faced with difficult financial decisions to continue making advancements in the restoration. Maintaining reduced nutrient levels will be a challenge due to expected human population growth in the area (Chesapeake Bay Program 1997).

In terms of fisheries management, the tremendous success of the federal striped bass legislation led to similar legislation to cover other migratory species. The Atlantic Coast Cooperative Fishery Management Act of 1993 mandated states to implement and enforce interstate management plans for other fish stocks. This action will help to foster stronger coordinated management between all Atlantic coastal species that migrate through the Chesapeake Bay.

The Chesapeake Bay, one of the most diverse and valuable ecosystems in North America, continues to improve only through the adoption of an intergovernmental ecosystem management approach. It serves as a model program for other watershed projects, large or small, to follow.

CASE STUDY 6:
COLUMBIA RIVER SALMONIDS



Background

Perhaps no issue in this country has raised the awareness of the interconnectedness between land use and aquatic ecosystem health more than salmon declines in the Pacific northwest. Although salmon populations range on both sides of the Pacific Ocean, their strong tendency to home back to natal streams has created numerous distinct stocks, each with particular characteristics that have made it adapted to its historic river of origin. It is these distinct stocks of the five salmon species, as well as steelhead and cutthroat trout, that are in danger of continuing declines and possible extirpation in the Pacific northwest.

In general, salmon spawn from late fall to winter in clean, gravel areas of streams in the northwest. Residence time of the young salmon in the freshwater environment varies. As adults, most salmon make long ocean migrations before returning to their natal stream one to seven years later to spawn and then die (for complete life history information, consult Groot and Margolis 1991).

Threats to the salmon life cycle begin in the natal area and extend throughout all life stages. Human-induced factors responsible for the decline of Pacific salmon include agriculture, dams, fishing pressure, forestry, urbanization, in-stream gravel harvest, irrigation, and dilution of native genetic strains through introduction of hatchery fish[5] (USDC 1996). Additionally, natural climatic effects as well as predation by birds, marine mammals, and introduced fishes play an important role in the survival of both adult and juvenile fish.

[5] Pacific States Marine Fisheries Commission. 1997. Factors responsible for the decline in salmon abundance and distribution in the Pacific northwest. Fact Sheet. (http://www.psmfc.org).

Problem

While no individual species of Pacific salmon is endangered (Lackey 1996), over 300 distinct native stocks of salmon, steelhead, and sea run cutthroat are at risk in the Pacific northwest (Allendorf and others 1997, FEMAT 1993) and 15 distinct population segments are listed under the Endangered Species Act (table 4). The largest drainage in this region is the Columbia River. This basin historically encompasses more than 30 unique sub-basins covering approximately 259,000 square miles. Of the current habitat in the basin, 15,000 miles of anadromous fish habitat are located on 16 national forests in Washington, Oregon, and Idaho. This accounts for over 50% of the remaining habitat suitable for salmon in the basin (Federal Register 1991). Another 1,800 miles are under the administration of the Bureau of Land Management (McGinnis 1995).

Despite being the most direct indicator of natural spawning trends, estimates for the total number of natural spawners are not available at this time (Anderson and others 1996). However, other surrogate estimates of abundance provide ample evidence of the decline of the Columbia River salmonids. Since 1938, the minimum estimated number of salmon and steelhead entering the Columbia river has ranged from a high of 3.2 million fish in 1986 to a low of 856,500 fish in 1994 (Anderson and others 1996). Total escapement (total number of adult spawners returning to a segment of stream) of salmon and steelhead has declined since 1986, with total escapement of spring chinook salmon being the lowest in recorded history in 1995 (figure 14). Total escapement of salmon and steelhead in 1995 was approximately 700,000 fish, with approximately 441,000 of those fish reaching regions above the Bonneville Dam (Anderson and others 1996). In terms of reproduction, surveys conducted by the Oregon Department of Fish and Wildlife in the Snake River drainage since the 1950s indicate that the 1994 redd counts in 44 streams showed only three redds per stream—the lowest ever recorded (Anderson and others 1996).

While there is little disagreement that stocks of Pacific salmon have declined, there is substantial controversy over the nature and extent of the factors that have contributed to these declines. Reaching historical spawning grounds is only the first of many challenges. With 19 major dams and 100 smaller projects (McGinnis 1995), only 44 miles of the 1,240 mile Columbia River remains free of hindrance from dam or reservoir (Wilcove and Bean, 1994, Moore and Wiley 1991). In the "interior Columbia River basin" (the eastern portion of the drainage), over 1,230 large dams (defined as storage capacity over 62,000 cubic meters) block spawning migrations to tributaries (USDA

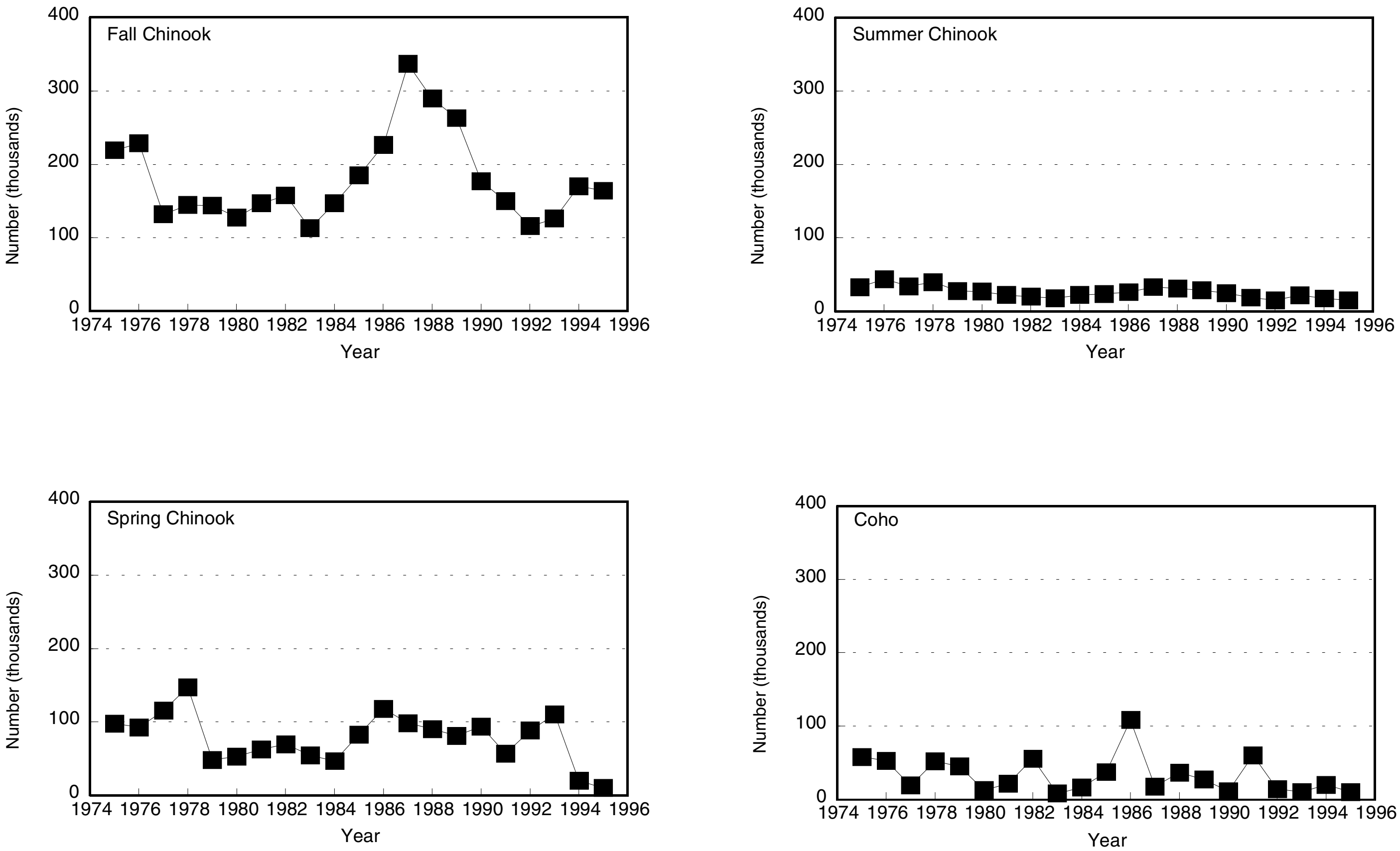


Figure 14—Escapement of four salmon runs in the Columbia River based on dam or weir counts below Bonneville dam (Pacific States Marine Fisheries Commission. http://www.streamnet.org).

Forest Service and USDI Bureau of Land Management 1996).

Once salmon and steelhead do reach spawning habitat, a variety of factors impede successful reproduction. As reviewed in Anderson and others (1996), the availability and quality of spawning habitat is severely restricted by inadequate flow levels, high stream temperatures, sedimentation, low pool/riffle ratios and other factors (table 6). For the eastern portion of the basin, the USDA Forest Service and USDI Bureau of Land Management determined that a minimum of 10% of the stream habitat (miles) had impaired water quality (table 7). This evaluation did not include an assessment of the habitat quality beyond water quality.

Once spawning and hatching occur, salmon and steelhead smolts face many challenges before reaching the sea. During their downstream migration, passing through turbines of hydroelectric facilities may impose 10–15% mortality rate per dam on juvenile salmon (Anderson and others 1986). Predation by northern squawfish is another significant problem for juvenile salmon and steelhead (Anderson and others 1986). Furthermore, during the downstream migration, juvenile salmon and steelhead require specific water temperature and salinity conditions to complete the metamorphosis that helps them to physiologically adapt to saltwater. The timing of water releases from dams is critical to providing the right mix of temperature, salinity, and flows that ensure survival and delivery of migrating salmon to the sea when optimum environmental conditions exist (DiSilvestro 1997).

Responses and Results

Initial attempts by state and federal governments to combat declining stocks focused on stocking hatchery-reared fish. However, such stocking programs have greatly intermingled distinct stocks of Pacific salmon (Groot and Margolis 1991) due to the lack of a scientifically based genetics policy. The Mitchell Act served to further promote stocking. However, it should also be noted that although salmon stocks have been planted outside of their native drainages, those drainages often do not possess the physical and chemical parameters in which the original distinct strains of salmon evolved. Extensive efforts by multiple state, federal, local, and tribal governments

Table 6—Major habitat constraints by stock and region. Values are expressed as percentages of total miles identified with constraints divided by total miles of spawning and/or rearing habitat (Anderson and others 1996). Spr – spring, Sum – summer, Win – winter.

Species/run	Columbia River Region	Flow Levels low	Gravel quantity low	High temperature	In-stream cover	Inter-specific competition	Pool-riffle ratio low	Sediments	Stream bank degraded
Coho	Below Bonneville	16.1%	7.6%	29.7%	2.6%	12.4%	9.2%	20.1%	2.7%
	Bonneville-Priest Rap	2.3%	0.4%	0.2%	4.6%	0.2%	5.1%	0.4%	0.2%
	Snake River [a]								
	Priest - Chief Joe	0.2%	0.8%		37.1%		3.5%	8.1%	
Fall chinook	Below Bonneville	9.3%	6.8%	25.0%	1.4%	16.8%	0.5%	20.4%	15.7%
	Bonneville-Priest Rap	9.1%	7.7%		2.2%		5.7%	16.2%	5.6%
	Snake River	1.1%		4.4%	2.5%	2.5%	2.5%	22.4%	
	Priest - Chief Joe				10.7%		6.3%		
Spr chinook	Below Bonneville	20.9%	8.9%	27.6%	3.3%	11.9%	2.8%	16.9%	4.1%
	Bonneville-Priest Rap	11.3%	9.8%	16.3%	10.6%	7.6%	10.2%	10.2%	14.4%
	Snake River	7.7%	2.0%	13.4%	5.4%		6.3%	20.4%	8.4%
	Priest - Chief Joe	41.3%	8.6%	0.8%	56.4%		12.7%	7.5%	
Sum chinook	Below Bonneville [a]								
	Bonneville-Priest Rap [a]								
	Snake River	4.5%						25.5%	2.3%
	Priest - Chief Joe	8.6%	8.4%	21.1%	36.7%			24.8%	
Sum steelhead	Below Bonneville	15.7%	13.8%	22.5%	9.7%	9.2%	5.8%	12.2%	2.8%
	Bonneville-Priest Rap	31.7%	12.4%	36.0%	17.9%	10.9%	16.0%	25.3%	40.1%
	Snake River	15.2%	2.0%	13.6%	6.2%	0.1%	9.1%	25.8%	13.5%
	Priest - Chief Joe	18.6%	6.8%	19.8%	28.0%		13.2%	7.5%	0.1%
Win steelhead	Below Bonneville	14.2%	13.0%	20.6%	6.4%	12.1%	5.3%	15.3%	1.9%
	Bonneville-Priest Rap	37.4%	6.4%	18.7%	30.1%		40.3%	18.8%	13.0%
	Snake River [a]								
	Priest - Chief Joe [a]								

[a] Species/run is not found in this region

and private partners are occurring to restore watersheds and aquatic conditions to a state that is more favorable for spawning, rearing, and migration of salmon stocks.

