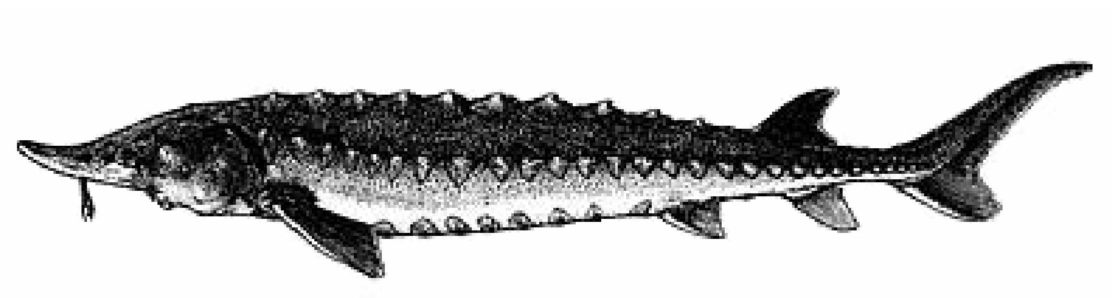
STATUS REVIEW OF ATLANTIC STURGEON
(*Acipenser oxyrinchus oxyrinchus*)



Prepared by the

Atlantic Sturgeon Status Review Team

for the

National Marine Fisheries Service
National Oceanic and Atmospheric Administration

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<u>List of Acronyms and Abbreviations</u>

ACE Basin	Ashepoo, Combahee and Edisto rivers
ACFCMA	Atlantic Coastal Fisheries Cooperative Management Act
ACOE	Army Corps of Engineers
AENRD	Army Environmental and Natural Resources Division (Ft. Stewart)
AFS	American Fisheries Society
AICW	Atlantic Intercoastal Waterway
ASMFC	Atlantic States Marine Fisheries Commission
BIW	Bath Iron Works
BRD	bycatch reduction device
C	centigrade
CAFL	Conte Anadromous Fish Laboratory
CAFOs	concentrated animal feeding operations
Cd	cadmium
cfs	cubic feet per second
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
cm	centimeters
CONED	Consolidated Edison Company
CPUE	catch-per-unit-of-effort
CTDEP	Connecticut Department of Environmental Protection
Cu	copper
DDE	dichlorodiphenyl dichloroethylene
DDT	dichlorodiphenyl trichloroethane
DFO	Department of Fisheries and Oceans (Canada)
DFW	Delaware Division of Fish and Wildlife
DNR	Department of Natural Resources
DNREC	Delaware Department of Natural Resources and Environmental Control
DO	Dissolved Oxygen
DPS	Distinct Population Segment
EDUs	Ecological Drainage Units
EEZ	Economic Exclusive Zone
EFH	Essential Fish Habitat
EPA	Environmental Protection Agency
ERA	extinction risk analysis
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FL	fork length
FMP	Fishery Management Plan
FPA	Federal Power Act
FR	Federal Register
FSS	Fall Shoals Survey
FST	Fixation Index
FWCA	Fish and Wildlife Coordination Act
FWPA	Federal Water Pollution Control Act (Clean Water Act)

GIS	Geographic Information System
Hg	mercury
HNP	Hatch Nuclear Power Plant
hp	horsepower
hr	hour
ICW	Intercoastal Waterway
IFAS	Institute for Food and Agricultural Science
IGNS	Independent Gill Net Survey
IHNV	infectious hematopoietic necrosis virus
in	inches
IUCN	International Union for the Conservation of Nature and Natural Resources
km	kilometer
lbs	pounds
LD	lethal dose
LHRHα	luteinizing hormone releasing hormone analog
LNG	Liquefied Natural Gas
LIS	Long Island Sound
LRS	Long River Survey
m	meters
MADMF	Massachusetts Division of Marine Fisheries
MDFRO	Maryland Fishery Resource Office
MEDMR	Maine Department of Marine Resources
MEBOH	Maine Bureau of Health
MEDEP	Maine Department of Environmental Protection
MGD	million gallons per day
mg/L	milligrams per liter (parts-per-million)
mm	millimeters
MPUE	mortality per unit of effort
MPRSA	Marine Protection, Research and Sanctuaries Act
mt	metric ton
mtDNA	mitochondrial DNA
NASCO	North Atlantic Salmon Conservation Organization
NCCFWRU	North Carolina Cooperative Fish and Wildlife Research Unit.
NCDMF	North Carolina Division of Marine Fisheries
NCSU	North Carolina State University
nDNA	nuclear DNA
NEFC	Northeast Fisheries Center (USFWS)
NEFO	Northeast Fisheries Observer program
NEPA	National Environmental Policy Act
NHFG	New Hampshire Fish and Game
NIEM	Nelson Institute of Environmental Medicine
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NSBL&D	New Savannah Bluff Lock and Dam
NPDES	National Pollutant Discharge Elimination System
NYSDEC	New York State Department of Environmental Conservation

PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzo-*p*-dioxins
PCDF	polychlorinated dibenzofurans
PECE	Policy for Evaluation of Conservation Efforts
pers.	Personal
pg/g	picograms-per-gram (parts-per-trillion)
ppm	parts-per-million
ppt	parts-per-thousand
PVA	Population Viability Analysis
QSWP	Quebec Society for Wildlife and Parks
RIDEM	Rhode Island Department of Environmental Management
rkm	river kilometer
rm	river mile
SAFCO	South Atlantic Fisheries Coordination Office
SCDNR	South Carolina Department of Natural Resources
SCPSA	South Carolina Public Service Authority
SDCOE	Savannah District of the U. S. Corp of Engineers
SOC	Species of Concern
SPA	Shore Protection Act
SPOIR	significant portion of its range
SRT	Status Review Team
SSC	Scientific and Statistical Committees
TCDD	tetrachlorodibenzo-*p*-dioxin
TED	turtle excluder device
TL	total length
TNC	The Nature Conservancy
µ	micro
UGA	University of Georgia
UME	University of Maine
UNCW	University of North Carolina at Wilmington
UPGMA	Unweighted Pair Group Method with Arithmetic Mean
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VMRC	Virginia Marine Resources Commission
VIMS	Virginia Institute of Marine Science
WSHV-2	white sturgeon herpesvirus type-2
WSIV	white sturgeon iridovirus
Yds	yards
YOY	young-of-year
yr	year
Zn	zinc

Executive Summary

In 2003, a workshop sponsored by the National Marine Fish Service (NMFS) and U. S. Fish and Wildlife Service (USFWS) (collectively, the Services) was held to review the status of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). The workshop provided an opportunity to gain additional information to determine if a new review of the status of the species was warranted. The status of Atlantic sturgeon was initially reviewed in 1998 after the Services received a petition to list the species under the Endangered Species Act (ESA), and it was determined, at that time, that listing was not warranted. Also in 1998, the Atlantic States Marine Fisheries Commission (ASMFC) initiated a coast-wide fishing moratorium on Atlantic sturgeon, until 20 year classes of adult females could be established. The 2003 workshop attendees concluded that some populations seemed to be recovering while other populations continued to be depressed. As a result, NMFS initiated a second status review of Atlantic sturgeon in 2005 to reevaluate whether this species required protection under the ESA.

A status review team (SRT) consisting of four NMFS, four USFWS, and three US Geological Survey (USGS) personnel participated in the status review process. The team was supplemented by eight state and regional experts who provided their individual expert opinions on the information contained in the status review report and provided additional data to ensure the report provided the best available data.

The SRT determined that Atlantic sturgeon populations should be divided into five distinct population segments (DPSs). The five DPSs were named: 1) Gulf of Maine, 2) New York Bight, 3) Chesapeake Bay, 4) Carolina, and 5) South Atlantic. These Atlantic sturgeon populations are markedly separated based on physical, genetic, and physiological factors; are located in a unique ecological setting; have unique genetic characteristics; and would represent a significant gap in the range of the taxon if one of them were to become extinct.

The SRT evaluated the status of Atlantic sturgeon using the five-factor analysis described in section 4(a)(1) of the ESA. The SRT identified 15 stressors within these five factors and summarized their impacts on Atlantic sturgeon using a semi-quantitative extinction risk analysis (ERA), similar to that used by other status review reports (e.g. *Acropora*). Of the stressors evaluated, bycatch mortality, water quality, lack of adequate state and/or Federal regulatory mechanisms, and dredging activities were most often identified as the most significant threats to the viability of Atlantic sturgeon populations. Additionally, some populations were impacted by unique stressors, such as habitat impediments (e.g., Cape Fear and Santee-Cooper rivers) and apparent ship strikes (e.g., Delaware and James rivers).

The outcome of the ERA concluded that three of the five DPSs (Carolina, Chesapeake, and New York Bight) were likely (> 50% chance) to become endangered in the foreseeable future (20 years). The SRT recommended that these three DPSs should be listed as threatened under the ESA. The remaining DPSs (South Atlantic and Gulf of Maine) were found to have a moderate risk (<50% chance) of becoming endangered in the next 20 years. However, the SRT did not provide a listing recommendation for these remaining DPSs as available science was insufficient to allow a full assessment of these populations.

Introduction

1.1. Background of the Review

This document provides a summary of the information gathered for an Endangered Species Act (ESA) status review for Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Initial reviews of the Atlantic sturgeon status began in 1977 when the Research Management Division of NMFS sponsored the preparation of a report on the biology and status of Atlantic sturgeon to assess the status of the stock and serve as a historical database and information library (Murawski and Pacheco 1977). Three years later, at the request of NMFS, another document was prepared by Hoff (1980) to assist in making future Atlantic sturgeon fisheries decisions and to determine what action was required, if any, to conserve the species under the ESA. In 1988, NMFS announced they would develop a “list of candidate species” under the ESA and requested information regarding the status of Atlantic sturgeon. At that time, a “candidate species” was any species being considered by the Secretary for listing as an endangered or a threatened species under the ESA, but not yet the subject of a proposed rule. NMFS added Atlantic sturgeon to its candidate species list published in 1997 (62 FR 37560). In April 2004, NMFS published a subsequent notice announcing that the NMFS “candidate species list” was being changed to the “Species of Concern (SOC) list” to better reflect the ESA definition of candidate species while maintaining a separate list of species potentially at risk (69 FR 19975). At that time, NMFS transferred 25 species from the candidate species list to the SOC list (including Atlantic sturgeon), placed 20 additional species on the SOC list, and removed 12 other species from the candidate species list. Candidate Species are those petitioned species that are actively being considered for listing as endangered or threatened under the ESA, as well as those species for which NMFS has initiated an ESA status review that it has announced in the *Federal Register*. NMFS SOC are defined as species about which NMFS has some concerns regarding status and threats but for which insufficient information is available to indicate a need to list the species under the ESA. NMFS believes it is important to highlight species for which listing may be warranted in the future so that Federal and state agencies, Native American tribes, and the private sector are aware of unlisted species that could benefit from proactive conservation efforts. Inclusion of a species on the SOC list is intended to stimulate voluntary conservation efforts that, if effective, may prevent an ESA listing. Currently, Atlantic sturgeon is a candidate species and by default, a SOC.

On June 2, 1997, a petition dated May 29, 1997, was received by the Services from the Biodiversity Legal Foundation. The petitioner requested that the Services list Atlantic sturgeon, where it continues to exist in the United States, as threatened or endangered and designate critical habitat within a reasonable period of time following the listing. The Services reviewed the request and determined that the petition presented substantial information indicating that the petitioned action may be warranted and announced the initiation of a status review (62 FR 54018). A review of the status of a species is required by section 4(b)(1)(A) of the ESA whenever a listing petition is found to contain substantial information. A status review consists of reviewing all the available information on a species to determine if protection under the ESA is warranted.

According to CFR424.11, a species shall be listed or reclassified if the Secretary determines, on the basis of the best scientific and commercial data available after conducting a review of the species' status, that the species is endangered or threatened because of any one or a combination of the following factors:

1) The present or threatened destruction, modification, or curtailment of habitat or range.
2) Overutilization for commercial, recreational or educational purposes.
3) Disease or predation.
4) The inadequacy of existing regulatory mechanisms.
5) Other natural or manmade factors affecting its continued existence.

The Services completed their status review in 1998 and concluded at that time Atlantic sturgeon were not threatened or endangered based on any of the five factors (NMFS and USFWS 1998). Concurrently, the Atlantic States Marine Fisheries Commission (ASMFC) completed Amendment 1 to the 1990 Atlantic Sturgeon Fishery Management Plan (FMP) that imposed a 20-40 year moratorium on all Atlantic sturgeon fisheries until the Atlantic Coast spawning stocks could be restored to a level where 20 subsequent year classes of adult females were protected (ASMFC 1998A). NMFS followed this action by closing the Exclusive Economic Zone (EEZ) to Atlantic sturgeon take in 1999. In 2003, a workshop on the "Status and Management of Atlantic Sturgeon" was held to discuss the current status of sturgeon along the Atlantic Coast and determine what obstacles, if any, were impeding the recovery of Atlantic sturgeon (Kahnle et al. 2005). The results of the conference reported "mixed" reviews where some populations seemed to be recovering while others were declining. Bycatch and habitat degradation were noted as possible causes for some population declines.

Based on the information gathered from the 2003 workshop on Atlantic sturgeon, NMFS decided that a second review of Atlantic sturgeon status was needed to determine if listing as threatened or endangered under the ESA was warranted. This document addresses the status of the species, addresses the five factors as they pertain to Atlantic sturgeon, and considers the effects of efforts underway to protect the species.[1]

1.2. Life History

While intensely studied since the 1970s, many important aspects of Atlantic sturgeon life history are still unknown (Murawski and Pacheco 1977, Van den Avyle 1983, Smith and Dingley 1984, Smith and Clugston 1997, Bain 1997, Bemis and Kynard 1997, Kynard and Horgan 2002). Although specifics vary latitudinally, the general life history pattern of Atlantic sturgeon is that of a long lived, late maturing, estuarine dependent, anadromous species.[2] The species' historic range included major estuarine and riverine systems that spanned from Hamilton Inlet on the coast of Labrador to the Saint Johns River in Florida (Reviewed in Murawski and Pacheco 1977, Smith and Clugston 1997). Interestingly, genetic, morphological, and archaeological evidence also suggest that Atlantic sturgeon once colonized the Baltic during the Middle Ages, and

[1] Since this document is an updated review of the status of Atlantic sturgeon, portions of the text were taken directly from the 1998 review to expedite the writing process (NMFS and USFWS 1998).
[2] An anadromous species is defined as a species that spends the majority of its life cycle in marine waters but reproduces in freshwater habitat.

replaced the native European sturgeon (*Acipenser sturio*) there, before recently becoming extinct itself in Europe as a result of human activities and climate change (Ludwig et al. 2002).

Atlantic sturgeon spawn in freshwater, but spend most of their adult life in the marine environment. Spawning adults generally migrate upriver in the spring/early summer; February-March in southern systems, April-May in mid-Atlantic systems, and May-July in Canadian systems (Murawski and Pacheco 1977, Smith 1985, Bain 1997, Smith and Clugston 1997, Caron et al. 2002). In some southern rivers, a fall spawning migration may also occur (Rogers and Weber 1995, Weber and Jennings 1996, Moser et al. 1998). A fall migration of ripening adults upriver in the Saint John River, NB is also observed; however, this fall migration is not considered a spawning run as adults do not spawn until the spring. Atlantic sturgeon spawning is believed to occur in flowing water between the salt front and fall line of large rivers, where optimal flows are 46-76 cm/s and depths of 11-27 meters (Borodin 1925, Leland 1968, Scott and Crossman 1973, Crance 1987, Bain et al. 2000). Sturgeon eggs are highly adhesive and are deposited on the bottom substrate, usually on hard surfaces (e.g., cobble) (Gilbert 1989, Smith and Clugston 1997). Hatching occurs approximately 94-140 hrs after egg deposition at temperatures of 20° and 18° C, respectively, and larvae assume a demersal existence (Smith et al. 1980). The yolksac larval stage is completed in about 8-12 days, during which time the larvae move downstream to rearing grounds over a 6 – 12 day period (Kynard and Horgan 2002). During the first half of their migration downstream, movement is limited to night. During the day, larvae use benthic structure (e.g., gravel matrix) as refugia (Kynard and Horgan 2002). During the later half of migration when larvae are more fully developed, movement to rearing grounds occurs both day and night. Juvenile sturgeon continue to move further downstream into brackish waters, and eventually become residents in estuarine waters for months or years.

Upon reaching a size of approximately 76-92 cm, the subadults may move to coastal waters (Murawski and Pacheco 1977, Smith 1985), where populations may undertake long range migrations (Dovel and Berggren 1983, Bain 1997, T. King supplemental data 2006). Tagging and genetic data indicate that subadult and adult Atlantic sturgeon may travel widely once they emigrate from rivers. Subadult Atlantic sturgeon wander among coastal and estuarine habitats, undergoing rapid growth (Dovel and Berggren 1983, Stevenson 1997).[3] These migratory subadults, as well as adult sturgeon, are normally captured in shallow (10-50m) near shore areas dominated by gravel and sand substrate (Stein et al. 2004a). Coastal features or shorelines where migratory Atlantic sturgeon commonly aggregate include the Bay of Fundy, Massachusetts Bay, Rhode Island, New Jersey, Delaware, Delaware Bay, Chesapeake Bay, and North Carolina, which presumably provide better foraging opportunities (Dovel and Berggren 1983, Johnson et al. 1997, Rochard et al. 1997, Kynard et al. 2000, Eyler et al. 2004, Stein et al. 2004a, Dadswell 2006). Despite extensive mixing in coastal waters, Atlantic sturgeon return to their natal river to spawn as indicated from tagging records (Collins et al. 2000a, K. Hattala, NYSDEC, Pers. Comm. 1998) and the relatively low rates of gene flow reported in population genetic studies (King et al. 2001, Waldman et al. 2002). Males usually begin their spawning migration early and leave after the spawning season, while females make rapid spawning migrations upstream and quickly depart following spawning (Bain 1997).

[3] Juveniles and subadults are used interchangeably throughout this report and are defined within this report as any sturgeon that is not considered a young-of-year (Age-0) or mature adult.

Atlantic sturgeon have been aged to 60 years (Mangin 1964); however, this should be taken as an approximation as the only age validation study conducted to date shows variations of ±5 years (Stevenson and Secor 1999). Vital parameters of sturgeon populations show clinal variation with faster growth and earlier age at maturation in more southern systems, though not all data sets conform to this trend. For example, Atlantic sturgeon mature in South Carolina at 5 – 19 years (Smith et al. 1982), in the Hudson River at 11 – 21 years (Young et al. 1998), and in the Saint Lawrence River at 22 – 34 years (Scott and Crossman 1973). Atlantic sturgeon likely do not spawn every year, where multiple studies have shown that spawning intervals range from 1-5 years for males (Smith 1985, Collins et al. 2000a, Caron et al. 2002) and 2-5 for females (Vladykov and Greeley 1963, Van Eenennaam et al. 1996, Stevenson and Secor 1999). Fecundity of Atlantic sturgeon has been correlated with age and body size (ranging from 400,000 – 8 million eggs) (Smith et al. 1982, Van Eenennaam and Doroshov 1998, Dadswell 2006). The average age at which 50% of maximum lifetime egg production is achieved estimated to be 29 years, approximately 3-10 times longer than for other bony fish species examined (Boreman 1997).

1.3. Distribution and Abundance

Assessment of the current distribution and abundance of Atlantic sturgeon is based on a comprehensive review of the literature and interviews with provincial, state, and Federal fishery management personnel regarding historic and ongoing sampling programs which targeted or incidentally captured Atlantic sturgeon. Water bodies where no information is available, either historic or current, were assessed as to whether Atlantic sturgeon could use the present habitat based on the geomorphology of the system and expert opinion. Riverine systems where gravid Atlantic sturgeon or young-of-year (YOY)(< age-1; ≤ 41 cm TL or 35 cm FL)[4] have been documented within the past 15 years were considered to contain extant spawning populations, as this is the average period of time to achieve sexual maturity. The presence of juveniles greater than age-0 (YOY) does not provide evidence of spawning within a river because subadults are known to undertake extensive migrations into non-natal riverine systems.[5]

Comprehensive information on current or historic abundance of Atlantic sturgeon is lacking for most river systems. Data are largely available from studies directed at other species and provide evidence primarily of presence or absence. Historic and current spawning populations of Atlantic sturgeon in East Coast estuarine systems of the United States are summarized in Table 1. Size and age data were used to indicate how a particular habitat (i.e., spawning, nursery, or migrating habitat) is utilized by sturgeon. The presence of multiple year classes demonstrates successful spawning in multiple years but not necessarily in that system. Available quantitative data on abundance and, where available, data that document changes in abundance of sturgeon populations are included in the text.

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[4] Lengths of 41 cm total length (TL) and 35 cm fork length (FL) represent the mean length of age-1 Atlantic sturgeon reported in Secor et al. (2000), that reviewed the FL of Atlantic sturgeon at age-1 from the Saint Lawrence, Saint John, Hudson, Delaware, Chesapeake Bay, Winyah Bay, and Suwannee watersheds. To calculate the TL of age-1 Atlantic sturgeon, the following equation was used: TL = (FL / 0.86) + 2.01.
[5] Subadults and juveniles are used interchangeably throughout this document and are defined as any sturgeon that is not considered a YOY or mature adult.