Extensive fiscal and personnel resources are being invested into resolving the salmon situation. Salmon declines have not come without a price to regional economies. In Washington and northern Oregon, the commercial salmon fishery was closed completely in 1994 (USDC 1996). In 1991, recreational anglers in Washington, Oregon, Idaho, and California spent nearly $604 million for salmon and steelhead fishing, generating $1.2 billion in total economic output, $25 million in state sales taxes, $16.2 million in state income taxes, and $76.1 million in federal income taxes (table 8). However, this represented a decline of 37 to 51% in each category between 1985 and 1991 (table 8). Overall, the Pacific Northwest salmon fisheries each year have produced over $1 billion in personal income and created more than 60,000 jobs (McGinnis 1995).

The Future

The fate of Pacific salmon stocks in the Columbia River basin is still uncertain. Returning the Columbia River system to its historic conditions is not a feasible solution in the short term because much of the electric power in the Pacific northwest is generated by these dams as well as providing water for irrigation and barge traffic. As McGinnis (1995) stated, "Effective restoration of wild salmon in the Pacific northwest is predicated on cooperation between myriad stakeholders including watershed management councils, the Northwest Power Planning Council, 11 state and federal agencies, 13 Indian tribes, eight utilities, and numerous fish, forest, and environmental interest groups." Reaching consensus among such diverse groups is just one of the complexities of the restoration and management in this region. Ongoing revisions in federal policies regarding land use, such as the debate within the Forest Service to retire roads and halt road building on 33 million acres, have potential ramifications for improving aquatic conditions but are extremely contentious among various user groups. However, the greatly increased public and scientific awareness of the relationship between the many dynamic factors affecting salmon populations, including land use, stocking impacts, natural climatic impacts, and harvesting implications, provides a stronger basis for managing these and other resources in a balanced way in the future.

Table 7—Water-quality impaired waters reported by the states and the U.S. Environmental Protection Agency as miles of streams and rivers in the portions of states within the Interior Columbia Basin Ecosystem Management Project assessment area. Note: The Utah Department of Environmental Quality reports no impaired streams or rivers within the project area in Utah. (USDA Forest Service and USDI Bureau of Land Management 1996).

	Total stream miles	Any impairment	Temperature impairment	Nutrient impairment	Sediment/siltation/turbidity impairment	Flow impairment
Oregon (1994/96)	75,186	8,123	7,358	280	948	1,263
Forest Service		2,528	2,464	0	320	134
BLM		646	570	49	65	78
Washington	49,150	3,962	2,815	33	ND[a]	2,551
Forest Service		578	204	0	ND	446
BLM		26	14	0	ND	16
Idaho		98,984	10,024	2,632	3,459	8,812 2,714
Forest Service		3,000	455	306	2,568	478
BLM		1,350	513	391	1,187	506
Montana	31,317	3,912	1,051	1,138	3,034	1,791
Forest Service		1,360	271	99	1,053	556
BLM		70	20	10	56 45	
Wyoming	4,785	71	0	0	46	0
Forest Service		39	0	0	35	0
BLM		2	0	0	2	0
Nevada	6,835	175	161	14	0	0
Forest Service		11	1	9	0	0
BLM		48	48	0	0	0
TOTALS						
All states		266,257	26,266 14,017	4,922	12,840	831
Forest Service		7,515	3,395	414	3,976	1,431
BLM		2,142	1,164	450	1,311	646

[a] ND: No Data

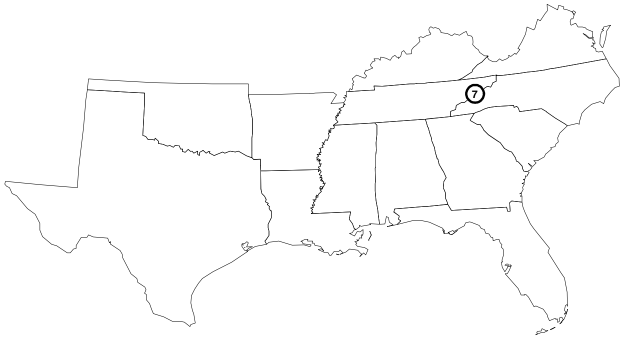
Table 8—Economic impacts of the declines in the recreational fishery for Pacific Northwest salmon and steelhead (American Sportfishing Association. Fact Sheet on Pacific Northwest Salmon and Steelhead Economic Impact. On file with C.H. Flather, Rocky Mountain Research Station, 2150 Centre Ave., Fort Collins, CO 80526).

	1991 estimates	Change from 1985		1991 estimates	Change from 1985
Expenditures	$ 603,981,000	–45%	State income taxes generated	$ 16,187,000	–37%
Economic output	$1,200,000,000	–46%	Federal income taxes generated	$ 76,118,000	–46%
Personal income	$ 76,118,000	–46%	Jobs (full time equivalents)[a]	$ 43,342	–42%
State Sales taxes generated	$ 25,000,000	–51%			

[a] Salmon and steelhead fishing-related jobs.

CASE STUDY 7:

SOUTHERN APPALACHIAN AQUATIC RESOURCES : AN IMPERILED ECOSYSTEM?[6]



Background

The Southern Appalachian region of the United States may be one of the most ecologically imperiled areas of the country. Its proximity to the large and growing population centers throughout the history of the settlement of this continent, and its relatively poorly buffered soils, have made it susceptible to influences from increasing human activities and acidic deposition.

During 1994–96, a consortium of state and federal agencies (including the USDA Forest Service), regional commissions, and private organizations teamed to conduct a comprehensive analysis of the resources in the Southern Appalachian Area (SAA). This area consists of parts of the Appalachian Mountains and Shenandoah Valley covering portions of eight states from northern Virginia to Alabama. It also contains the headwaters of nine major rivers in the Southern Appalachian region.

As human settlement increased in this region in the past two centuries, land use in the southern Appalachian area has undergone several dramatic changes. These land use patterns, in combination with other impacts of human settlement, have affected the status and distribution of aquatic fauna of this region.

Problem

In the early part of this century, the landscape of the southern Appalachians was shaped by agriculture and exploitation of timber resources. These activities were not evenly distributed across the watershed. Prime agricultural lands typically lay in river valley bottoms and lowlands, whereas accessible timber resources were located at lower elevations in the mountains or where natural streams cut through the mountain ranges. By 1910, logging in this region provided 40% of the lumber in the United States. Many of the timber harvesting and agricultural practices resulted in excessive erosion, increased sedimentation in streams, and associated impacts to stream habitat. However, by the 1930s and 1940s, government acquisition of large tracts of land and subsequent reforestation through programs such as the Civilian Conservation Corp began to repair some of the effects of logging.

Today, 71% of the land is forested, 22% is used for pasture or is in some herbaceous cover, 3% is cropped, and 4% is developed or barren (e.g., rock outcroppings). Seven national forests and three national parks in the region constitute the largest contiguous block of public lands east of the Mississippi.

Past effects of land use on aquatic habitats are not quickly reversible and, combined with environmental pressures from increasing urbanization, are impacting the quality of aquatic systems. There are numerous degraded streams; more than 20% of stream miles are impacted in 15 states. Thirty-eight percent of lakes exhibit characteristics of excessive eutrophication. In some watersheds, there is a loss of up to 75% of riparian forest. Fifty percent of the stream miles in the area show habitat impairment as compared to relatively unimpacted reference conditions.

The land use impacts, exploitation of aquatic species, and introduction of exotic species are not quickly or easily reversed. Seventy percent of the locations sampled in the SAA region showed moderate or severe fish community degradation. In states such as Tennessee, native brook trout ranges have shrunk to 20 to 30% of their estimated native range since the early 1900s due to activities associated with logging, overfishing, and introduction of non-native rainbow trout. Although most of the losses occurred in the early part of this century, they still continue today, with encroachment of non-native rainbow trout and stream degradation being the current primary threats (Bivens and others 1985). Whereas streams once supported one species of trout, they now support three: one native species (brook trout) and two introduced species (brown trout and rainbow trout). One hundred ninety other aquatic or semi-aquatic species are endangered, threatened, or of special concern in this region, with 57 of these being freshwater mussels and 62 being fish. These comprise 50% of the mussel species and 45% of the fish species in the area.

Two-thirds of the water quality impacts are due to nonpoint sources (agricultural runoff, stormwater, landfill, and mining leachate). The Mid-Atlantic highlands, which encompasses the SAA, has one of the highest rates of acidic deposition in the country (Herlihy and others

[6] Synopsis based on *Southern Appalachian Man and the Biosphere* (SAMAB) 1996.

1993). Additionally, 54% of stream miles have high sensitivity to acid deposition. Fifty-nine percent of wild trout streams are in areas highly vulnerable to acidification and 27% are in areas moderately susceptible to acidification.

Response and the Future

There are signs of improvement to the water quality and landscape that hold promise for improving the conditions of aquatic life. Since provisions of the Clean Water Act of 1972 were implemented, 75% of the river miles in the SAA are now rated as partially or fully supporting their designated uses. Within the Southern Appalachian area, the Chesapeake Bay drainage has the highest percentage of water bodies that meet water quality standards for the protection of aquatic life. Furthermore, terrestrial habitat conditions, which greatly influence fisheries and have been identified as a major factor influencing ecological integrity of aquatic resources, are improving. In the SAA region, soil disturbance related to agriculture declined from 1982 to 1992 and current forestry activities are so dispersed within the region that the cumulative impacts over the region are now considered to be low.

Projections for the SAA provide some hope for improved aquatic systems in the future. Whereas agriculture, logging and mining once posed the greatest threats to the ecosystem, increasing urbanization in the watershed is now a principal factor impacting aquatic habitats and fauna in the future. Between 1970 and 1990, human population density in the SAA increased 28% to 101.8 individuals per square mile and will likely continue to increase. However, water quality indices have improved. To accommodate future increases in population and urbanization will require continued control of sources of pollution and siltation from urban landscapes. Increasing programs to control point sources of pollution, combined with an increasing awareness and application of improved land use practices (such as implementing Best Management Practices), will contribute to a trend of improving water quality and will help to foster improved habitat conditions for supporting aquatic life.

CASE STUDY 8:
ATLANTIC SALMON

Background

The case of the Atlantic salmon epitomizes the impacts that the combined effects of fishing practices, habitat destruction, dilution of genetic stocks, and water quality can have on wild fish populations. Atlantic salmon, which was once plentiful in the rivers of the Northeast and which provided sustenance and commerce for a developing nation, has been driven to historically low levels. Despite prior and ongoing attempts to restore U.S. stocks, the future of Atlantic salmon in U.S. waters remains uncertain.

The original range of Atlantic salmon in the United States was from the Houstonic River in Connecticut to the U.S. tributaries of the lower portions of the St. Johns River in New Brunswick, Canada. Historic runs of Atlantic salmon numbered in the vicinity of 500,000 fish throughout the New England rivers (Federal Register 1995) and Native Americans and early settlers depended on the salmon for food (Buck 1993).

Atlantic salmon begin their life cycle in freshwater tributaries of New England rivers. Eggs deposited in gravel redds in late fall and early winter begin to hatch in late spring. The young stay in these areas, dependent on the availability of clean waters and abundant food supply for one to three years. Usually after the third year, at which time the salmon are five to six inches long, they undergo physiological changes to better adapt them for living in an ocean environment and begin their seaward migration. In some rivers during these downstream migrations, a run of salmon may be reduced by 4 to 20% as the young salmon pass through turbines of dams (Buck 1993).

Once in the ocean, the pelagic salmon are highly migratory, spreading throughout waters of the North Atlantic and mingling with other stocks of salmon originating in river systems of other north Atlantic and Scandinavian countries. It is in the open ocean that they are targeted by a variety of predators, including marine mammals, sharks, tunas, and commercial fishing fleets of many countries.

Although some salmon return to their natal streams after only one year at sea, most spend two to three years feeding and growing rapidly in the open ocean. Near-shore fisheries (including recreational fisheries) as well as pollution and stream blockages, take further toll on the salmon numbers as they begin to return. If they can reach their spawning grounds in the freshwater tributaries, they will spawn, beginning the life cycle for another generation.

Problem

As industrial and commercial needs of the United States increased during the early parts of the 19th century, the construction of dams and water diversions on New England Rivers intensified to run the mills and factories and transport goods around natural waterfalls. Later, the increasing need for electrical power exacerbated the situation as hydroelectric facilities were constructed to harness the energy of free flowing rivers (Buck 1993). These water diversion activities blocked salmon access to spawning habitat and reduced available habitat to only a small fraction of what it was, thereby effectively disrupting the Atlantic salmon's life cycle. On the Connecticut River, for example, only 12 years after a dam was erected in the lower portion of the river, salmon populations throughout the entire river system were driven to extinction (Buck 1993). With the exception of the Penobscot River and a few other Down East rivers in Maine, salmon runs had virtually disappeared from New England by the middle 19th century (Buck 1993, Federal Register 1995).

In addition, degrading water quality contributed to a demise of Atlantic salmon populations. A growing human population and increasing industrialization brought with it increased waste disposal into rivers. Buck (1993) noted that, in addition to dams, "severe pollution and unregulated fishing at the mouth of the Merrimack prevented the salmon's passage and they disappeared completely."

Unregulated fishing has been the third major cause of the salmon's decline. Although efforts to restore salmon extend back as early as 1875, the harvest of returning adults prior to their spawning precluded the restoration of salmon runs (Buck 1993). States including Maine and New Hampshire enacted measures to prohibit the harvesting of salmon once they reached their waters, but loopholes in the laws and illicit harvesting undermined the effectiveness of these efforts.

In the 20th century, the increasing size of, and harvesting by, distant water fleets from foreign nations resulted in a large escalation of the ocean harvest of salmon, particularly from Denmark. Atlantic salmon harvest increased from 132,240 pounds in 1960 to 3,528,604 pounds by 1967 (Buck 1993) (figure 15). Since salmon stocks originating from different natal streams (and different countries) comingle in the ocean, it is not possible to segregate the harvest of salmon originating in different nations in order to protect one stock over another.

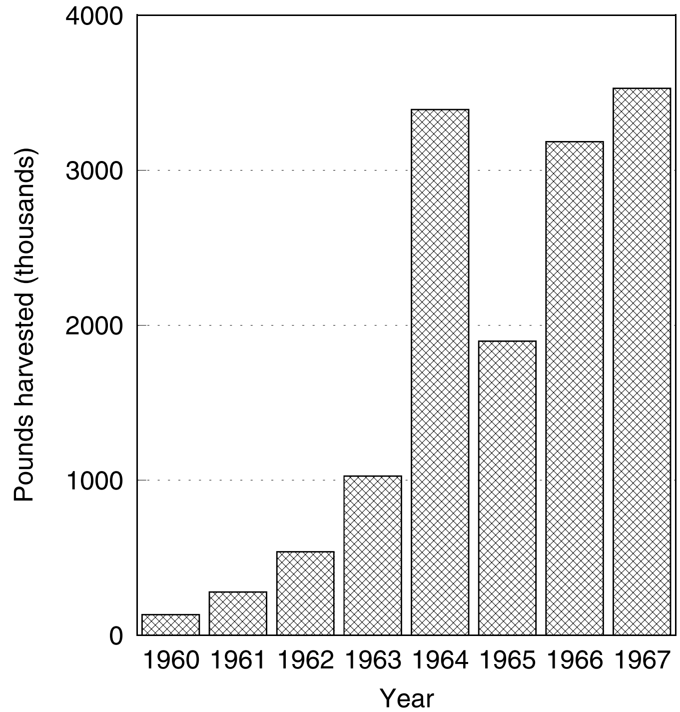


Figure 15—World catch of Atlantic salmon (Buck 1993).

Responses and Results

Since the 1970s, tremendous progress has been made in Atlantic salmon restoration efforts. The North Atlantic Salmon Conservation Organization (NASCO) was formed in 1984 to provide international management of salmon on the high seas.

Although salmon populations in New England once numbered near one-half million fish, by 1996 their abundance was estimated at approximately 4,000 throughout the 20 major rivers in the region (Atlantic Salmon Assessment Committee 1997). In September of 1995, the U.S. Fish and Wildlife Service published a notice of intent to list the populations of Atlantic salmon in seven Down East rivers (Sheepscot, Ducktrap, Narraguagus, Pleasant, Machias, East Machias, and Dennys Rivers) as threatened under the Endangered Species Act of 1973. Adult returns to these seven rivers (figure 16) average less than 10% of the number of adult returns needed to "fully seed" the available habitat (Federal Register 1997). In making this proposal, however, the U.S. Fish and Wildlife Service determined that populations of Atlantic salmon in the Kennebec, Penobscot, Tunk Stream, and St.Croix Rivers are persistent and continue to have a genetic link to native populations and therefore would be designated as a "Species of Concern." It was also noted that, primarily due to stocking and inter-basin transfers of differing stocks of fish, it is unlikely that Atlantic salmon exist in their genetically pure native form in any New England system. South

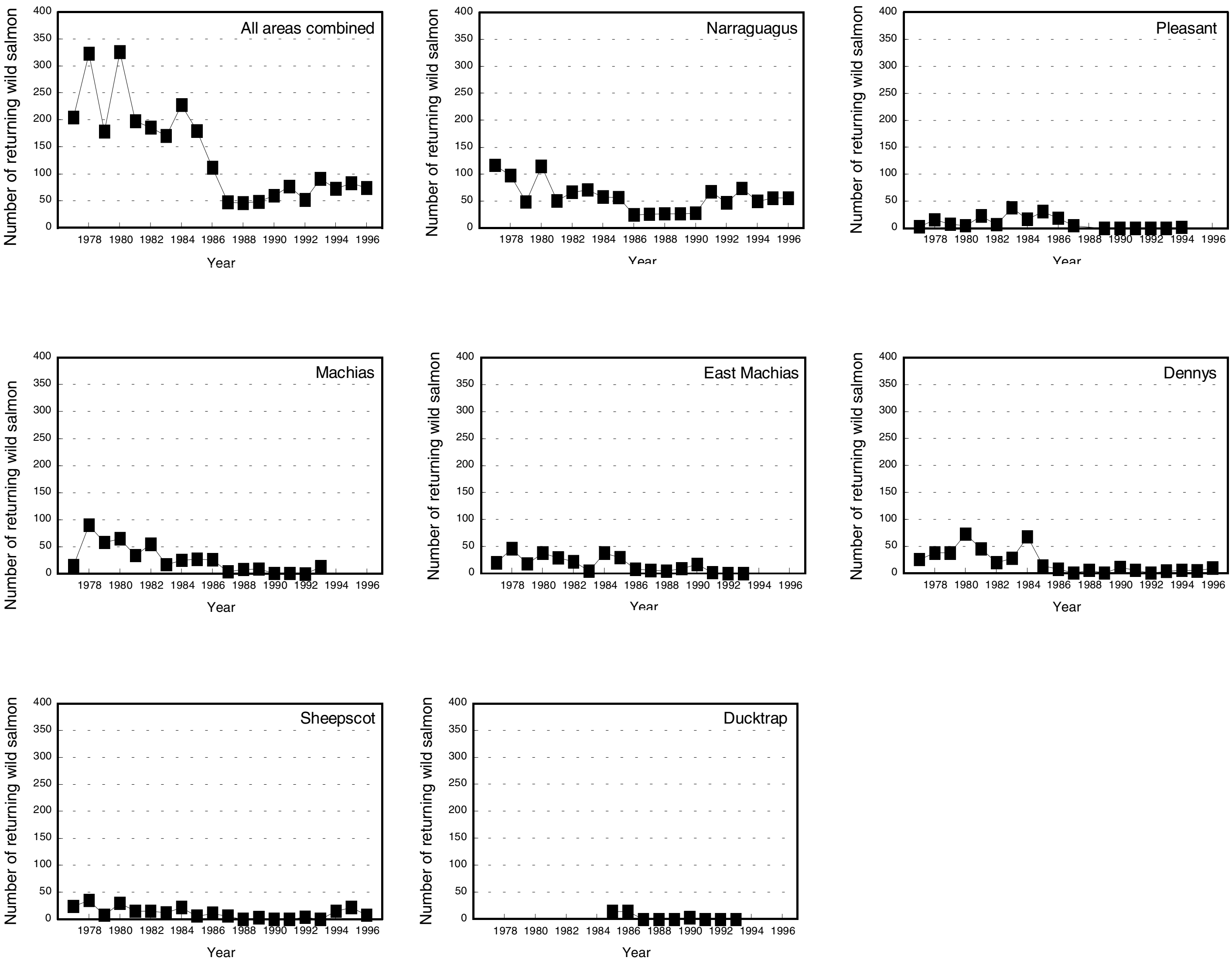


Figure 16—Population trends of Atlantic salmon stocks proposed for federal protection (Atlantic Salmon Assessment Committee 1997).

of the Maine river systems, original populations had been extirpated completely (Federal Register 1997). Despite the available information indicating low populations, the Service withdrew this proposed listing due to the ongoing conservation efforts that "substantially reduced threats to the species" and that would facilitate rehabilitation in these river systems (Federal Register 1997).

In addressing the causes of the salmon decline, the Federal Register (1995) noted:

> "One of the predominant land uses of central and northern coastal Maine watersheds is the growth and harvest of forest products. Forest management practices can cause numerous short and long term negative impacts on Atlantic salmon. Deforestation alters the water retention of watersheds resulting in high seasonal runoff followed by inadequate river flows. The removal of riparian vegetation reduces shading and increases water temperature. Poor logging practices and road construction adjacent to streams results in the deposition of substantial loads of woody debris and silt into waterways. Insecticides used to control insect infestations and herbicides used to manage competing vegetation enter waterways and impact salmon. Historic logging practices have impacted salmon in these ways, but current forest practices due to state and federal laws are not now considered a threat to Atlantic salmon."

The challenges of providing sufficient spawning habitat in both quality and quantity still remain, however. The Connecticut and Merrimack rivers once provided 40% of spawning habitat for salmon in all of New England (Federal Register 1995). On the Merrimack River, comprehensive surveys by the states have quantified the abundance and quality of potential spawning habitat in upstream tributaries. This was followed by the initial construction of fish passage facilities in the lower portion of the river, but blockages still remain farther upstream. These facilities are in their infancy of operation and are still be being refined to provide suitable upstream passage. Additionally, passage of smolts downstream is a critical component of restoration (Technical Committee for Anadromous Fishery Management of the Merrimack River Basin & Advisors to the Technical Committee 1997). Atlantic salmon now return to the river annually as a product of hatchery smolt and fry releases but at a fraction of their historical level. Since salmon have been extirpated, the restoration effort, in addition to relying on obtaining upstream fish passage, has relied on stocking hatchery-produced fish of varying ages (Technical Committee for Anadromous Fishery Management of the Merrimack River Basin & Advisors to the Technical Committee 1997).

The Future

Although access to historical spawning habitat remains a key impediment to Atlantic salmon recovery, evidence suggests that low natural survival in the marine environment is now a major factor contributing to the decline of Atlantic salmon (Federal Register 1995). If West Greenland and Canadian intercept fisheries were eliminated, returns of U.S. Atlantic salmon could potentially double (Federal Register 1995). Further, past stocking practices and current escapements from commercial aquaculture operations may have diluted genetic pools of native fish and contributed to the decline.

The plight of Atlantic salmon continues as attempts at recovery are impeded by continued complexities in managing international fisheries; restoring both access to, and quality of, natural spawning habitat; and potential factors related to the loss of historic genetic characteristics. The elimination of unique genetic strains from some systems means that these stocks will never be reestablished. However, genetic stocks that are able to adapt to current-day environmental conditions may be able to survive in these same systems. Even though Federal listing under the Endangered Species Act was deemed unnecessary at this time, conservation efforts by the federal and state governments will continue and provide one more step to attaining restoration of Atlantic salmon to the rivers of New England.

TRENDS IN COMMERCIAL AND RECREATIONAL FISHERS

The RPA Assessment is to include an analysis of present and anticipated uses, demand for, and supply of, the renewable resources. Trends in the use of aquatic resources reflect several variables, including resource condition, state of the economy, public perception regarding the resource, and societal values and desires that may change over time. For example, in 1991 the Sport Fishing Institute reported that a decline in the number of sport fishing license holders in the Great Lakes region was in part attributable to heightened reports about contaminants in Great Lake fish. This decline was not related to fish abundance or actual increase in contaminant burdens. Therefore, interpreting the causes behind changes in participation must be done with care.

There is no single data source that accurately measures the public's use of fisheries resources. User groups can be generally classified as commercial harvesters, recreational anglers, subsistence fishers, and "watchable wildlife" participants. Little information on a regional or nationwide basis is available for either subsistence fishers or watchable wildlife specifically related to fish. For commercial harvesters and recreational anglers, several data sets exist and will be discussed below.