1.3.1. Historic Overview

Historically, Atlantic sturgeon were present in approximately 38 rivers in the United States from St. Croix, ME to the Saint Johns River, FL, of which 35 rivers have been confirmed to have had a historical spawning population. Atlantic sturgeon are currently present in 35 rivers, and spawning occurs in at least 20 of these rivers (Table 1). In the mid-1800s, incidental catches of Atlantic sturgeon in the shad and river herring haul seine fisheries indicated that the species was very abundant (reviewed in Armstrong and Hightower 2002). Massachusetts and Maine have reports dating back to the early 1600s noting an important sturgeon fishery (Wheeler and Wheeler 1878, Jerome et al. 1965). However, a major fishery for this species did not exist until 1870 when a caviar market was established (reviewed in Smith and Clugston 1997). Record landings were reported in 1890, where over 3350 metric tons (mt) of Atlantic sturgeon were landed from coastal rivers along the Atlantic Coast (reviewed in Smith and Clugston 1997, Secor and Waldman 1999).[6] The majority of these landings (75%) were dominated by the Delaware River fishery that presumably supported the largest population along the Atlantic Coast (reviewed in Secor and Waldman 1999). Ten years after peak landings, the fishery collapsed in 1901, when less than 10% (295 mt) of its 1890 peak landings were reported (Figure 1). The landings continued to decline to about 5% of the peak until 1920 and have remained between 1-5% since then. During the 1950s, the remaining fishery switched to targeting sturgeon for flesh, rather than caviar. The Atlantic sturgeon fishery was closed by ASMFC in 1998, when a coast-wide fishing moratorium was imposed for 20-40 years, or at least until 20 year classes of mature female Atlantic sturgeon were present (ASMFC 1998A).[7] Presently, there are only two U.S. populations for which an abundance estimate is available; the Hudson (~870 spawning adults/yr) and Altamaha (~343 spawning adults/yr) (Schueller and Peterson 2006, Kahnle et al. *In* press,). The Hudson and Altamaha are presumed to be the healthiest populations within the U.S. Thus, other spawning populations within the U.S. are predicted to have less than 300 adults spawning per year.

The Atlantic sturgeon fishery in the Saint Lawrence River is somewhat different from that of the U.S. and Saint John River[8] market as it has never been a caviar market, instead focusing on the flesh market and local sales. Thus, large gravid females and males are rarely taken (Trencia et al. 2002). Landings have increased slightly from approximately 35 mt in the 1940s to 60 mt in the 1990s (Figure 1). Since 1993, harvest/fishing restrictions have been implemented and landings have averaged approximately 60 mt/year (the harvest quota) since 2000 (Figure 2). The Saint Lawrence fishery did experience a crash, however, during the late 1960s and 1970s. The cause of the crash is unknown. However, it is suspected to be related to the massive use of DDT above Montreal during 1966 and 1967 to eliminate the mayfly bloom for the 1967 Worlds Fair, which has also been linked to the extinction of striped bass in the river (Tremblay 1995; M. Dadswell, Acadia University, Pers. Comm. 2006).

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[6] Though shortnose and Atlantic sturgeon were not differentiated in the landing records at this time, it is believed that the larger Atlantic sturgeon were targeted more so than the smaller shortnose sturgeon for the caviar market (Secor and Waldman 1999).

[7] Some states had initiated a moratorium on the fishery prior to the ASMFC ruling (i.e., Maryland and Virginia 1973, South Carolina 1985, North Carolina 1991, etc.)

[8] All sturgeon captured in the Saint John were exported to the US for caviar and there were no local sales.

1.3.2. Recent River Specific Information

<u>Canadian Rivers</u>

Atlantic sturgeon have been reported to occur as far north as the lower George River in Ungave Bay and Hamilton Inlet in Labrador, Canada, but it is not known if spawning ever occurred in any Labrador river (Vladykov and Greeley 1963, Leim and Scott 1966). Very little systematic sampling had been conducted to document the presence of Atlantic sturgeon in many Canadian rivers; however, it is likely that Atlantic sturgeon spawn(ed) in the Miramichi, Shubenacadie, Avon, Annapolis, St. Croix, and in other systems of similar size (reviewed in Dadswell 2006). There are, however, two major river systems in Canada that are known to still support Atlantic sturgeon - the Saint Lawrence and Saint John rivers.

<u>Saint Lawrence River – Quebec</u>

Historical records indicate that Atlantic sturgeon were found from Maryland to Sorel (approximately river km (rkm) 760). Vladykov and Greeley (1963) reported that young Atlantic sturgeon (15-28 cm) were abundant at St. Vallier (about 30 km downstream of Quebec City). Although the exact location of spawning areas in the Saint Lawrence River is not well documented, Vladykov and Greeley (1963) suggested that Atlantic sturgeon spawned in pools below waterfalls on tributaries to the Saint Lawrence River (Bastican River on the south shore and Rivier-aux-Outardes on the north shore). In 1997 and 1998, one running ripe female and 32 running ripe males were captured, tagged, and released in a deep section of the river located about 100 km upriver from the saltwater front, near Portneuf (rkm 95-98) (Caron 1998, Hatin et al. 2002). Subsequent tracking of these fish identified six adult aggregation areas. Three of the aggregation areas were believed to be spawning areas (Richelieu Rapids, Saint – Antoinede-Tilly, mouth of the Chaudiere River). The other three areas were identified as feeding/resting areas (Saint-Charles River estuary, Traverse du Milieu Channel, and the northern channel between Sault-au-Cochon and Petite Riviere-Saint-Francois).

Fishing effort has been recorded since 1994 and indicates that populations have stabilized within the Kamouraska and Montmagny fishing areas, despite a dramatic decline in catch-per-unit-of-effort (CPUE) within the Kamouraska decreasing from 1.71 in 1994 to 0.44 in 1995 and remaining low between 0.44 – 0.52 until 2000. Reported size classes did change over the period of 1994-2000. In 1994, the majority of Atlantic sturgeon landed were split (50:50) between small (<100 cm FL) and medium (100-150 cm FL) sized fish. By 2000, 80% of the catch had shifted to medium sized fish, indicating that recruitment had been poor in prior years, and possibly over-fishing was occurring (Trencia et al. 2002). Since 2000, management regulations have restricted catch to 100-150 cm FL fish, and annual quotas of 60 mt have been met every year (including suspected bycatch mortality) (Figure 2). Recruitment seems to have been improving over the last two to three years (G. Trencia, QSWP, Pers. Comm. 2005) and based on recent tagging studies, Caron et al. (2002) suggest that the St. Lawrence population supports 500+ spawning adults.

<u>Saint John River – New Brunswick</u>

Atlantic sturgeon are thought to spawn in the mainstem of the Saint John River and tributaries such as the Kennebecasis, Canan, Grand Lake, and Oromocto (M. Dadswell, Acadia University, Pers. Comm. 2006). Atlantic sturgeon may also migrate occasionally above the head-of-tide, noting that construction of the Mactaquac Dam did not greatly diminish the amount of spawning habitat (M. Dadswell, Acadia University, Pers. Comm. 2006). Sampling conducted in the mid 1970s, 1980s, and 1990s with small and large mesh gill nets (up to 10" stretched mesh) resulted in the capture of a large number of juvenile and adult Atlantic sturgeon ranging in size from 19 – 480 cm in the Long Reach section of the Saint John River, the mouth of the Kennebecasis, and in the Wasademoak and Grand Lakes (Pottle and Dadswell 1979, Dadswell 2006). Within the Saint John River, Dadswell (2006) calculated that approximately 200 – 300 adults are captured each year in the Atlantic sturgeon fishery; based on the minimum size limit of 122 cm TL. It is unknown, however, if these landings are solely Saint John River Atlantic sturgeon or represent a mixed stock of neighboring populations. Overall, commercial landings within the Saint John River were relatively stable until the 1980s averaging approximately 10 mt per year (Figure 3). Landings increased drastically in the 1980s and peaked in 1994 at 80 mt. Following 1994, however, landings returned to 10 mt per year.

U. S. Rivers

Maine Rivers

The geomorphology of most small coastal rivers in Maine is not sufficient to support Atlantic sturgeon spawning populations, except for the Penobscot and the estuarial complex of the Kennebec, Androscoggin, and Sheepscot rivers. During the summer months, the salt wedge intrudes almost to the site of impassable falls in these systems: St. Croix River (rkm 16), Machias River (rkm 10), and the Saco River (rkm 10). Although surveys have not been conducted to document Atlantic sturgeon presence, subadults may use the estuaries of these smaller coastal drainages during the summer months.

St. Croix River – Maine/Nova Scotia

The historic and current status of a St. Croix Atlantic sturgeon population is largely unknown. Mike Dadswell (Arcadia University, Canada) notes from personal communications with Nova Scotia Power (in 1993) that a small population of large sturgeon may be spawning annually below the hydropower dam on the St. Croix River (Dadswell 2006). Other than this personal communication, there is no additional information that an Atlantic sturgeon population exists on the St. Croix or regarding their status.

Penobscot River – Maine

There have been two surveys conducted in the last 15 years to document the presence of shortnose and Atlantic sturgeon in the Penobscot River. The Maine Department of Marine Resources (MEDMR) conducted a limited sampling effort in 1994 and 1995 to assess whether shortnose sturgeon were present in the Penobscot River. The MEDMR made 55 sets of 90 meter experimental gill nets for a total fishing effort of 409 net hrs (1 net hr = 100 yds fished for 1 hr). The majority of the fishing effort in the Penobscot River was in the upper estuary near head-of-tide. No shortnose or Atlantic sturgeon were captured. The sampling was determined to be inadequate to assess the presence of adult Atlantic sturgeon because the mesh sizes would have been selective only for subadult Atlantic sturgeon that are commonly found in the lower estuary of larger river systems. In 2006, a similar gill net survey was implemented in the lower river using both 15 cm and 30 cm stretched mesh sinking gill nets. As of January 2007, sixty-two shortnose and seven Atlantic sturgeon have been captured in 1004.39 net hours, (506.18 net hours using the smaller mesh and 498.21 net hours using the larger mesh (M. Kinnison, UME, Pers. Comm. 2006). One of these Atlantic sturgeon, captured in July, may have been an adult based on its size (145 cm TL) and time of capture. Thus, it is probable that a small population of Atlantic sturgeon persists in the Penobscot River. This speculation is supported by archeological evidence that sturgeon were present, occasional observations by fishers, and at least one capture of an adult Atlantic sturgeon by a recreational fisherman (Bangor Daily News 2005).

Estuarial Complex of the Kennebec, Androscoggin, and Sheepscot Rivers – Maine

Atlantic sturgeon were historically abundant in the Kennebec River and its tributaries, including the Androscoggin and Sheepscot rivers (Bigelow and Schroeder 1953, Vladykov and Greeley 1963, Kennebec River Resource Management Plan 1993). In 1849, a directed fishery for Atlantic sturgeon landed 160 mt. Population estimates based on the landings indicated that approximately 10,240 adult sturgeon were present prior to 1843 (Kennebec River Resource Management Plan 1993). Three hundred and thirty-six Atlantic sturgeon (nine adults and 327 subadults) have been captured in the Kennebec River in a multi-filament gill net survey conducted intermittently from 1977-2000 (Squiers 2004). During this period, the CPUE of Atlantic sturgeon has increased by a factor of 10-25 (1977 – 1981 CPUE = 0.30 versus 1998 – 2000 CPUE = 7.43)(Figure 4).[9] The mean length of the 327 subadults was 86.7 cm TL with a range from 48-114.5 cm TL (a subadult was classified as being 40-130 cm TL). The majority of the adult captures were in July between Merrymeeting Bay and Gardiner. Additional insight concerning the timing of Atlantic sturgeon spawning season emerged from a small commercial fishery on the Kennebec River in South Gardiner near Rolling Dam from June 15 – July 26, 1980. Thirty-one adult Atlantic sturgeon (27 males, 4 of which were ripe and 4 females, 1 of which was ripe) were captured. Two adults tagged in 1978 by the MEDMR in South Gardiner were recaptured in this fishery.