Commercial Fishers

The National Marine Fisheries Service (NMFS) is the primary source for commercial harvesting data. Commercial harvest of wild stocks of fish is an activity that occurs principally in ocean waters and the Great Lakes, and to a much lesser degree in freshwater environments other than the Great Lakes. Commercial harvesting capacity is generally measured in terms of the number of commercial vessels registered. This is problematic since it does not accurately reflect either harvesting capacity or time spent at sea. In general, it may not accurately reflect the condition of the resource since other factors influence participation including market price, government regulation, government incentive programs, and weather.

Trends in commercial craft have remained fairly steady in the last decade. In 1995, approximately 33,000 vessels in excess of five net tons were registered in the United States (USDC 1996). Since the time series of data collection began in 1964, the number of vessels slowly increased until 1984. Since 1990, the number of vessels has remained stable but at a lower level than in the earlier time period (figure 17). In 1987, the last year of a comparable data set on commer-

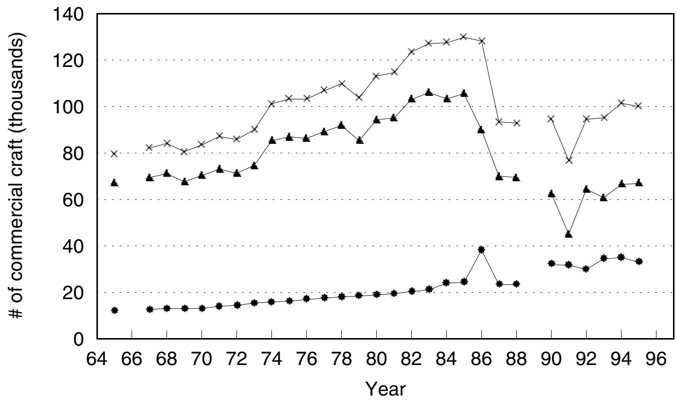


Figure 17—National trends in the number of commercial fishing craft, 1965–1995 (X's). Boats are craft less than 5 net registered tons (triangles); vessels are greater than 5 net registered tons (circles). Includes Great Lakes fisheries other than tribal fisheries (USDC National Marine Fisheries Service 1971–1997; USDI Bureau of Commercial Fisheries 1967–1970).

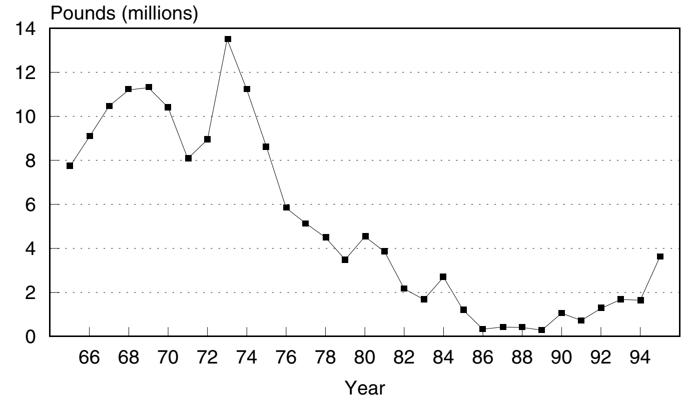


Figure 18—Commercial harvest of striped bass, 1965–1995 (USDC National Marine Fisheries Service 1971–1997; USDI Bureau of Commercial Fisheries 1967–1970).

cial fishing vessels worldwide, U.S. vessels accounted for only 3% of the world's fishing vessels (USDC 1996). U.S. commercial seafood harvesting and processing supports over 30,000 full time jobs and produces approximately 6% of the world's commercial landings (USDC 1993).

Using the weight or number of individuals harvested to reflect trends in populations is also very problematic. The same factors that influence commercial harvesting capacity also influence total harvest and harvest does not necessarily indicate the species' status. One of the largest factors is changes in regulations or incentives governing the fishery. If regulations cap the allowable harvest of a species, as is becoming more prevalent as more intensive management is evolving to combat declining fisheries, total pounds or numbers of fish harvested would be expected to provide a false indication of species status. As an example, the declining trend in striped bass harvest in the 1980s (figure 18) does not accurately portray the trend in the population (figure 12). Moratoriums on fishing and other restrictive regulations by the states depressed the harvest but such actions allowed the stock size to rebound.

Recreational Fishers

Although recreational harvest is not always as readily visible as commercial harvest, it often can equal or exceed that of the commercial sector of particular fisheries. Information about the status and trends of recreational anglers on a nationwide basis are available in the *National Survey on Fishing, Hunting and Wildlife Associated Recreation* (which is conducted every five years by the USDC Bureau of Census and USDI Fish and Wildlife Service), the *Marine Recreational Fisheries Statistics Survey* (conducted annually by the USDC National Marine Fisheries Service), and the number of anglers who bought licenses sold as compiled by the U.S. Fish and Wildlife Service. Each survey has its strengths and weaknesses and a composite of all three can provide general information on status and trends of recreational fishing.

National Survey on Fishing, Hunting, and Wildlife-Associated Recreation

Every five years the U.S. Fish and Wildlife Service conducts the *National Survey on Fishing, Hunting and Wildlife Associated Recreation* (hereinafter referred to as the National Survey). This comprehensive survey provides information on participation, economics, trends in species preference, and angler demographic information related to these categories. Unfortunately, changes in survey methodology in certain years (most dramatically in 1991) preclude simple comparisons of most trends for an unbroken time series. However, general trend information for specific categories of fishers can be ascertained.

In 1996 the number of recreational fishers (age 16 and older) nationwide declined slightly from 1991, but this does not reflect a statistically significant decline (table 9). Therefore, the number of participants is considered to have remained unchanged. Over the last decade, both the numbers of anglers and days of participation have increased (figure 19). However, values indexed to the initial year of the National Survey demonstrate that while the rate of increase in the number of anglers outpaced the rate of increase in total U.S. population between 1955 and 1991, in recent years this gap has begun to narrow (figure 20). In addition to a declining rate of increase in actual numbers of recreational anglers, this trend also highlights the declining participation as a function of the entire U.S. adult population.

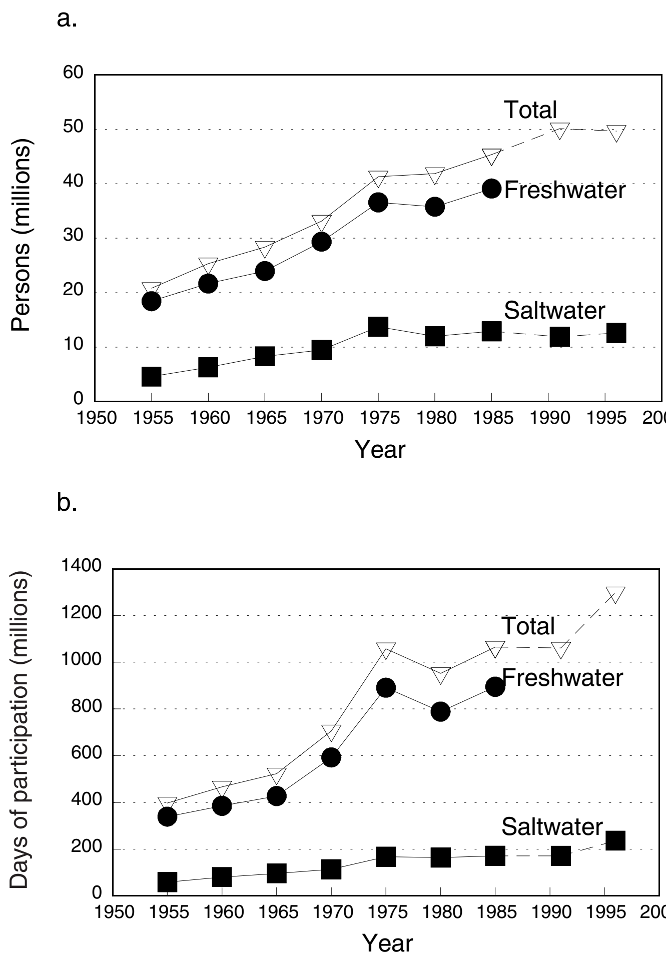


Figure 19—(a) Trends in the number of anglers and (b) Trends in the days of angling - for anglers age 12 years older in the United States. Dashed lines represent extrapolated estimates of participation in fishing activities for 1991 and 1996 based on percentage changes applied to 1985 estimates. Freshwater anglers and days could not be comparably extrapolated in the 1991–1996 estimates because of changes in categorization in the survey. Data for freshwater could not be extrapolated due to changes in survey classification between "freshwater" and "Great Lakes" fishing in 1991 (USDI Fish and Wildlife Service and USDC Bureau of Census 1993, 1998).

In 1996, although the total number of anglers remained statistically level from 1991, the number of fishing trips increased as did the number of saltwater-oriented anglers and trips. The total number of days fishing in the United States increased 22% from 1991 to 1996. Regionally, the increase in the number of angling trips ranged from 16% in the Northern RPA region to 37% in the Pacific region (table 9). Mirroring this increase, nationwide fishing expenditures increased 37%. Significant to these statistics are the fishing expenditures for boats, 4x4 vehicles, campers, vans, and cabins, which increased 123%.

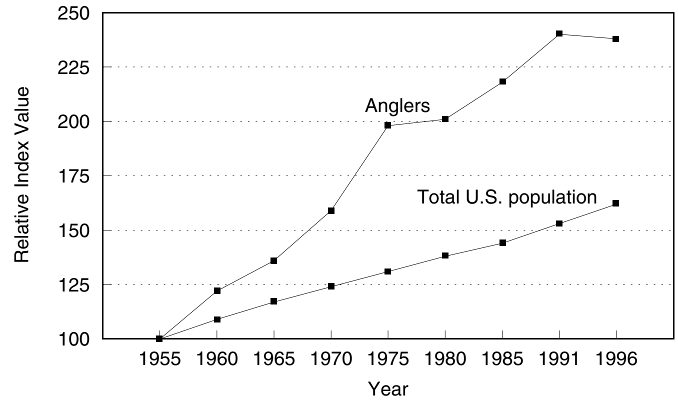


Figure 20—Trends in recreational fishing and population growth in the United States, indexed to 1955=100 (USDI Fish and Wildlife Service and USDC Bureau of Census 1998).

Marine Recreational Fisheries Statistics Survey

Each year since 1981, the National Marine Fisheries Service has collected information on the recreational fishing participation in saltwater. A combination of telephone and intercept surveys are conducted in bimonthly waves throughout the year. The sampling universe for the telephone survey (which provides trip estimates) is generally considered to be coastal counties. However, changes in survey coverage and methodology on the Pacific coast since 1981 have not been consistent and make data for that region difficult to compare over time. Therefore the following discussion applies primarily to the Atlantic and Gulf coasts (and excludes Texas, which conducts a separate survey).

Between 1994 and 1996, the number of marine recreational trips declined. However, there are large temporal fluctuations in the estimated number of trips (figure 21). Recent declines not withstanding, participation in saltwater fishing has increased greatly since 1981. On a regional basis, the northern RPA region has experienced a general increase since 1992 (figure 22). Much of this is attributable to more recreational anglers seeking striped bass, which have made a tremendous recovery in the past decade (see Case Study 5). The southern region (excluding Texas, which does not participate in the survey) has declined slightly since 1994, although participation in 1996 is higher than at the beginning of the time series in 1981 (figure 22).

State License Sales

Each year, the U.S. Fish and Wildlife Service compiles information on fishing license holders in each of the 50 states and the District of Columbia. The number of license holders is "certified" through a review process to ensure accurate reporting of statistics. These estimates are then used as part of a formula to apportion funds through the Federal Aid in Sport Fish Restoration Act (this Act,

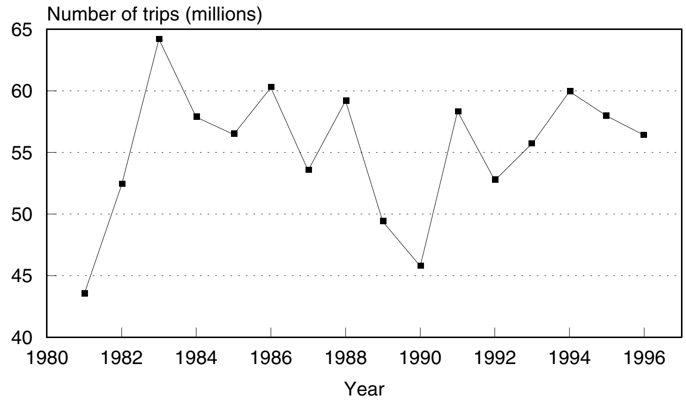


Figure 21—Trends in marine recreational fishing trips on the Atlantic and Gulf coasts of the United States (USDC National Marine Fisheries Service 1998: http://st.nmfs.gov).

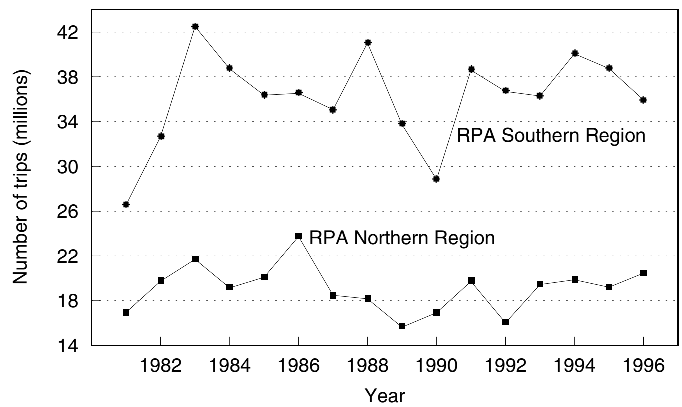


Figure 22—Trends in marine recreational fishing trips by RPA region on the Atlantic and Gulf coasts of the United States. Estimates do not include data from Texas participants 1986–1996 (USDC National Marine Fisheries Service 1998: http://st.nmfs.gov).

originally created in 1950 under the popular name of the Dingell-Johnson Act, was greatly expanded in 1984 under the popular name of the Wallop-Breaux Act). While license sales information provides fairly reliable information on license holders nationwide, it may be problematic since state licensing regulations are not always uniform across states (for example, some residents such as younger or older persons may be exempt from licensing requirements) and substantial changes in any state licensing program may not necessarily reflect total participation.

Nationwide, license sales declined during the period 1991–96 (figure 23). Since 1991, license sales declined by 2.6%, mirroring the slight (but statistically insignificant) decline in participation as seen in the National Survey. Over the last decade (1986–1996), license sales fluctuated on an annual basis but over the period have remained relatively unchanged except for the sharp decline in 1996.

On a regional basis, there has been a dramatic decrease in license sales in the northern region between 1991 and 1996 (figure 24). Part of the reason may be attributable to weather, since this region experienced periods of severe flooding (1993 and 1996), and concerns over contaminants in fish (Sport Fishing Institute 1991). Similarly, declines in 1993 license sales in the southern region may be attributable to the high water levels that occurred in that year. However, sales in this region have also been declining since 1994. In the Rocky Mountain Region, license sales have been increasing since 1993. In the Pacific region, part of the decline in license sales during the late 1980s and early 1990s may be attributable to drought conditions that reduced the water supply and fishing opportunities in areas such as northern California.

Recreational Fishing on Forest Service Lands

Recreational fishing on Forest Service lands is estimated to be nearly 47 million freshwater angling days annually (table 1) with the majority of this taking place on inland waters (Sport Fishing Institute 1993*b*). In the process, anglers spend nearly $3 billion, creating an economic impact (as measured by economic output) of $8.5 billion. Unfortunately, comparable estimates across federal agencies are not readily available. In 1993, the Sport Fishing Institute compiled the best estimates available of participation on lands of five Department of Interior agencies, determining that participation ranged from 5.4 million angler use days to 27.1 million angler use days, depending on agency (table 1).

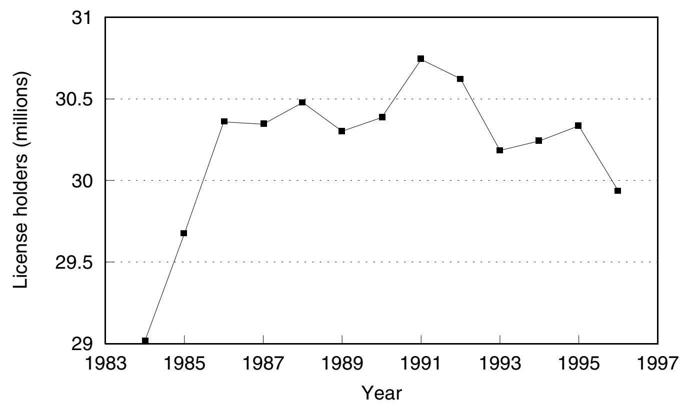


Figure 23—Trends in sport fishing license holders in the United States (USDI Fish and Wildlife Service 1997; Maharaj and Athey 1996).

Trend Summary and Factors Affecting Participation

At best, participation in recreational fishing appears to be stable between 1991 and 1996 according to the National

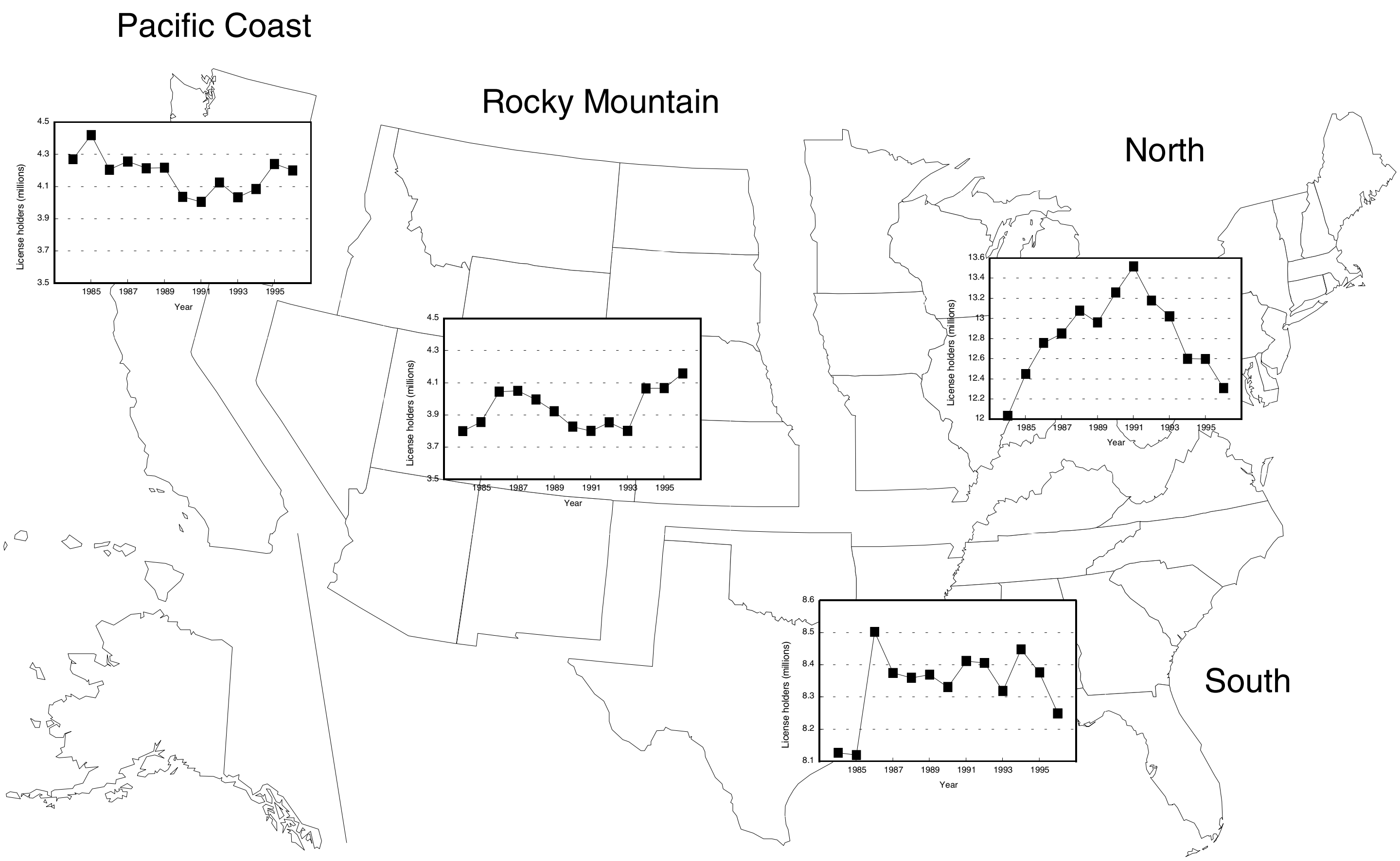


Figure 24—Trends in sport fishing license holders by region in the United States (USDI Fish and Wildlife Service 1997; Maharaj and Athey 1996).

Table 9—Regional trends in the number of anglers and angling days for participants age 16 and older, 1991-1996. U.S. totals include responses from participants living in the District of Columbia, but regional totals do not (USDI Fish and Wildlife Service and USDC Bureau of Census 1993, 1998).

Region	Number of anglers [a] (thousands)			Angling days [b] (thousands)		
	1991	1996	% change	1991	1996	% change
Total	35,578	35,246	—	511,329	625,893	22.4
(% of population)	(18.7)	(17.5)				
North	15,248	14,625	–4.1	225,271	261,210	15.9
	(17.6)	(16.5)				
South	12,758	12,806	1.4	204,757	256,319	25.2
	(21.5)	(19.8)				
Rocky Mountain	3,049	3,303	8.3	32,968	44,530	35.1
	(21.5)	(20.5)				
Pacific Coast	4,505	4,501	—	48,228	66,149	37.1
	(15.3)	(14.2)				

[a] Number of anglers based on state-of-residence participation.
[b] Angling days based on place where activity occurred.

Survey. Just as relevant though is the fact that, although the *number* of participants is remaining stable, the *percentage* of the U.S. population that fishes continues to decline.

Evaluating the factors that may influence recreational fishing participation estimates, and actual participation, is difficult. Using license sales as an indication of participation, a survey by the Sport Fishing Institute in 1990 to assess the impact of various license fees on license sales revealed that the three most significant factors impacting sales were: license price, per capita income, and population growth (Fedler and Sweezy 1990). While license price had a slight negative impact on sales, the depressed sales were generally recouped in a period of a few years. However, whether these recouped license sales were anglers returning to fish after having dropped out after the increase, or they simply reflected increased sales resulting from increased population growth, is a matter of debate.[7] The other two factors both had positive impacts on license sales. As per capita income rose and population increased, license sales in a state also increased (Fedler and Sweezy 1990).

Several surveys have been conducted to ascertain causative factors behind the decline in participation. None of these surveys indicates that degrading resource conditions are a cause behind the decline. Duda and others (1995) found that the largest determinants of male fishing decline are increasing age and fewer men growing up in rural areas. Among inactive anglers surveyed, the top five reasons given for no longer fishing included the amount of free time, lost interest, family obligations, work obligations, and having no one to go with (table 10). "Not enough game fish" ranked Number 15 with only 5% of respondents citing this as a factor for no longer fishing.

Similarly, a survey conducted annually by the sport fishing industry ranked the major reasons for not fishing more in 1995 as: no time, no place to go, other interests, weather, family issues, and other (unidentified) issues (table 11). Consistently over the course of this survey (1989–1995), a low number of respondents (0–2%) identified resource conditions (poor water quality, no fish, or fish too hard to catch) as a reason for not fishing more. Anglers were also asked what attributes of the angling experience have degraded or become more difficult than in previous years. Under this question, attributes reflective of the quality of the fishing experience became important (table 12). Crowding and competing uses of water resources were the most commonly cited factors that had made the fishing experience more difficult. Again, resource supply indicators (e.g. too few fish) were rarely a substantial concern of respondents.

In the 1996 National Survey, respondents were asked if they fished as much as they would have liked. Sixty-five percent (22,765,000 anglers age 16 and above) of the respondents indicated that they did not fish as much as desired. Overwhelmingly, the reasons stated were other obligations or not enough time (table 13). Factors related to resource conditions ranked at 1% or less. Considering the results of these individual surveys overall, it appears that a combination of factors, led by "competing interests," are reducing the available time that individuals have to spend on recreational fishing.

This is not to say that resource conditions do not play a role in participation. The increasing fishing trips for striped bass on the Atlantic coast parallels with the increasing abundance of striped bass (figure 25). Although the relaxed fishing regulations in 1990 may, in part, have contributed to increased trips, regulations were substantially more restrictive than pre-1984 and the increasing trend in trips began when regulations were being tightened prior to 1990. This fact, combined with an increase in the incidence of catch-and-release fishing (which is largely unaffected by regulatory changes), indicates that factors other than regulatory changes caused this large surge in striped bass fishing trips. According

Table 10—Reasons inactive anglers stopped fishing (Duda and others 1995).