On July 13, 1994, while sampling for sturgeon, the MEDMR captured seven adult Atlantic sturgeon just below the spillway of the Edwards Dam in Augusta. Five of the seven Atlantic sturgeon (56-195 cm TL) were males expressing milt. In 1997, a biweekly trawl survey conducted from April – November by Normandeau Associates in the lower Kennebec River, captured thirty-one subadults and one adult Atlantic sturgeon. Subadults were also captured by the MEDMR in September of 1997 in the Eastern River (n = 18) and the Cathance River (n = 5), which are freshwater tributaries to the Kennebec, in overnight sets of gill nets (T. Squiers, MEDMR, Pers. Comm. 1998). Additional sampling from 2000-2003 of the MEDMR inshore groundfish trawl survey collected 13 subadults at the mouth of the Kennebec River, which had the greatest occurrences of Atlantic sturgeon among five regions sampled along the New

[9] A 10-25 fold increase in abundance was estimated because in 1998 the CPUE was extremely large (14.44) compared to 1999 and 2000 estimates of 4.17 and 3.70, respectively. Thus, the CPUE in 1998 may be an outlier skewing the data.

Hampshire and Maine coasts (Squiers 2003). The most recent capture of an adult Atlantic sturgeon occurred in June of 2005, where a 178 cm TL sturgeon was captured in an American shad gill net (12.7 cm stretched mesh) in Ticonic Bay, just upstream of the confluence between Sebasticook and the Kennebec rivers (Squiers 2005).

The presence of adult male Atlantic sturgeon in ripe condition near the head-of-tide during June and July of 1994, 1997, and possibly in 2005 presents strong evidence that a spawning population still exists in the Kennebec River. While no eggs, larvae, or YOY have been captured in the last 15 years, the presence of subadults (48 cm to over 100 cm TL) in tidal freshwater tributaries and the mid-estuary and mouth of the Kennebec River from at least April – November provides additional evidence that a spawning population of Atlantic sturgeon persists in the Kennebec River estuary.

The only documented occurrence of Atlantic sturgeon in the Androscoggin River was an adult captured and released approximately one km downstream of the Brunswick Dam in 1975. No studies have been conducted to assess whether Atlantic sturgeon are presently utilizing the Androscoggin River for spawning. Subadults have been captured in the Sheepscot River, which may function as a nursery area for Kennebec River Atlantic sturgeon.

Piscataqua River/Great Bay Estuary System – New Hampshire

Few Atlantic sturgeon have been captured in the Piscataqua River (Hoff 1980). A subadult Atlantic sturgeon (57 cm; likely age-1) was captured by New Hampshire Fish and Game (NHFG) in June 1981 at the mouth of the Oyster River in Great Bay (New Hampshire Fish and Game 1981). Between July 1, 1987, and June 30, 1989, New Hampshire Fish and Game surveyed the deeper tributaries of the Great Bay Estuary including the Piscataqua, Oyster, Little and Lamprey rivers, as well as the Great Bay for shortnose sturgeon, using 30.5 m nets (3 m deep with 14 and 19 cm stretch mesh) that were fished for 146 net days. In 1988, sampling occurred in suspected spawning areas (salinities 0-10 ppt) in the spring and in suspected feeding areas (salinities around 24 ppt) in the summer. In 1989, nets were fished in May and June only (salinities 6-15 ppt). No Atlantic sturgeon were captured. However, a large gravid female Atlantic sturgeon (228 cm TL) weighing 98 kg (of which 15.9 kg were eggs) was captured by a commercial fisherman in a small mesh gill net at the head-of-tide in the Salmon Falls River in South Berwick, ME on June 18, 1990 (D. Grout, NHFG, Pers. Comm. 2006). The Salmon Falls River is a shallow tributary of the Piscataqua and is the delineation between New Hampshire and Maine state lines. Since 1990, the NHFG has not observed or received reports of Atlantic sturgeon of any age-class being captured in the Great Bay Estuary and its tributaries (B. Smith, NHFG, Pers. Comm. 2006).[10] It is the conclusion of the SRT and NHFG biologists that the Great Bay Atlantic sturgeon population is likely extirpated.

Merrimack River – New Hampshire and Massachusetts

[10] Great Bay Estuary fishing effort is limited to a small mesh gill net bait fishery (< 3 in stretched mesh). New Hampshire Fish and Game require that all catch, including bycatch, be reported (D. Grout, NHFG, Pers. Comm. 2006).

Historical reports of Atlantic sturgeon in the Merrimack River include a 104 kg sturgeon taken at Newburyport on September 14, 1938, while netting for blueback herring (Hoover 1938). An intensive gill net survey was conducted in the Merrimack River from 1987-1990 to determine annual movements, spawning, summering, and wintering areas of shortnose and Atlantic sturgeon (Kieffer and Kynard 1993). Thirty-six Atlantic sturgeon were captured (70-156 cm TL); most being under 100 cm TL. One dead Atlantic sturgeon was found on June 30, 1990 at the shortnose spawning area in Haverhill, MA (between rkm 31-32). Of 23 subadult Atlantic sturgeon sonically tracked in the river, 11 left the river within seven days, and the rest left by September or October of each year (Kieffer and Kynard 1993). Fish captured in one year were not observed in the river during subsequent years. On June 9, 1998, a 24 inch (estimated length) Atlantic sturgeon was captured and released in the Merrimack River by the USFWS personnel, who were conducting a contaminant study on the river (D. Major, USFWS, Pers. Comm. 2006). This information provides no evidence of a spawning population of Atlantic sturgeon in the Merrimack River, although it seems that the estuary is used as a nursery area (B. Kynard, Conte Anadromous Fish Research Center, Pers. Comm. 1998).

Taunton River – Massachusetts and Rhode Island

Historical records indicate that Atlantic sturgeon spawned in the Taunton River at least until the turn of the century (Tracy 1905). A gill net survey was conducted in the Taunton River during 1991 and 1992 to document the use of this system by sturgeon. Three subadult Atlantic sturgeon were captured but were determined to be non-natal fish (Burkett and Kynard 1993). In June 2004, a fisherman fishing in state waters noted that the first three fathoms of towed up gear held three juvenile Atlantic or shortnose sturgeon (Anoushian 2004).[11] Trawlers fishing in state waters (less than three miles offshore) also occasionally report Atlantic sturgeon captures. Since 1997, only two sturgeon have been captured by the Rhode Island Department of Environmental Management Trawl Survey (RIDEM), one measuring 85 cm TL was captured in 1997 in Narragansett Bay, and another (130 cm TL) was captured in October 2005 in Rhode Island Sound (A. Libby, RIDEM, Pers. Comm. 2006). The NMFS observer program has also documented Atlantic sturgeon bycatch off the coast of Rhode Island in Federal waters. Since spawning adults were not found during the expected spawning period of May and June, it is likely that a spawning population of Atlantic sturgeon does not occur in the Taunton River, though the system is used as a nursery area for Atlantic sturgeon (Burkett and Kynard 1993).

Thames River – Connecticut

The Thames River is formed by the joining of the Yantic and Shetucket rivers in Norwich Harbor, Connecticut. Information on abundance of Atlantic sturgeon in the Thames River is scarce. Sturgeon scutes have been documented at an archeological site along the river, and historical reports note sturgeon use by Native Americans. Atlantic sturgeon were reportedly abundant in the system until the 1830s (reviewed in Minta 1992). Whitworth (1996) speculated that populations of both shortnose and Atlantic sturgeon in the Thames were always low because the fall line is located near the limit of saltwater intrusion, leaving little to no freshwater habitat for spawning. The construction of the Greenville Dam in 1825 further restricted available habitat and probably prevented sturgeon from spawning in the river. There have been some

[11] It is expected that these three juveniles were not shortnose sturgeon due to their rarity in this system.

reports of low dissolved oxygen (DO) levels during the summer months. The mouth of the river is dredged to accommodate the shipyard, and the channel was recently improved to provide deeper depths to accommodate the Sea Wolf submarine. Subadult Atlantic sturgeon have been captured in the estuary (Whitworth 1996), but it is unlikely that a spawning population is present.

Connecticut River – Massachusetts and Connecticut

Judd (1905) reports that sturgeon were speared at South Hadley Falls in the mid 1700s. There are historical reports of sturgeon migration as far as Hadley, MA, but regular migration of Atlantic sturgeon beyond Enfield, CT is doubtful due to presence of significant rapids (Judd 1905). A dam constructed at Enfield in 1827 effectively blocked any migration beyond this point, until 1977 when the dam was breached. Until recently, there has been no evidence that Atlantic sturgeon currently use the Massachusetts portion of the Connecticut River. On August 31, 2006, a 152.4 cm TL Atlantic sturgeon was observed in the Holyoke Dam spillway lift (~ rkm 143). The Atlantic sturgeon was not sexed and was described as a subadult (R. Murray, Holyoke Gas and Electric, Pers. Comm. 2006). However, based on the size of the Atlantic sturgeon it is possible that the fish was a mature adult. This is the first time an Atlantic sturgeon has been reported at the Holyoke Dam fish lift.

Six juvenile fish (9-11 kg) were reportedly taken opposite Haddam Meadows in 1959, but it is unclear if these were Atlantic or shortnose sturgeon. As late as the 1980s, the Connecticut Department of Environmental Protection (CTDEP) fisheries staff reported occasional visual observations of Atlantic sturgeon below the Enfield Dam during May and June. From 1984-2000, the CTDEP studied the abundance, locations, and seasonal movement patterns of shortnose sturgeon in the lower Connecticut River and Long Island Sound (Savoy and Pacileo 2003). Sampling was conducted using gill nets ranging from 10-18 cm stretched mesh in the lower Connecticut River (1988-2005) and a stratified random-block designed trawl survey (12.8 m 1984-1990 and 15.2 m 1990-2005) in the Long Island Sound (also referred to as the LIS Trawl Survey). One hundred and thirty-one Atlantic sturgeon were collected from the lower Connecticut River gill net survey, and average lengths of fish reported from 1988-2000 were 77 cm FL (51-107 cm FL). The majority of these subadult Atlantic sturgeon were captured in the lower river (between rkm 10-26) within the summer range of the salt wedge (Savoy and Shake 1993).[12] A total of 347 fish were collected in the LIS trawl survey from 1984-2004, of these with reported lengths (1984-2000) the mean length was 105 cm FL (ranging from 63-191 cm FL) (Figure 5). Data from 1984-2000, indicated that 68% of the Atlantic sturgeon captured in the trawl survey came from the Central Basin (off Faulkner Island), while 6% of catches occurred in northern portions of the LIS survey near the mouth of the Connecticut River.

While research efforts have not specifically investigated the occurrence of Atlantic sturgeon in the upper Connecticut River, the species has never been collected incidentally in this region during extensive sampling for shortnose sturgeon. Occasional reports, sightings, and capture of large Atlantic sturgeon (150-300 cm) are made, but most Atlantic sturgeon captured within tidal waters or freshwater in Connecticut are consistent with the size and seasonal locations of immature Atlantic sturgeon from the Hudson River (Savoy 1996). Based on the lack of evidence

[12] Three Atlantic sturgeon were captured in September (1 in 1990, 2 in 2000) at rkm 46, however the date of capture does not overlap with the region's spawning period from April to May.

of spawning adults, stocks of Atlantic sturgeon native to Connecticut waters are believed to be extirpated (Savoy 1996).