Reason	Percent of responses
Amount of free time	30%
Lost interest	24%
Family obligations	20%
Work obligations	19%
No one to go with	16%
Personal health	15%
Pollution or litter	12%
Having to travel to go fishing	9%
Not enough access	7%
Not enough places to fish	6%
Fishing endangers fish populations	6%
Interference from others while fishing	6%
Cost of fishing license	5%
Not enough game fish	5%
Cost of fishing equipment	5%
Poor behavior of other anglers	4%
Too many fishermen	3%
Complex regulations	3%
Not enough officers	3%
Not enough trophy fish	2%
Frequent changes in regulations	2%
Finding a place to buy licenses	2%
Creel limit/season length	1%
Strictness of officers	1%

[7] Mike Costello, pers. comm., Ohio Division of Wildlife, 10517 Canal Road SE, Hebron, OH 43025, 1998.

Table 11—Trends in reasons anglers provide for not fishing more (Responsive Management 1996).

Reason	1989	1990	1991	1992	1993	1994	1995
No time	80%	80%	75%	74%	73%	70%	78%
No place to go	5%	6%	5%	7%	8%	7%	5%
Other interests	NA[a]	3%	2%	13%	20%	6%	8%
Weather	0%	7%	2%	11%	7%	5%	6%
Family issues	6%	6%	6%	8%	7%	4%	4%
Health/age	4%	4%	5%	7%	5%	4%	2%
Too expensive/no money	7%	4%	6%	6%	5%	3%	4%
No one to go with	4%	3%	4%	5%	4%	3%	1%
Other	11%	10%	11%	12%	11%	10%	6%
Fish too hard to catch	1%	2%	1%	2%	1%	2%	1%
No fish to catch	NA	2%	1%	1%	1%	2%	1%
Poor water quality	NA	1%	1%	1%	1%	1%	0%
Too many other anglers	NA	NA	NA	NA	NA	NA	1%
Not interested	3%	1%	3%	4%	3%	1%	1%

[a] NA: Not Applicable, insignificant response.

Table 12—Attributes of recreational fishing that are identified as making fishing "more difficult" than in the past (Responsive Management (1996). Blanks represent those situations when the attribute did not appear as survey response for that year.

Attribute (more difficult)	1990	1992	1993	1994	1995
Too crowded	19%	33%	33%	9%	8%
Boats and watercraft	NA[a]	10%	12%	9%	9%
Too many jet skis					5%
Too many anglers		9%	15%	11%	12%
Poor behavior of anglers/boaters	NA	4%	4%	5%	5%
Weeds in water	NA	4%	1%	2%	2%
Water level	NA	3%	0%	4%	8%
Litter in water	10%	6%			
Litter on land	NA	2%	6%	7%	3%
More expensive-licenses	7%	9%	8%	6%	9%
More expensive-equipment	NA	NA	5%	3%	4%
No place to go	NA	2%	1%	6%	7%
Land restrictions	NA	8%	4%	6%	5%
Increased regulations	6%	6%	14%	11%	8%
Poor health/age	NA	6%	5%	4%	4%
Kids	NA	4%	1%	1%	2%
Too few fish -fishing pressure	NA	2%	3%	1%	NA
Sport fishing					11%
Commercial fishing					4%
Too few fish - netting	NA	2%	3%	1%	NA
Fish are polluted	6%	6%	6%	2%	NA
Bugs	3%	3%	4%	2%	2%
Weather	1%	2%	0%	4%	2%
Other					14%

[a] NA: Not Applicable, insignificant response.

Table 13—Reasons anglers did not participate more in fishing in 1996 (USDI, Fish and Wildlife Service and USDC, Bureau of Census 1998).

Reason	Percent of respondents
Family or work obligations	43%
Not enough time	21%
Not enough money/cost too much	4%
Personal health or disability	4%
Weather	3%
No one to fish with	1%
Not enough places to fish/not enough access	1%
Not enough fish	1%

Table 14—Most sought-after saltwater species (nationwide) by anglers (USDI, Fish and Wildlife Service and USDC, Bureau of Census 1998).

Species	Days of fishing [a] (thousands)	Percent of total days of fishing
Flatfish/Flounder/halibut[b]	28,644	28
Striped Bass	15,023	15
Salmon[c]	3,976	4
Bluefish	13,190	13
Lingcod	1,900	2
Weakfish	14,245	14
Mackerel	15,108	5
Anything	24,807	24
Other	45,091	44

[a] Anglers can specify multiple target species on a single trip.
[b] Likely to include summer flounder, winter flounder, halibut, witch flounder, yellowtail flounder, American plaice, windowpane flounder.
[c] Likely primarily Pacific salmon.

to National Survey estimates of saltwater fishing trips directed at specific species (discounting responses of "Anything" and "Other"), striped bass-directed trips rose from the fourth largest in 1991 to the second position in 1996 in terms of the percent of days targeting a *specific* species (table 14).

In a companion report, Bowker and others (1999) project that participation in recreational fishing will increase by 36% over the next 55 years. Given the recent trends in the National Survey and state license sales, this projected growth in participation may be optimistic. The model used to predict participation patterns (number of participants) is a static logistic regression model incorporating age, income, ethnicity, gender, population density, and residential proximity to fish resources. However, as is evident in the attitudinal surveys referenced previously,

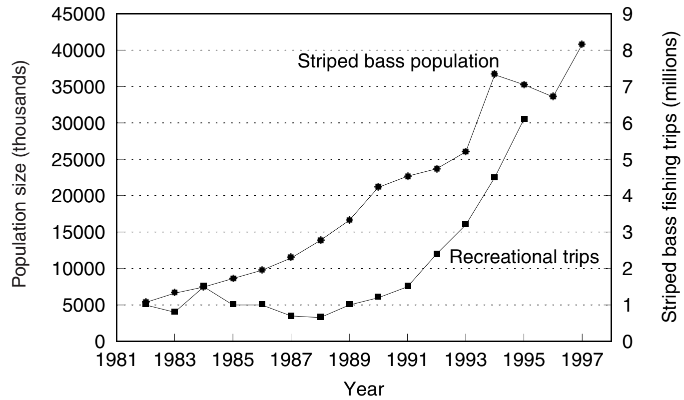


Figure 25—Relationship between striped bass population size and targeted recreational fishing trips (USDC 1998*b*; Salz 1996).

competing interests (either leisure activities or work obligations) are consistently cited as a reason for not fishing more. This is a very difficult variable to define, measure, or incorporate into projection models.

Bowker and others (1999) also predict that over the next 55 years the total U.S. population will increase by 44%, indicating that the percentage of U.S. residents who fish will continue to decline and that days of fishing will increase by 27%. This is consistent with the trends exhibited in the last decade in the National Survey.

CONCLUSION: MANAGEMENT IMPLICATIONS TO FOREST SERVICE STRATEGIC PLANNING

The data needed to complete a comprehensive assessment of the status and trends of freshwater species in the United States is not currently accessible. The lack of consistent and reliable aquatic resource information, especially that specific to Forest Service lands, precludes an accurate assessment of whether current Forest Service management practices are meeting public demand. In terms of angling opportunities, if we assume that the reasons stated in broad angler surveys for not fishing (or not fishing more) apply to Forest Service lands, then the condition of aquatic resources is not limiting the availability of angling opportunities overall. However, some surveys have shown that conditions related to access (too many anglers or too crowded) are making angling opportunities more difficult to enjoy.

Based on attitudinal surveys, resource condition generally does not seem to be the major concern among users.

However, as is demonstrated with striped bass, resource condition may play a major role in participation rates in specific circumstances (figure 25). In Canyon Creek (see Case Study 2), although managers were successful in establishing a naturally reproducing brown trout population (many in the trophy category) and increasing brown trout densities (measured as fish per square meter), there was a 75% decrease in angler days between 1989–92 due in part to substantially reduced stocking of rainbow trout (which do not reproduce or overwinter). Finally, the reduced Pacific salmon stocks has resulted in millions of days of lost fishing opportunities to the recreational, commercial, and subsistence fisheries.

Data and Information Reporting Needs

Despite the expansiveness of aquatic resources on Forest Service lands and the impact of Forest Service activities on both inland and anadromous fish, an adequate reporting mechanism to document changes in the aquatic communities and habitats in a consistent manner across Forest Service lands is lacking. In a survey of Forest Service line officers and fisheries program personnel, less than one-third of respondents thought that monitoring and evaluation efforts were adequate to document aquatic habitat changes on their Forest alone (Forsgren and Loftus 1993). The current reporting mechanism is intended to satisfy broad national needs documenting the accomplishments resulting from the expenditure of funds but has little meaning to aquatic resource condition.

This lack of fisheries and aquatic habitat data is not unique to the Forest Service, however. As has been noted in the management of the Pacific northwest salmon, "Management agencies need to improve coordination of survey efforts to develop long-term data collection systems. Improved information-sharing between state management agencies and federal lands managers (e.g., Forest Service and Park Service) is needed to integrate fisheries and habitat data and to ensure that surveys of resources by the federal agencies on the lands they control are included in escapement monitoring data sets" (Baker and others 1996).

Furthermore, in a pilot study to assess the feasibility of compiling information over broad geographic regions, Loftus and Waldon (1992) observed a lack of consistent reporting formats, data collection, and assessment techniques. The Multi-State Aquatic Resource Information System outlined in Case Study 9 of this report is an attempt to develop such a system by starting with a restrictive and select set of variables. Some federal agencies have made an attempt to develop broad scale measures of aquatic species health. The EPA's Environmental Monitoring and Assessment Program (EMAP) was one such attempt to establish standardized monitoring points to evaluate relative changes in aquatic resources health but was limited in scope and costly to conduct.

Several national and regional "needs assessments" have indicated the utility of developing a shared information system for aquatic species. An assessment by the American Fisheries Society in 1984–86 and a NOAA assessment in 1985–86 (Calio Committee) both recommended the development "of national and regional fishery information centers accessible to all agencies (federal, state, tribal, etc.) to which all agencies contribute operationally compatible data, disregarding geopolitical boundaries" (Harville 1992). Technological advancements in data sharing capabilities (particularly via the Internet) may reduce the necessity of a centralized data warehouse in favor of dispersed information accessible via a common system. However, the need for shared information to conduct baseline assessments over larger geographic units (as opposed to political units) remains. In the views of fishery administrators and technical personnel, such a system would serve to demonstrate fisheries status and trends across interjurisdictional boundaries; help to develop national and regional priorities and budgets to more effectively utilize funding and manage resources; eliminate duplication of effort in sampling programs; assist in identifying species approaching threatened and endangered status; more easily evaluate management activities/research; and maximize use of administrative resources.[8] Additionally, with the increasing interest in developing the capabilities for an aquatic Gap Analysis Program, quantitative fisheries information tied to specific geographic locales will become a vital data element to develop a statistical-based framework for estimates and projections.

Other Implications for Forest Service Strategic Planning and Activities

In terms of habitat management, several specific case studies have provided recommendations for modifying timber harvesting and other forest management practices to improve water quality and aquatic system integrity. Instances such as the Canyon Creek project highlighted earlier and others (Morris and others 1992) indicate that most soil erosion from logging results from road construction. The sediment yield from a conventionally harvested watershed (using roads) has been shown to be 100 times greater than that from an undisturbed control (Morris and others 1992). Sediment yield from a site harvested with a skyline system (lifting timbers off the land rather than extracting with ground-based vehicles) was only three

[8] Loftus, A.J. 1993. Proceedings of a workshop on refining fisheries information systems. Sport Fishing Institute, Washington, DC. 41 p. On file with C.H. Flather, Rocky Mountain Research Station, 2150 Centre Ave., Fort Collins, CO 80526-1891.

times more than an undisturbed control site (Morris and others 1992). The Forest Service has acknowledged the problem of the deteriorating road system and is developing plans to rectify the problems associated with it.

The Canyon Creek restoration, Chesapeake Bay success, Pacific salmon management, Southern Appalachian Assessment, Atlantic Salmon situation, and Rathbun Lake scenario outlined as case studies in this report all clearly indicate that changing the management of the surrounding landscape can be substantially beneficial to the aquatic ecosystem. Each of these case studies involved different anthropogenic influences on aquatic systems. These influences derive from human desires and needs for living which, in the process of fulfilling, impacts the landscape and aquatic systems. In fulfilling these needs, a more holistic approach to ecosystem management must be implemented that considers both the actual physical aquatic habitat as well as the surrounding terrestrial habitat. Williams and others (1989) recommended that natural resource management agencies manage for the conservation of entire ecosystems rather than individual species. Additionally, they recommended the establishment of long-term monitoring programs to provide baseline information for future reference to gauge the trend of species conditions.

Modifying Forest Service planning and activities to better meet the changing social, demographic, economic, and environmental conditions of the next century will require stable and consistent sources of information. Extensive searches of published literature and agency reports reveal that information on the status and trends of aquatic species is available primarily on a case-by-case basis. This often provides valuable guidance for establishing cause-and-effect relationships for the impact of specific Forest Service practices on aquatic species. However, predicting ecosystem change at broad geographic scales based on patterns at finer geographic scales is not necessarily valid and may result in erroneous conclusions (Lewis and others 1996). Information that indicates status and trends on broad geographic scales needs to be compiled to more accurately define the overall aquatic resource conditions and satisfy the reporting mandates of the RPA. Until the time when such information programs are established, initiating a comprehensive and accurate system for the analysis of the aquatic species status and trends in the United States is not likely to be possible.

CASE STUDY 9:

EVALUATION OF THE MULTI-STATE AQUATIC RESOURCES INFORMATION SYSTEM FOR ASSESSING TRENDS IN AQUATIC SPECIES

Background

Federal agencies, such as the USDA Forest Service, USDA Natural Resources Conservation Service, USDI Fish and Wildlife Service, and USDI Geological Survey Biological Resources Division each have a variety of needs for aquatic species information that are not currently being met. These include the need for long-term data sets on aquatic species for purposes such as evaluating the effects of possible land use or climate change, conducting trend analysis on species to fulfill mandates such as the RPA, or identifying population trends and potential management scenarios before populations reach critically low levels. Compilation of the aquatic assessment component of the RPA report and development of USDA farm programs and legislation affecting millions of acres is currently done without the benefit of detailed fisheries data. Realizing the capability to provide regional fishery analyses will create the opportunity to include land use or management provisions, which benefit identified fisheries resources, into federal programs that are regional in scope.

Recognizing the value in the aquatic species information that was already being collected by the states, the USDA Forest Service combined with several other federal agencies and private organizations to investigate mechanisms through which agencies could share information on the quantitative status and trends of aquatic species. Between 1990 and 1993, this initiative completed a pilot project involving several Midwestern states that successfully demonstrated that a regional effort was possible (and identified some of the problems that could be expected).

As a result of that project, a more focused effort was initiated in late 1994 involving six states (figure 26) to imple-

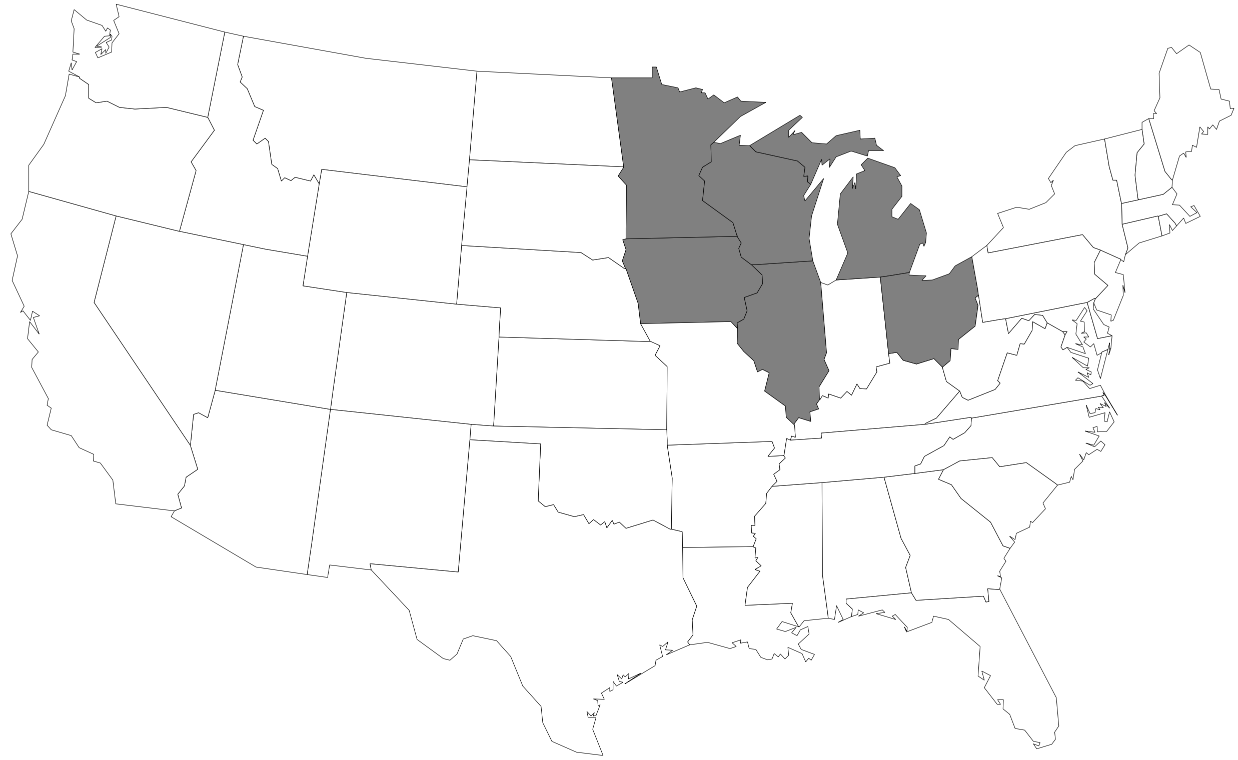


Figure 26—States participating in the Multi-state Aquatic Resources Information System initiative.

ment a useful and workable information sharing system using state-of-the art Internet technology. The Multi-State Aquatic Resources Information System (MARIS) is based on the premise that states currently control the majority of aquatic species information collected, and that helping states to strengthen the computerization and management of their information will facilitate the sharing of information with other agencies in the long run.

How It Works

The MARIS initiative links aquatic databases of several states and provides that information through a common format via the Internet (figure 27). Each individual state retains their information on a server within their state. For the initial development of the system, the states constructed a standard "MARIS" format to which these data could be automatically converted based on a list of variables that were generally common to each state database (tables 15–17). The common "quantitative" variable for the initial system development was determined to be catch-per-unit-effort. Since lookup tables and conversion programs are constructed, states are able to maintain their data in any format and database software/hardware platform that they desire. MARIS data sets are constructed from individual state data sets using these conversion programs and look-up tables. All variables are linked through a series of geographic locator codes to facilitate compatibility with other external databases such as land use/land cover.

When a "client" submits a query to the MARIS central server, this is broken into separate queries to be sent to the individual states where the information resides. The responses of these individual queries are then compiled by the MARIS server and a consolidated response is returned to the original client. Linking the MARIS information (quantitative information on aquatic populations) to existing physical/chemical databases, land use databases, GIS systems, and other databases will allow the capability to evaluate effects of factors such as land use patterns on aquatic systems on a large scale.

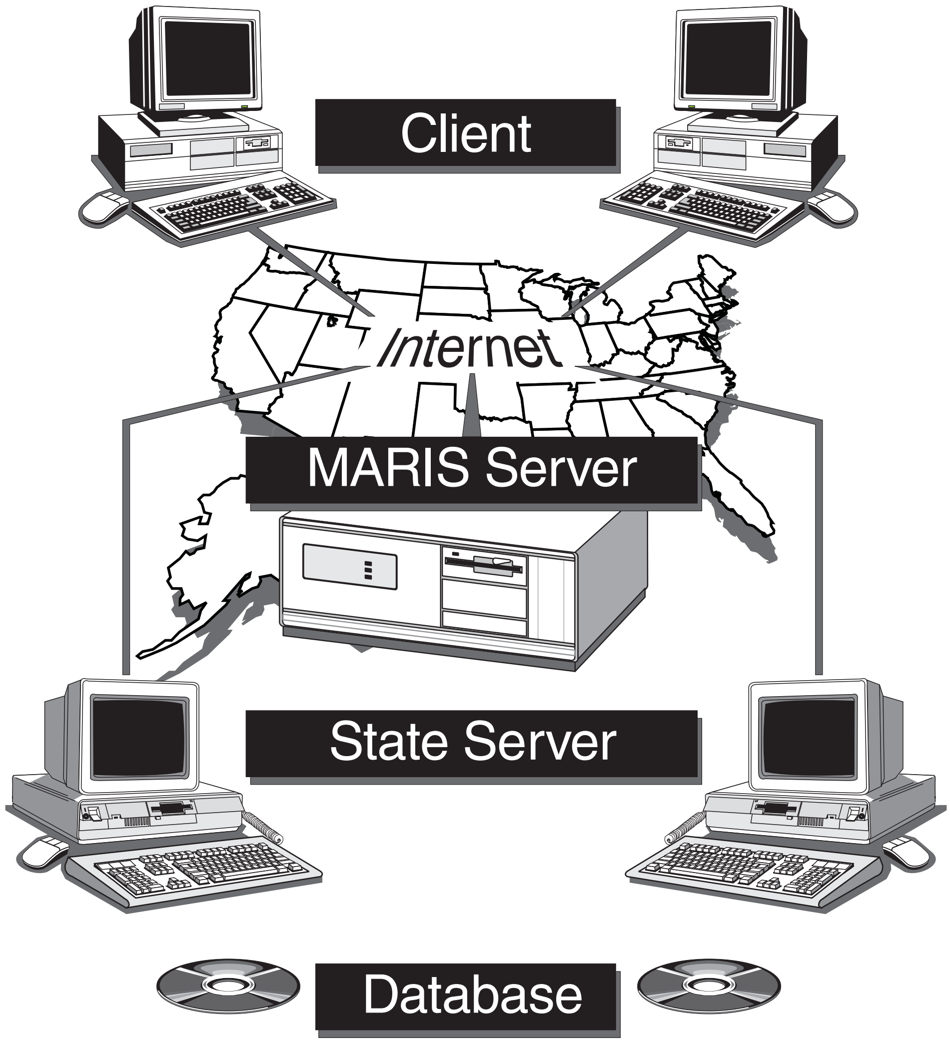


Figure 27—Application of the dispersed data set form of information sharing utilized by MARIS.

Application

To evaluate the applicability of the MARIS system and identify areas for refinement, queries were made to the MARIS server that required a multi-state response. At present, Internet linkages have been made with four of the MARIS state servers but the state fisheries information also currently resides on the MARIS home server at the University of Illinois.

The unique characteristic of MARIS is the ability to compile and compare *quantitative* information regarding the status of fish populations from several jurisdictions. Therefore, information was gathered regarding the catch-per-unit effort/time (number of fish caught over a standard period of time, or CPUETN) and the catch-per-unit-effort/area (weight of fish caught over standard unit of area, or CPUESB).

In this initial evaluation of trend analysis, a species was chosen which: 1) had not been intensively managed through either extensive stocking or extirpation; 2) occurred in at least three of the MARIS states; and 3) had data reported for at least three years. Using these criteria, black crappie and white crappie were chosen from the available data. These data were further refined by selecting only those water bodies that had records for at least three years within a five-year time span. Once data were selected and screened, correlation and Least Absolute Regression (LAD; Slauson and others 1991) analyses were conducted to determine if there were any relationships between crappie abundance and time (measured as year of sampling) within lakes.

Table 15—Variables and variable characteristics found in MARIS waterbody description file.

Field name	Data type	Description
MWBCODE	Text	Master Waterbody Identification Code, unique code for each waterbody within state
STATE	Text	State Postal Code Abbreviation
LAKENAME	Text	Geographic Place Name
MANAGE	Text	State Management Location Code (wildlife district)
LATITUDE	Number	Latitude at Lake Outfall (decimal degrees)
LONGITUDE	Number	Longitude at Lake Outfall (decimal degrees)
FIPSCODE	Text	County FIPS Code (3 digits)
SECTION	Text	Section in which lake exists
TOWNSHIP	Text	Township in which lake exists
RANGE	Text	Range in which lake exists
USGSHYDR	Text	USGS Hydrologic Unit
WATERTYPE	Text	Waterbody Type (1=Lake, 2=Stream, or 3=Impoundment)
MEANDEPTH	Number	Mean depth of lake (m, 3 digit rounded)
MAXDEPTH	Number	Maximum depth of lake (m, 3 digit rounded)
AREA	Number	Surface area of lake (ha)
SHORELINE	Number	Lake Shoreline length (km, 4 digits)
WATERSHED	Number	Lake Watershed Area (ha)
LITTORAL	Number	% Littoral Zone (state specific)
WINTERKILL	Text	Evidence of winter fishkill (Y/N)
PUBLICACCESS	Text	Public access possible (Y/N)

Table 16—Variables and variable characteristics found in MARIS water quality description file.