Housatonic River – Connecticut

Coffin (1947) reports that Atlantic sturgeon were abundant in the Housatonic River and were captured by Native Americans. According to Whitworth (1996), there was a large fishing industry for sturgeon in this basin, and subadults have been captured in the estuary. Atlantic sturgeon likely spawned at a natural fall (Great Falls) at rkm 123 until 1870 when the Derby Dam was constructed at rkm 23.5. The Derby Dam restricted access to approximately 100 km or 81% of historical habitat. The Housatonic has not been systematically sampled for sturgeon in recent years (last 15 years), but it is unlikely that a spawning population is present (NMFS and FWS 1998).

Hudson River – New York

Atlantic sturgeon in the Hudson River have supported subsistence and commercial fishing since colonial times (Kahnle et al. 1998). No data on abundance of juveniles are available prior to the 1970s; however, catch depletion analysis estimated conservatively that 6,000-6,800 females contributed to the spawning stock during the late 1800s (Secor 2002, Kahnle et al. 2005). Two estimates of immature Atlantic sturgeon have been calculated for the Hudson River stock, one for the 1976 year class and one for the 1994 year class. Dovel and Berggren (1983) marked immature fish from 1976-1978. Estimates for the 1976 year class at age one ranged from 14,500-36,000 individuals (mean of 25,000). In October of 1994, the NY State Department of Environmental Conservation (NYSDEC) stocked 4,929 marked age-0 Atlantic sturgeon, provided by a USFWS hatchery, into the Hudson Estuary at Newburgh Bay. These fish were reared from Hudson River brood stock. In 1995, Cornell University sampling crews collected 15 stocked and 14 wild age-1 Atlantic sturgeon (Peterson et al. 2000). A Petersen mark-recapture population estimate from these data suggests that there were 9,529 (95% CI = 1,916 – 10,473) age-0 Atlantic sturgeon in the estuary in 1994. Since 4,929 were stocked, 4,600 fish were of wild origin, assuming equal survival for both hatchery and wild fish and that stocking mortality for hatchery fish was zero. Estimates of spawning adults were also calculated by dividing the mean annual harvest from 1985 to 1995 by the exploitation rate (u). The mean annual spawning stock size (spawning adults) was 870 (600 males and 270 females) (Kahnle et al. *In press*).[13]

Current abundance trends for Atlantic sturgeon in the Hudson River are available from a number of surveys. From July to November during 1982-1990 and 1993, the NYSDEC sampled the abundance of juvenile fish in Haverstraw Bay and the Tappan Zee Bay. The CPUE of immature Atlantic sturgeon was 0.269 in 1982 and declined to zero by 1990. The American shad gill net fishery in the Hudson River estuary, conducted from early April to late May, incidentally captures young Atlantic sturgeon (< 100 cm) and therefore, has been monitored by onboard observers since 1980. Annual CPUE data from the observer program were summarized as total observed catch/total observed effort. Catch-per-unit-of-effort of Atlantic sturgeon as bycatch was greatest in the early 1980s and decreased until the mid 1990s. It has gradually begun to increase since then (Figure 6).

[13] Confidence intervals were not provided.

Hudson River Valley utilities (Central Hudson Electric and Gas Corp., Consolidated Edison Company of New York, Inc., New York Power Authority, Niagara Mohawk Power Corporation, Orange and Rockland Utilities, Inc.) conduct extensive river-wide fishery surveys to obtain data for estimating impacts of power plant operations. Detailed survey descriptions are provided in the utilities' annual reports (CONED 1997). Two surveys regularly catch sturgeon, despite the fact that these surveys were not specifically designed to capture sturgeon. The Long River Survey (LRS) samples ichthyoplankton river-wide from the George Washington Bridge (rkm 19) to Troy (rkm 246) using a stratified random design (CONED 1997). These data, which are collected from May-July, provide an annual index of juvenile Atlantic sturgeon in the Hudson River estuary since 1974. The Fall Shoals Survey (FSS), conducted from July – October by the utilities, calculates an annual index of the number of fish captured per haul. Between 1974 and 1984, the shoals in the entire river (rkm 19-246) were sampled by epibenthic sled; in 1985 the gear was changed to a three-meter beam trawl. Length data are only available for the beam trawl survey from 1989 to the present; fish length ranged from 10 – 100 cm TL, with most fish less than 70 cm TL. Based on these length data, it seems that ages-0 (YOY), 1, and 2 sturgeon are present in the river. Indices from utility surveys conducted from 1974 to the present (LRS and FSS) indicate a trend consistent with NYSDEC American shad monitoring data. Abundance of young juvenile Atlantic sturgeon has been declining, with CPUE peaking at 12.29 in 1986 (peak in this survey) and declining to 0.47 in 1990. Since 1990, the CPUE has ranged from 0.47-3.17, increasing in recent years to 3.85 (2003). In 2000, the NYSDEC created a sturgeon juvenile survey program to supplement the utilities' survey; however, funds were cut in 2000, and the USFWS was contracted in 2003 to continue the program. In 2003 – 2005, 579 juveniles were collected (N = 122, 208, and 289, respectively) (Sweka et al. 2006). Pectoral spine analysis showed they ranged from 1 – 8 years of age, with the majority being ages 2 – 6. None of the captures were found to be YOY (< 41 cm TL).

Indices for post-migrant Atlantic sturgeon are provided by the New Jersey Bureau of Marine Fisheries from surveys of the coastal waters along the entire state (Sandy Hook to Delaware Bay). Since 1988 when the survey was initiated, a total of 96 Atlantic sturgeon have been captured.[14] Abundances of post-migrants seem to be declining as CPUE has decreased from a high of 8.75 in 1989 to 1.5 in 2003. This trend differs from Hudson River Fall Shoals Utility Survey, which indicated an increasing or stable trend over the last several years (Figure 7).

All available data on abundance of juvenile Atlantic sturgeon in the Hudson River estuary (i.e., mark/recapture studies, bycatch data from commercial gill net fishery, and utilities sampling) indicate a substantial drop in production of young since the mid 1970s. The greatest decline seemed to occur in the middle to late 1970s, followed by a secondary drop in the late 1980s. Sturgeon are still present, and juveniles (age-0 (YOY), 1, and 2 years) were captured in recent years and a slight increasing trend in CPUE has been observed. The capture of YOY sturgeon in 1991, 1993-1996, and 2003, provides evidence of successful spawning.

Delaware River – New Jersey, Delaware, and Pennsylvania

[14] No data for 2004 and 2005.

The Delaware River, flowing through New Jersey, Delaware, Pennsylvania and into Delaware Bay, historically may have supported the largest stock of Atlantic sturgeon of any Atlantic coastal river system (Kahnle et al. 1998; Secor and Waldman 1999, Secor 2002). Prior to 1890, it is expected that more than 180,000 adult females were spawning in the Delaware River (Secor and Waldman 1999, Secor 2002). Juveniles were once abundant enough to be considered a nuisance bycatch of the American shad fishery. Very little is known about adult stock size and spawning of Atlantic sturgeon in the Delaware river; however, based on reported catches in gill nets and by harpoons during the 1830s, they may have spawned as far north as Bordentown, south of Trenton, NJ (Pennsylvania Commission of Fisheries 1897). A recent sonic tracking project, on-going in 2006, has reported at least one adult Atlantic sturgeon migrating to Bordentown during the spawning season (D. Fox, DSU, Pers. Comm. 2006). Borodin (1925) reported that running-ripe sturgeon were captured near Delaware City, DE adjacent to Pea Patch Island. Spawning grounds with appropriate substrate occurred near Chester, Pennsylvania. Ryder (1888) suggested that juvenile Atlantic sturgeon used the tidal freshwater reach of the estuary as a nursery area. Lazzari et al. (1986) reported that the Roebling-Trenton stretch of the river may be an important nursery area for the species.

The current abundance of all Atlantic sturgeon life stages in the Delaware River has been greatly reduced from the historical level. Brundage and Meadows (1982) recorded 130 Atlantic sturgeon captures between the years of 1958 – 1980. The Delaware Division of Fish and Wildlife (DFW) began sampling Delaware Bay in 1966 by bottom trawl and have rarely captured Atlantic sturgeon. During the period from 1990 to 2004, the trawl survey captured 17 Atlantic sturgeon (Murphy 2005). However, there are several areas within the estuary where juvenile sturgeon regularly occur. Lazzari et al. (1986) frequently captured juvenile Atlantic sturgeon from May-December in the upper tidal portion of the river below Trenton, New Jersey (N = 89, 1981 – 1984). In addition, directed gill net surveys by DFW from 1991-1998 consistently took juvenile (N > 1,700 overall) Atlantic sturgeon in the lower Delaware River near Artificial Island and Cherry Island Flats from late spring to early fall (Shirey et al. 1999). The number of fish captured in the lower river annually has declined dramatically throughout this time period from 565 individuals in 1991 to 14 in 1998. Population estimates based on mark and recapture of juvenile Atlantic sturgeon declined from a high of 5,600 in 1991 to less than 1,000 in 1995; however, it is important to note that population estimates violated most tagging study assumptions and should not be used as unequivocal evidence that the population has declined dramatically. No population estimates are available from 1996 and 1997, given the low number of recaptures.

Voluntary logbook reporting of Atlantic sturgeon bycatch in the spring gill net fishery indicate that abundance varies year to year with no indication of decline or increase mainly because the number of bycatch reports varies considerably by commercial fishers reporting. Bycatch data are represented as the average bycatch per fisher per year (total bycatch/number of fishers). An annual small mesh gill net survey began in 1991 until 1998 when sampling was restricted to every three years in the lower Delaware River. The results of this study indicated that CPUE (fish per gill net hr) estimates have declined from 32 fish/effort hr in 1991 to only 2 fish/effort hr in 2004 (Figure 8).

Carcasses of large adult fish (> 150 cm TL) are commonly reported along the lower Delaware River and upper Delaware Bay during the historic spawning season (G. Murphy, DFW, Pers. Comm. 2006). Fifteen adult size fish have been documented since 1994, including several gravid females and males. A 2.4 m female Atlantic sturgeon was found dead on June 14, 1994, adjacent to Port Penn; ageing of a pectoral spine indicated it was approximately 25 years old (D. Secor, University of Maryland, Pers. Comm. 1998). Three years later, a second female sturgeon was found in late spring/early summer of 1997 adjacent to Port Penn, just south of the eastern end of the Chesapeake/Delaware Canal. A male sturgeon carcass was found on May 19, 1997, just north of the mouth of the Cohansey River, on Beechwood Beach; it seemed that the fish was cut in half by the propeller of a large vessel. Gonadal tissue and a pectoral spine were collected and sent to USFWS-Northeast Fisheries Center (NEFC), Fish Technology Section, Lamar, PA for analysis, where it was confirmed to be a male (W. Andrews, New Jersey Division of Fish, Game, and Wildlife, Pers. Comm. 1998). In 2005, DFW began tracking reported sturgeon mortalities during the spawning season. During the first year, six adults were found dead washed ashore in May 2005, including two from Woodland Beach (~250 cm and 170 cm TL), one from Artificial Island (>180 cm TL), one from South Bowers Beach (205 cm TL), one from Conch Bar (160 cm TL) and one from Slaughter Beach (160 cm TL). Six additional carcasses, presumed adults, were found during April-May 2006, including a gravid female at Augustine Beach (144 cm), a gravid male at Sleusch Ditch (180 cm), one at South Bowers Beach (119 cm), one at Brockonbridge Gut (112 cm), one at Kitts Hummock (208 cm), and one at Little Tinicum Island, PA (106 cm). The majority of adults documented had substantial external injuries and were severed.