Field name	Data type	Description
MWBCODE	Text	State Master Water Body Identification Code
SAMPLEDATE	Date/Time	Date of data collection
ALKALINITY	Number	Alkalinity (mg/l)
CONDUCTIVITY	Number	Conductivity (mmhos)
PH	Number	Lake pH
LITTORAL	Number	Lake Littoral zone, expressed as % of total surface area of lake, where maximum depth < state-defined reference depth.
SECCHI	Number	Mean secchi disk (transparency) read (m)
WATERTEMP	Number	Surface Water Temperature (°C)

Results and Discussion

Only four of the six MARIS states currently have data available. At the time of the analysis, data from Iowa were in the process of being entered into their system. Information from Minnesota was entered and made available but had not yet been made accessible via the MARIS server. Of the four states whose information was available, only three (Illinois, Ohio, and Wisconsin) had records of crappie status under the criteria established. Wisconsin had data for black crappie. The measure of relative abundance common to all three of these states was CPUETN and therefore was used for the trend analysis.

Since the use of desktop computers for data entry is a relatively recent advancement (within the last decade) in most states, a great deal of historical trend information is not yet computerized. It has only been fairly recently that data in the states has been made available in standard formats and computerized. Despite this, in some cases the MARIS states, either with assistance from federal agencies or on their own, have invested in entering all of their available historical data. For our query of crappie trends, Wisconsin data extend from 1964–1992, although

Table 17—Variables and variable characteristics found in MARIS catch and effort description file.

Field Name	Data type	Description
MWBCODE	Text	State Master Water Body Identification Code, unique code for each water body
SPECIESCODE	Text	3-letter code assigned each species
SAMPLEDATE	Date/Time	Date of data collection
GTMAJ	Text	Major Gear Type
GTMIN	Text	Minor Gear Type (state specific)
TOTCATN	Number	Total number of fish caught in sample (6 digits max)
TOTCATW	Number	Total weight of fish caught in sample (kg, 6 digits max)
EFFTIME	Number	Total duration of sampling effort
STDTIME	Text	Time units for sampling effort (H=hours,D=days)
EFFSPACE	Number	Total lake area sampled
STDSPACE	Text	Space units for sampling effort (ex. km)
CPUETN	Number	Catch Per Unit Effort Time (total number of fish caught per standard unit of time)
CPUESN	Number	Catch Per Unit Effort Space (total number of fish caught per standard unit of area)
CPUETB	Number	Catch Per Unit Effort Time Biomass (total weight of fish caught per standard unit of time)
CPUESB	Number	Catch Per Unit Effort Space Biomass (total weight of fish caught per standard unit of area)
TARGET	Text	Species or species group code of fish targeted if the sampling effort was directed at a specific taxa.

the majority of the data is found in the 22-year time span from 1971–1991. Illinois data extend from 1983 to 1991 and Ohio data from 1987 to 1996. However, states are still in the process of computerizing their data. Ohio is one such state and data were available for only one waterbody. This, combined with the restrictive nature of the requirements of the query, resulted in seven lakes for Illinois, one lake for Ohio, and 15 for Wisconsin that met the criteria for black crappie. For white crappie, 15 lakes in Illinois and one in Ohio met the criteria.

We tested for temporal trends in both species by regressing catch-per-unit-effort against year using Least Absolute Regression (LAD; Slauson and others 1991). LAD was chosen because it has greater power than least squares regression for asymmetric error distributions and it is more robust to the influence of a few outlying observations (Cade and Richards 1996). Although the MARIS data sets incorporate several geographic locator codes such as latitude/longitude and hydrologic unit, no attempt was made in this analysis to link fish population trends to external data sets for assessing the impact of variables such as environmental conditions, land use changes, or regulatory changes. The only attempt to factor out external influences was in the criteria for the choice of species (as discussed previously). Therefore, the causative factors behind the significant trends were not examined.

From this analysis, it can be seen that three out of 15 lakes in Illinois exhibited significant ($P<.10$) negative trends in catch-per-effort for white crappie. Two out of these 15 Illinois lakes and the single lake in Ohio exhibited significant positive slopes for this variable (table 18). For black crappie catch-per-effort, two out of seven lakes exhibited significant positive slopes in Illinois. In Wisconsin, four out of 15 lakes exhibited significant positive slopes while one exhibited a significant negative slope for black crappie (table 19).

The information in this basic analysis can be used to point to areas of further investigation, including evaluating factors of lakes with similar trends, such as geographic dispersion of lakes, land use changes in the surrounding watershed, and management changes. The multi-state nature of the information expands the geographic scope beyond political boundaries and allows analysis on a geological, watershed, and ecotype classification basis. In addition, by making data available from multiple states, this approach expands the number of lakes (sample size) for which agencies or researchers have data available for conducting analysis.

More importantly, since this was the first assessment of the application of the MARIS system, several areas of potential improvement were noted. Requiring the return of metadata (information about data records, data quality measures, collection techniques, analysis, etc.) with records would help to reduce the incidence of misinterpretation of data and assist in determining appropriateness of comparisons of records from several sources. Creating structured reports (as opposed to free form queries) would reduce potential errors in interpretation by preventing queries of invalid comparisons. Bringing data from all states on-line would result in more comprehensive analysis capability and help to pinpoint geographic-based trends. This extended analysis capability would

Table 18—Comparison of trends in white crappie in select MARIS states as measured by catch-per-unit-effort by year (CPETN). Period is time span of sampling records. For significant slopes (P<.10), P-values are denoted by *.

State	Lake name	N	Slope	P-value	CD[a]	Period
IL	Beaver Dam Lake	12	–0.50	0.75	0.03	1985–1991
IL	Braidwood Lake	26	0.00	1.00	0.00	1984–1991
IL	Clinton Lake	17	2.42	0.21	0.11	1985–1991
IL	Coffeen Lake	13	6.02*	0.04	0.22	1986–1991
IL	Dawson Lake	15	0.67	0.75	0.01	1984–1988
IL	Forbes Lake	22	–4.35*	0.00	0.13	1985–1991
IL	Lake Jacksonville	22	–0.87	0.18	0.05	1985–1991
IL	Lake Sangchris	18	–0.17*	0.04	0.09	1984–1991
IL	Lake Shelbyville	39	0.70	0.12	0.04	1984–1991
IL	Lake Springfield	36	–7.34	0.22	0.04	1984–1991
IL	Lincoln Trail Lake	13	–0.12	0.44	0.08	1983–1991
IL	Mill Creek lake	16	0.00	1.00	0.00	1983–1991
IL	Pittsfield Lake	31	4.60	0.33	0.02	1984–1991
IL	Siloam Springs Lake	25	1.00*	0.05	0.09	1985–1991
IL	Waverly Lake	10	–3.07*	0.02	0.28	1984–1991
OH	Delaware Lake	55	4.99*	0.00	0.25	1987–1996

[a] CD=Coefficient of Determination

Table 19—Comparison of trends in black crappie in select MARIS states as measured by catch-per-unit-effort by year (CPETN). Period is time span of sampling records. For significant slopes (P<.10), P-values are denoted by *.

State	Lake name	N	Slope	P-value	CD[a]	Period
IL	Beall Woods Lake	11	2.00	0.27	0.06	1985–1990
IL	Beaver Dam Lake	12	–0.67	0.68	0.04	1985–1991
IL	Lake Shelbyville	25	0.33*	0.09	0.04	1984–1991
IL	Lincoln Trail Lake	31	–0.28	0.32	0.02	1983–1991
IL	Spring Lake (South)	21	2.37	0.35	0.03	1986–1991
IL	Walnut Point Lake	22	0.60*	0.01	0.05	1982–1991
IL	Weldon Springs Lake	21	0.13	0.62	0.01	1985–1991
OH	Delaware Lake	55	–3.00	0.78	0.00	1987–1996
WI	Black Lake (Birch)	8	13.75*	0.05	0.10	1986–1992
WI	Chequamegon Waters Flowage[b]	10	0.09	0.20	0.04	1966–1992
WI	Day Lake Flowage[b]	8	–0.43	0.75	0.02	1971–1977
WI	Kathryn Lake	11	0.94	0.55	0.02	1985–1992
WI	Kegonsa lake	5	0.46	0.68	0.10	1976–1988
WI	Long Lake	7	0.23*	0.10	0.33	1970–1992
WI	Mendota Lake	6	0.83	0.34	0.24	1977–1983
WI	Mineral lake	7	–1.26	0.76	0.01	1968–1990
WI	Minnesuing Lake	7	–0.59*	0.05	0.27	1964–1976
WI	Mondeaux Flowage[b]	28	6.09	0.01	0.10	1971–1992
WI	Park Lake	11	0.47	0.39	0.07	1970–1988
WI	Sailor Lake	10	2.46	0.17	0.18	1985–1991
WI	Spillerberg Lake	6	8.33*	0.04	0.60	1986–1991
WI	Twin Lake (East)	7	–0.73	0.85	0.04	1970–1990
WI	Waubesa Lake	6	0.41	0.74	0.14	1968–1984

[a] CD=Coefficient of Determination
[b] Includes species identified simply as Pomoxis spp and assumed to be *Pomoxis nigromaculatus*.

also be enhanced by filling in the geographic gaps which exist in the MARIS region by bringing on additional states. Additionally, as resources allow, historical data should be entered into the state systems.

Conclusion

There are multiple advantages to a MARIS-type system. Since states retain direct control of the data, updates or corrections to data sets are easier, there is no need to reformat data to accommodate specified format and software, and states control exactly what data are made available. Additionally, this provides a single primary point of contact for state-based information. Database administration is reduced dramatically as compared to a "central database" system. Additionally, there is no additional data management being conducted by third parties, thereby taking advantage of the current expertise of state agency staffs and improving the value and quality of the information.

It is important to note that these data queries were completed without contacting any of the state agencies but rather through the MARIS remote query process. Refining this system and expanding its scope of geographic coverage and content will facilitate gathering information for programs such as the RPA.

These initial six states, because of their data system technology and expressed willingness to work together and with the federal agencies, are establishing a template for data sharing. This template is likely to be adopted by other states across the country who recognize the need and advantages of compatible information systems. In the process, the states are strengthening their own internal information systems through the funding brought by the federal agencies that allows states to convene and share expert advice/technologies and that provides funds for equipment acquisition, data entry services, and consultation services of a leading university computer research facility. The evaluation of this system has demonstrated that this type of dispersed information system can be successfully used to analyze aquatic species trends across geopolitical boundaries. Considering the value of multi-state data over periods of several years, promoting this method of data acquisition and compilation, both for historical data and future data collection, can be extremely beneficial to evaluating status and trends over long time periods and broad geographic scales.

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APPENDIX A—Scientific names of species mentioned in the text.

Common name	Scientific name	Common name	Scientific name
American plaice	*Hippoglossoides platessoides*	Lingcod	*Ophiodon elongatus*
American Shad	*Alosa sapidissima*	Mackerel	Scomber scombrus
Arctic Grayling	*Thymallus arcticus*	Paddlefish	*Polyodon spathula*
Atlantic Salmon	*Salmo salar*	Northern Pike	*Esox lucius*
Asian Clam	*Corbicula fluminea*	Red Snapper	*Lutjanus campechanus*
Atlantic Croaker	*Micropogonias undulatus*	Rainbow Trout	*Oncorhynchus mykiss*
Atlantic Sturgeon	*Acipenser oxyrhynchus*	Scup	*Stenotomus chrysops*
Black Crappie	*Pomoxis nigromaculatus*	Sea Lamprey	*Petromyzon marinus*
Black Sea Bass	*Centropristis striata*	Shortnose Sturgeon	*Acipenser brevirostrum*
Bluefish	*Pomatomus saltatrix*	Smallmouth Bass	*Micropterus dolomieui*
Brook Trout	*Salvelinus fontinalis*	Sockeye salmon	*Oncorhynchus nerka*
Brown Trout	*Salmo trutta*	Speckled Dace	*Rhinichthys osculus*
Chum salmon	*Oncorhynchus keta*	Spiny Dogfish	*Squalus acanthias*
Cod	*Gadus morhua*	Steelhead trout	*Oncorhynchus mykiss*
Coho salmon	*Oncorhynchus kisutch*	Striped Bass	*Morone saxatilis*
Chinook salmon	*Oncorhynchus tshawytscha*	Summer Flounder	*Paralichthys dentatus*
Crappie	*Pomoxis spp.*	Weakfish	*Cynoscion regalis*
Cutthroat trout	*Oncorhynchus clarki clarki*	White Crappie	*Pomoxis annularis*
Desert Sucker	*Catostomus clarki*	Windowpane flounder	*Scophthalmus aquosus*
Halibut	*Hippoglossus hippoglossus*	Winter Flounder	*Pleuronectes americanus*
Lake Sturgeon	*Acipenser fulvescens*	Witch flounder	*Glyptocephalus cynoglossus*
Lake Trout	*Salvelinus namaycush*	Yellowtail flounder	*Pleuronectes ferrugineus*
Largemouth Bass	*Micropterus salmoides*	Zebra Mussel	*Dreissena polymorpha*

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