In addition to the carcasses reported annually during the spawning season, several males were captured by directed gill net efforts and a reward program conducted by Delaware State University during April and May 2006. These males were collected in the lower Delaware River and upper Delaware Bay and were implanted with sonic transmitters to assist in determining spawning locations in the Delaware River.

Although catch rates declined throughout the mid 1990s, the mature adults documented within the Delaware System provide evidence that a reproducing population exists. It is speculated, however, that the abundance of subadults within the Delaware River during the 1980s and early 1990s was the result of a mixture of stocks including the Hudson River stock. However, genetic data indicate that the Delaware River has a distinct genetic signature of a remnant population (Waldman et al. 1996, Wirgin 2006, King supplemental data 2006).

Chesapeake Bay and Tributaries (Potomac, Rappahannock, York, James, Susquehanna, Nanticoke) – Pennsylvania, Maryland, and Virginia

Historically, Atlantic sturgeon were common throughout the Chesapeake Bay and its tributaries (Kahnle et al. 1998, Wharton 1957, Bushnoe et al. 2005). There are several newspaper accounts of large sturgeon in the lower reaches of the Susquehanna River from 1765-1895, indicating that at one time, Atlantic sturgeon may have spawned there. Commercial landings data during the 1880s are available for the Rappahannock (8 mt), York (23 mt), and James (49 mt) providing evidence that Atlantic sturgeon were historically present in these rivers as well (Bushnoe et al. 2005). Historical harvests were also reported in the Patuxent, Potomac, Choptank, Nanticoke, and Wicomico/Pocomoke rivers (S. Minkkinen, USFWS, Pers. Comm. 2006). Prior to 1890, when a sturgeon fishery began, Secor (2002), using U.S. Fish Commission landings, estimated approximately 20,000 adult females inhabited the Chesapeake Bay and its tributaries.

For the past several decades, state fishery agencies and research facilities operating in the Chesapeake Bay have conducted extensive finfish sampling surveys in the mainstem Bay and all major tributaries. These surveys occurred in all seasons and were conducted using many gear types, including trawls, seines, and gill nets. While no surveys were directed at sturgeon, incidental captures were recorded. These data supplement reports of sturgeon captures from commercial fishers using gill nets, pound nets, and fyke nets with occasional visual observations of large sturgeon, including carcasses found on beaches during the summer.

A mixed stock analysis, performed from nDNA microsatellite markers, indicated that the Chesapeake Bay population was comprised of three main stocks: 1) Hudson River (23-30%), 2) Chesapeake Bay (0-35%), and 3) Delaware River (17-27%) (King et al. 2001). The contribution of fish with Chesapeake Bay origin fish, which had not been identified in previous genetic studies, indicates the likely existence of a reproducing population within the Bay. This is further supported and substantiated by the capture of young juveniles at the mouth of the James River and two YOY Atlantic sturgeon captured in the river in 2002 and 2004 (Florida Museum of Natural History 2004, A. Spells, USFWS, Pers. Comm. 2006).

Several sturgeon sightings were made by commercial fishers and researchers between 1978 and 1987 near the Susquehanna River mouth. A deep hole (19 m) on the Susquehanna River near Perryville, MD also supported a limited sturgeon fishery (R. St. Pierre, USFWS retired, Pers. Comm. 1998). Maryland DNR personnel reported a large mature female Atlantic sturgeon in the Potomac in 1970 and another in the Nanticoke River in 1972 (H. Speir, Maryland DNR, Pers. Comm. 1998).

A Virginia Institute of Marine Science (VIMS) trawl survey was initiated in 1955 to investigate finfish dynamics within the Chesapeake Bay; the survey was standardized in 1979. Since 1955, 40 Atlantic sturgeon have been captured, 16 of which were captured since 1990, and two of these collections may have been YOY based on size. No fish were captured between 1990 and 1996; however, seven were captured in 1998. In subsequent years, catch declined ranging between zero and three fish per year. Similarly, American shad monitoring programs (independent stake gill net survey) also recorded a spike in Atlantic sturgeon bycatch that peaked in 1998 (N = 34; 27 from James River) and declined dramatically in later years to only one to three sturgeon being captured in each year from 2002-2004 (Figure 9). These observations could be biased by stocking 3,200 juveniles in the Nanticoke River in 1996; however, the capture of wild fish in the Maryland Reward Tagging program conducted from 1996 to present shows identical rates of capture for wild fish (see additional information below and Figure 9).

The Maryland reward tagging has resulted in the capture of 1,700 Atlantic sturgeon. Five hundred and sixty seven of these fish were hatchery fish, of which 462 were first time captures (14% recapture rate), the remaining captures (1,133) were wild (Figure 9). However, none of these 1,700 Atlantic sturgeon were considered YOY based on length data (S. Minkkinen, USFWS, Pers. Comm. 2006). Similarly, Virginia initiated a reward tagging program in 1996 through 1998. The majority of their recaptures were wild Atlantic sturgeon taken from the lower James and York rivers in the 20 – 40 cm size range and are believed to be YOY (A. Spells, USFWS, Pers. Comm. 1998). Captures of YOY and age-1 sturgeon in the James River during 1996 and 1997 suggest spawning has occurred in that system.[15] Since then, captures from the reward program have varied, declining from 1999 to 2002 and then increasing in 2005 to levels similar to that of 1998 and with record levels during 2006 (Figure 9). Further evidence that spawning may have occurred recently is provided by three carcasses of large adults found in the James River in 2000-2003, the discovery of a 213 cm carcass of an adult found in the Appomattox River in 2005, as well as the release of a 2.4 m Atlantic sturgeon near Hoopers Island (the Bay) in April, 1998 (S. Minkkinen, USFWS, Pers. Comm. 2006).

These data indicate that some of the Chesapeake Bay tributaries may continue to support spawning populations as evidenced by YOY captures (James River) and carcasses of mature adults being found occasionally within the Bay during the spawning season. Commercial fishers have regularly reported observations of YOY or age-1 juveniles in the York River over the past few years (K. Place, Commercial Fisherman, Pers. Comm. 2006). In 2006, tissue samples from 38 juvenile Atlantic sturgeon measuring between 500 – 600 mm TL (~ age-1) were haplotyped and genotyped by researchers (I. Wirgin – NIEM and T. King – USGS, supplemental data 2006). These 38 juveniles from the York River were significantly different ($P < 0.01$) from neighboring subpopulations including the James River subpopulation, based on frequency differences in mtDNA and nDNA markers. However, the York River does not contain unique mtDNA haplotypes differentiating it directly from other sturgeon populations, and the population could not be differentiated from the James River population using classification techniques (Figure 10). Additionally, a review of spawning habitat availability in the Chesapeake Bay and its tributaries indicated that spawning habitat is available in the James, York, and Appomattox rivers (Bushnoe et al. 2005). Therefore, the above information provides some evidence that a spawning population may exist in the York River, as the population exhibits significantly different haplotype frequencies from its neighboring subpopulations, and spawning habitat appears to be available. However, there is a possibility that samples taken from the York River were of a mixed stock since they measured 500 – 600 mm in total length (the size range of migratory subadults) and many of the collections were taken from the mouth of the river.

North Carolina Rivers

Historically, Atlantic sturgeon were abundant in most North Carolina coastal rivers and estuaries; the largest fishery occurring in the Roanoke River/Albemarle Sound system and in the Cape Fear River (Kahnle et al. 1998). Historic landing records from the late 1800s indicated that Atlantic sturgeon were very abundant within the Albemarle Sound (~ 61.5 mt/yr); however, these landings are relatively small compared to the Delaware fishery (~2,700 mt/yr) (Secor 2002). Abundance estimates derived from these historical landings records indicated that between 7,200 and 10,500 adult females were present within North Carolina prior to 1890 (Armstrong and Hightower 2002, Secor 2002).

[15] Other references (Kahnle et al. 2005) noted that 90% of the wild Atlantic sturgeon captured in the reward program were thought to be from a 1995 year class.

Albemarle Sound (Roanoke and Chowan/Nottoway Rivers) – North Carolina

Historic and current survey data indicate that spawning occurs in the Roanoke River/Albemarle Sound system, where both adults and small juveniles have been captured. Since 1990, the NC Division of Marine Fisheries (NCDMF) has conducted the Albemarle Sound Independent Gill Net Survey (IGNS), initially designed to target striped bass. The survey is conducted from November-May, using a randomized block sampling design and employing 439 m of gill net, both sinking and floating, with stretched mesh sizes ranges from 63.5 mm (2.5 in) to 254 mm (10 in). Since 1990, 842 sturgeon have been captured ranging from 15.3 to 100 cm FL, averaging 47.2 cm FL. One hundred and thirty-three (16%) of the 842 sturgeon captured could be classified as YOY (≤ 41 cm TL, ≤ 35 cm FL); the others were subadults. Incidental take of Atlantic sturgeon in the IGNS indicate that the subpopulation has been increasing in recent years (1990-2000), but since then recruitment has dramatically declined (Figure 11). Similarly, the NCDMF Observer Program documented the capture of 30 Atlantic sturgeon in large and small mesh gill nets; two of these individuals being YOY (< 410 mm TL) (Blake Price, NCDMF, Pers. Comm. 2006).

In 1997 and 1998, NC State University (NCSU) researchers characterized the habitat use, growth, and movement of juvenile Atlantic sturgeon (Armstrong and Hightower 2002). Their survey collected 107 Atlantic sturgeon, of which 15 (14%) could be considered YOY (≤ 41 cm TL or 35 cm FL). Young juveniles were observed more often over organic rich mud bottoms and at depths of 3.6-5.4 meters. Adult running ripe sturgeon have not been collected in the Roanoke River even though the NC Wildlife Resources Commission has sampled the spawning grounds since the 1990s during their annual striped bass electrofishing survey.[16] However, in 2005, an angler captured a YOY (39 cm TL) Atlantic sturgeon in the Roanoke River, near the city of Jamesville, NC (see Figure 12). These multiple observations of YOY from the Albemarle Sound and Roanoke River provide evidence that spawning continues, and catch records indicate that this population seemed to be increasing until 2000, when recruitment began to decline.

Pamlico Sound (Tar and Neuse Rivers) – North Carolina

Evidence of spawning was reported by Hoff (1980), who noted captures of very young juveniles in the Tar and Neuse rivers. More recently, two juveniles (approximately 45 and 60 cm TL) were observed dead on the bank of Banjo Creek, a tributary to the Pamlico system (B. Brun, USFWS and US Army Corps of Engineers (retired), Pers. Comm. 1998). An independent gill net survey, following the Albemarle Sound IGNS methodology, was initiated in 2001. Collections were low during the periods of 2001-2003, ranging from zero to one fish/yr. However, in 2004, this survey collected 14 Atlantic sturgeon ranging from 460 to 802 mm FL, and averaging 575 mm FL. During the same time period (2002 – 2003), four Atlantic sturgeon (561 – 992 mm FL) were captured by NCSU personnel sampling in the Neuse River (Oakley 2003). Similarly, the NCDMF Observer Program documented the capture of 12 Atlantic sturgeon in the Pamlico Sound from April 2004 to December 2005; none of these were YOY or spawning adults, averaging approximately 600 mm TL (Blake Price, NCDMF, Pers. Comm. 2006).

[16] Electrofishing does not usually collect sturgeon (P. Kornegay, NCWRC, Pers. Comm. 2006).

The incidental capture of two juvenile Atlantic sturgeon in the Tar (1) and Neuse rivers (1) in 2005 also provides evidence that spawning may be occurring within those rivers. The Tar River juvenile was captured near Greenville, NC by an angler and reported to be less than 40 cm in TL (P. Kornegay, NCWRC, Pers. Comm. 1998). The other juvenile was captured in an illegal gill net set upstream of New Bern, NC, and measured 46 cm TL (Figure 12). Although not confirmed as YOY, these two captures are important in that they represent the only evidence of possible spawning activities within the Pamlico Sound Drainage for at least the last 15 years.

Cape Fear River – North Carolina

A gill net survey for adult shortnose and juvenile Atlantic sturgeon was conducted in the Cape Fear River drainage from 1990-1992, and replicated 1997-2005. Each sampling period included two overnight sets (checked every 24 hrs). The 1990-1992 survey captured 100 Atlantic sturgeon below Lock and Dam #1 (rkm 95) for a CPUE of 0.11 fish/net-day. No sturgeon were collected during intensive sampling above Lock and Dam #1. In 1997, 16 Atlantic sturgeon were captured below Lock and Dam #1, an additional 60 Atlantic sturgeon were caught in the Brunswick (a tributary of the Cape Fear River), and 12 were caught in the Northeast Cape River (Moser et al. 1998). Relative abundance of Atlantic sturgeon below Lock and Dam #1 seemed to have increased dramatically since the survey was conducted in 1990-1992 (Moser et al. 1998) as the CPUE of Atlantic sturgeon was two to eight times greater during 1997 than in the earlier survey.[17] Since 1997, Atlantic sturgeon CPUE has been gradually increasing: a regression analysis revealed that CPUE doubled between the years of 1997 (~0.25 CPUE) and 2003 (0.50 CPUE) (Williams and Lankford, 2003) (Figure 13). This increase may reflect the effects of North Carolina's ban on Atlantic sturgeon fishing that began in 1991; however, the increase in CPUE may also be artificial as these estimates are similar among years except in 2002 (large increase) that likely skewed the regression analysis. In 2003, the NCDMF continued the sampling program (Cape Fear River Survey) and have collected 91 Atlantic sturgeon (427 - 1473 mm FL).

Adult Atlantic sturgeon have been observed migrating upstream in the fall within the Cape Fear River, indicating that there may be two spawning seasons or some upstream overwintering may be occurring (M. Williams, Former UNCW, Pers. Comm. 2006). One large Atlantic sturgeon was tracked moving upstream in the Black River, which is a tributary of the Cape Fear River, in early October. Moreover, all of the largest sturgeon collected by UNCW personnel were later captured only during September and October in both the Cape Fear and Northeast Cape Fear rivers. Finally, a carcass of an adult female Atlantic sturgeon with fully developed ovaries was discovered in an area well upstream of the saltwater-freshwater interface in mid-September. Studies in other river systems have also demonstrated that some sturgeon will participate in upstream spawning migrations in the fall (Rogers and Weber 1995, Weber and Jennings 1996, Moser et al. 1998).

South Carolina Rivers

[17] Data may be biased as some sampling sites varied between the two periods, and more sites were sampled in 1997-2003 compared to 1990-1992.

Historically, Atlantic sturgeon were likely present in many South Carolina river/estuary systems, but it is not known where spawning occurred. Secor (2002) estimated that 8,000 spawning females were likely present prior to 1890, based on US Fish Commission landing records. Since the 1800s, however, populations have declined dramatically (Collins and Smith 1997). During the last two decades, Atlantic sturgeon have been observed in most South Carolina coastal rivers, although it is not known if all rivers support a spawning subpopulation (Collins and Smith 1997).

Winyah Bay (Waccamaw, Great Pee Dee, and Sampit Rivers) – South Carolina

Recent shortnose sturgeon sampling (using 5, 5.5, 7, and 9 inch stretched mesh experimental gill nets; 16' otter trawl) conducted in Winyah Bay captured two sub-adult Atlantic sturgeon during 4.2 hrs of effort in 2004. Captures of age-1 juveniles from the Waccamaw River during the early 1980s suggest that a reproducing population of Atlantic sturgeon may persist in that river, although the fish could have been from the nearby Great Pee Dee River (Collins and Smith 1997). In 2003 and 2004, nine Atlantic sturgeon (48.4-112.2 cm FL) were captured in the Waccamaw River during the SC Department of Natural Resources (SCDNR) annual American shad gill net survey, although none were considered spawning adults or YOY. However, Collins et al. (1996) note that unlike northern populations, in South Carolina, YOY are considered to be less than 50 cm TL or 42.5 cm FL, as growth rates are greater in the warmer southern waters compared to cooler northern waters. Therefore, the capture of a 48.4 cm FL sturgeon provides some evidence that YOY may be present in the Waccamaw River and some evidence of a spawning subpopulation. Lastly, watermen on the lower Waccamaw and Pee Dee rivers have observed jumping sturgeon, which suggest that rivers either serve as a nursery/feeding habitat or support an extant subpopulation(s) (W. Laney, USFWS, Pers. Comm. 2007).

Until recently, there was no evidence that Atlantic sturgeon spawned in the Great Pee Dee River, although subadults were frequently captured and large adults were often observed by fishers. However, a fishery survey conducted by Progress Energy Carolinas Incorporated captured a running ripe male in October of 2003 and observed other large sturgeon, perhaps revealing a fall spawning run.

There are no data available regarding the presence of YOY or spawning adult Atlantic sturgeon in the Sampit River, although it did historically support a subpopulation and is thought to serve as a nursery ground for local stocks (ASMFC *In Prep*).

Santee and Cooper Rivers – South Carolina

The capture of 151 subadults, including age-1 juveniles, in the Santee River in 1997 suggests that an Atlantic sturgeon population exists in this river (Collins and Smith 1997). This is supported by three adult Atlantic sturgeon carcasses found above the Wilson and Pinopolis dams in Lakes Moultrie (Santee-Cooper reservoirs) during the 1990s (M. Collins, SCDNR, Pers. Comm. 2006). Although shortnose sturgeon spawning above the dam has been documented, there is scant information to support existence of a land-locked subpopulation of Atlantic sturgeon. In 2004, 15 subadult Atlantic sturgeon were captured in shortnose sturgeon surveys during 156.6 hrs of effort conducted in the Santee estuary. The previous winter, four juvenile (YOY and subadults) Atlantic sturgeon were captured (360 – 657 mm FL) from the Santee (N =

1) and Cooper (N = 3) rivers. These data support previous hypotheses that a fall spawning run occurs within this system, similar to that observed in other southern river systems. However, SCDNR biologists are skeptical as to whether these smaller sturgeon (360 and 378 mm FL) from the Santee-Cooper are resident YOY as flood waters from the Pee Dee or Waccamaw River could have transported these YOY to the Santee-Cooper system via Winyah Bay and the Intercoastal Waterway (ICW) (McCord 2004).

Ashley River – South Carolina

The Ashley River, along with the Cooper River, drains into Charleston Bay; only shortnose sturgeon have been sampled in these rivers. While the Ashley River historically supported an Atlantic sturgeon spawning subpopulation, it is unknown whether the subpopulation still exist.

ACE Basin (Ashepoo, Combahee, and Edisto Rivers) – South Carolina

From 1994 - 2001, over 3,000 juveniles have been collected in the ACE Basin including 1,331 YOY sturgeon (Collins and Smith 1997, M. Collins, SCDNR, Pers. Comm. 2005). Sampling for adults began in 1997, with two adult sturgeon captured in the first year of the survey, including one gravid female (234 cm TL) captured in the Edisto River and one running ripe male (193 cm TL) captured in the Combahee River. The running ripe male in the Combahee River was recaptured one week later in the Edisto River, which suggests that the three rivers that make up the ACE basin may support a single subpopulation that spawns in at least two of the rivers. In 1998, an additional 39 spawning adults were captured (M. Collins, SCDNR, Pers. Comm. 2006). These captures show that a current spawning subpopulation exists in the ACE Basin as both YOY and spawning adults are regularly captured.

Broad/Coosawatchie River – South Carolina

There has been little or no scientific sampling for Atlantic sturgeon in the Broad/Coosawatchie River. One fish of unknown size was reported from a small directed fishery during 1981-1982 (Smith and Dingley 1984).

Savannah River – South Carolina and Georgia

The Savannah River supports a reproducing subpopulation of Atlantic sturgeon (Collins and Smith 1997). According to the NOAA-National Ocean Service, 70 Atlantic sturgeon have been captured since 1999 (J. Carter, NOS, supplemental data 2006). Twenty-two of these fish have been YOY (< 410 mm TL). A running ripe male was captured at the base of the dam at Augusta during the late summer of 1997, which supports the hypothesis that spawning occurs there in the fall.

Georgia Rivers

Prior to the collapse of the fishery in the late 1800s, the sturgeon fishery was the third largest fishery in Georgia. Secor (2002) estimated from U.S. Fish Commission landing reports that approximately 11,000 spawning females were likely present prior to 1890. The sturgeon fishery was mainly centered on the Altamaha River, and in more recent years, peak landings were recorded in 1982 (13,000 lbs). Based on juvenile presence and abundance, the Altamaha seems to currently support one of the healthiest Atlantic sturgeon subpopulations in the southeast (D. Petersen, UGA, Pers. Comm. 2006). Atlantic sturgeon are also present in the Ogeechee River; however, the absence of age-1 fish during some years and the unbalanced age structure suggests that the subpopulation is highly stressed (Rogers and Weber 1995). Spawning adults have been collected in recent years from the Satilla River (Waldman et al. 1996b). Recent sampling of the St. Mary's River failed to locate any sturgeon, which suggests that the subpopulation may be extirpated (Rogers et al. 1994). In Georgia, Atlantic sturgeon are believed to spawn in the Savannah, Ogeechee, Altamaha, and Satilla rivers.

Ogeechee River – Georgia

Previous studies have shown the continued persistence of Atlantic sturgeon in this river, as indicated by the capture of age +1 fish. Sampling efforts (including 1991-1994, 1997 and 1998) to collect age-1 sturgeon as part of the Savannah River genetics study suggest that juvenile abundance is rare with high inter-annual variability, indicating spawning or recruitment failure. However, the Army's Environmental and Natural Resources Division (AENRD) at Fort Stewart, GA, collected 17 sturgeon in 2003 considered to be YOY (less than 30 cm TL) and an additional 137 fish in 2004, using a 30 m x 2 m experimental gill net (3.8, 7.7, 12.7, 15.2, 17.8 cm stretched mesh). Most of these fish were juveniles; however, nine of these fish measured less than 41 cm TL and were considered YOY. In 2003, 17 sturgeon captured in this survey were also considered YOY (reported as less than 30 cm TL). The AENRD survey provides the most recent captures of YOY in the Ogeechee.

Altamaha River – Georgia

The Altamaha River supports one of the healthiest Atlantic sturgeon subpopulations in the Southeast, with over 2,000 subadults captured in trammel nets, 800 of which were nominally age-1 as indicated by size. Independent monitoring of the American shad fishery also documents the incidental take of Atlantic sturgeon within the river. Using these data, the subpopulation does not seem to be increasing or decreasing, as catch trends are variable (Figure 14).[18]

A survey targeting Atlantic sturgeon was initiated in 2003 by the University of Georgia. Trammel nets (91 m x 3 m) and gill nets were set in the lower 27 rkm of the Altamaha River, and were fished for 20-40 minutes during slack tides only. Sampling for adults was conducted using large mesh-gill nets set by local commercial fishermen during the months of April through May 2003. During 2005, similar gill nets were drift set during slack tides to supplement catches. As of October 2005, 1,022 Atlantic sturgeon have been captured using these gear types (trammel and large gill nets). Two hundred and sixty seven of these fish were collected during the spring spawning run in 2004 (N = 74 adults) and 2005 (N = 139 Adults). From these captures, 308 (2004) and 378 (2005) adults were estimated to have participated in the spring spawning run, which is 1.5% of Georgia's historical spawning stock (females) that were estimated from U.S. Fish Commission landing records (Schueller and Peterson 2006, Secor 2002).

[18] Voluntary bycatch estimates are known to be severely underreported.

Satilla River – Georgia

Sampling results indicate that the Atlantic sturgeon subpopulation in the Satilla River is highly stressed (Rogers and Weber 1995). Only four spawning adults or YOY, which were used for genetic analysis (Ong et al. 1996), have been collected from this river since 1995.

St. Mary's River – Georgia and Florida

The lack of Atlantic sturgeon captures (in either scientific sampling and/or as bycatch in other fisheries) in the St. Mary's River indicates that the river neither supports a spawning subpopulation nor serves as a nursery ground for Atlantic sturgeon (Rogers and Weber 1995, Kahnle et al. 1998). However, no directed sampling surveys have been conducted in recent years.

St. Johns River – Florida

In the 1970s and 1980s, there were several reports of Atlantic sturgeon being captured by commercial fishermen, although these fish were considered juveniles measuring 69 – 84 cm in length (J. Holder, Florida Fish and Wildlife Commission, Pers. Comm. 2006). There have been reports of Atlantic sturgeon tagged in the Edisto River (South Carolina) having been recaptured in the St. Johns River, indicating this river may serve as a nursery ground; however, there are no data to support the existence of a spawning subpopulation (i.e., YOY or running ripe adults) (Rogers and Weber 1995, Kahnle et al. 1998).

2. Consideration as a Distinct Population Segment under the ESA

2.1. Distinct Population Segment Background

According to Section 3 of the ESA, the term "species" includes "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife that interbreeds when mature." Congress included the term "distinct population segment" in the 1978 amendments to the ESA. One of the purposes of establishing distinct population segments (DPSs) is to conserve genetic diversity. In February of 1996, the Services published a policy to clarify their interpretation of the phrase "distinct population segment" for the purpose of listing, delisting, and reclassifying species (61 FR 4721). The policy identified the following three elements to be considered in determining whether to designate a DPS and to list the DPS as endangered or threatened under the ESA:

1. The discreteness of the population segment in relation to the remainder of the species or subspecies to which it belongs;
2. The significance of the population segment to the species or subspecies to which it belongs;
3. The conservation status of the population segment in relation to the ESA's standards for listing (i.e., is the population segment, when treated as if it were a species, endangered or threatened?).

Determining if a population is discrete requires either one of the following conditions:

1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
2. It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of Section 4(a)(1)(D) of the Act.

If a population is deemed discrete, then the population segment is evaluated on terms of significance which may include, but is not limited to, the following:

1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon.
2. Evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon.
3. Evidence that the DPS represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range.
4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

If a population segment is deemed discrete and significant then it is a distinct population segment. The DPS should be evaluated for endangered and threatened status based on the Act's definitions of those terms and a review of the factors enumerated in Section 4(a)(1).[19]

2.2. DPS Determination

The SRT concluded that Atlantic sturgeon should be divided into five distinct population segments (Figure 15). The five DPSs were named: 1) Gulf of Maine, 2) New York Bight 3) Chesapeake Bay, 4) Carolina, and 5) South Atlantic. The Saint Lawrence and Saint John rivers were not evaluated as a DPS because of a combination of the following factors:

- Both mtDNA and nDNA studies have been performed on the Saint Lawrence and Saint John River populations (King et al. 2001, Waldman et al. 2002, Supplemental data from Ike Wirgin and Tim King 2006). Mitochondrial DNA analysis has shown that little divergence has occurred in northern populations of Atlantic sturgeon as populations ranging from the Kennebec River, ME to the Saint Lawrence River, Canada are predominately homogenous (1 genotype). However, nDNA microsatellite analysis has found these same rivers to be genetically diverse (T. King supplemental data 2006). The

[19] ESA Section 4(a)(1) states that a species is "threatened" or "endangered" if any one or more of following factors causes it to be, or likely to become, in danger of extinction throughout all or a significant portion of its range: (A) the present or threatened destruction, modification, or curtailment of habitat or range; (B) overutilization for commercial, recreational or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence.

SRT concluded that the difference in nDNA exhibited by the Saint Lawrence and Saint John subpopulations were sufficient to exclude them from DPS analysis.

- The SRT concluded that differences in terrestrial and marine ecoregional data, developed by the Nature Conservancy (TNC), illustrated that habitat variability between the Gulf of Maine and Saint Lawrence River was sufficient to exclude the Saint Lawrence subpopulations from analysis.
- The SRT concluded that the Saint Lawrence subpopulation was distinct from other Atlantic sturgeon populations due to the drastic difference in age of maturity between the U.S. populations (age range: 5 – 21; Smith 1982 and Young et al. 1998) and the Saint Lawrence (age range: 22 – 34; Scott and Crossman 1973).
- The SRT also concluded, that since the Saint Lawrence and Saint John River subpopulations still support a commercial fishery with annual quotas ranging from 10 to 60 mt, there are significant differences in control of exploitation and regulatory mechanisms for these subpopulations; therefore, they should be excluded from the DPS analysis.

Discreteness and significance criteria supporting the five U.S. distinct population segments determined by the SRT are described below.

2.2.1. Support for Discreteness

<u>Markedly Separated Based on Physical Factors</u>

Atlantic sturgeon do not have physical barriers that separate subpopulations from mixing, as evidenced from tagging studies that show extensive mixing of Atlantic sturgeon along the Atlantic coast. However, tagging studies, indirect gene flow estimates (< 2 individuals per generation (mtDNA), genetic distance, and assignment results (nDNA) indicate that Atlantic sturgeon home to their natal streams to spawn, and thus, are spatially and temporally separated during the spawning season (K. Hattala, NYSDEC, Pers. Comm. 1998; Wirgin et al. 2000, King et al. 2001, Waldman et al. 2002).

<u>Markedly Separated Based on Genetic Factors</u>

The genetic diversity of Atlantic sturgeon along its range has been well documented. Initial investigations began in the early 1990s and have continued to present (Bowen and Avise 1990, Ong et al. 1996, Waldman et al. 1996a, Waldman et al. 1996b, Waldman and Wirgin 1998, King et al. 2001, Wirgin et al. 2002). Overall, these studies have consistently found subpopulations to be genetically diverse and the majority can be readily differentiated (Table 2). The most recently published articles on Atlantic sturgeon genetic diversity [King et al. (2001), Wirgin et al. (2002), Waldman et al. (2002)] indicate that from the areas that have been sampled, there are between seven and 10 subpopulations that can be statistically differentiated; however, there are some differences between studies and results do not include samples from all rivers inhabited by Atlantic sturgeon. More recently, these authors (Wirgin and King) have increased their sample sizes from multiple rivers and have re-evaluated their data using only YOY and spawning adult samples; thus, reducing classification error introduced from migrating sub-adults in their sample by approximately 14% (King, nDNA supplemental data 2006). The results from these unpublished reports indicate that most, if not all, subpopulations are statistically different ($P < 0.05$) based on allelic/haplotype frequencies, AMOVA, and FST (and mtDNA equivalent) statistical tests using both mtDNA and nDNA genetic markers (Table 3, 4, and 5; Figure 16, 17, and 18). King also increased the number of loci used in his nDNA analysis from seven to 12, to help identify the genetic relatedness between Atlantic sturgeon subpopulations with greater certainty.[20] The use of 12 microsatellite markers resulted in an average accuracy of 88% for determining a sturgeon's natal origin and an average accuracy of 94% for correctly classifying it to a DPS determined by the SRT (Table 6). These results are an improvement to earlier findings using only 7 microsatellite markers and resulted in a 12% (~9 percentage points) increase in natal origin classification rates and 8% (~6percentage points) increase in DPS classification rates (Table 6). However, tissue samples from YOY and adults are limited to 12 subpopulations; thus, the SRT also evaluated subadults in some cases (18). There were no major differences observed between the two genetic tree analyses that included or excluded subadults. As a result of the high classification success rate using nDNA microsatellites and similar findings using mtDNA, the SRT concluded that nDNA analysis would be used for the remainder of the DPS analysis.

<u>Markedly Separated Based on Physiological or Behavioral Factors</u>

Though the genetic markers used to differentiate among the subpopulations examined were not linked to specific traits (mtDNA d-loop region and nDNA microsatellites), it is assumed that these genetic markers indicate differences in physiological, ecological, or behavioral factors as the level of genetic differentiation between subpopulations is high (Vannote et al. 1980, MacLean and Evans 1981, Avise 1992, Nielsen 1998). Some potential physiological or behavioral factors that are unique to Atlantic sturgeon are related to spawning conditions. The majority of southern subpopulations (specifically the Cape Fear, Pee Dee, ACE Basin, Savannah, Congaree, and Altamaha rivers) have been documented to participate in a fall spawning run, as well as a spring run (Collins et al. 2000a, D. Peterson, UGA, Pers. Comm. 2006). It is unknown why a fall run may be beneficial for Atlantic sturgeon, although many salmonids exhibit similar characteristics (NRC 1996). Benefits may include reduced competition or avoidance of unfavorable environmental conditions (e.g., low DO) occurring during the summer months.

Differences in the innate dispersal patterns of sturgeon species in early life stages also suggest that there are markedly separated differences in behavior between subpopulations of sturgeon (B. Kyndard, CAFL, Pers. Comm. 2006). Boyd Kynard (USGS), a researcher at Conte Anadromous Fish Laboratory (Turner Falls, Massachusetts), has noted major differences in innate dispersal patterns of early life stage sturgeon species including *Acipenser fulvescens* (Wolf and Menominee rivers), *A. brevirostrum* (Connecticut and Savannah rivers), *A. transmontanus* (Sacremento and Kootenai rivers), and Atlantic/Gulf sturgeon subpopulations (Hudson and Suwannee rivers). This research suggests that Atlantic sturgeon are likely adapted to unique features of their watershed, considering their genetic discreteness and differing migration behaviors. These findings are similar to research conducted on striped bass (*Morone saxatilis*), an anadromous fish like Atlantic sturgeon, which correlated egg characteristics (egg diameter, egg density, etc.) with watershed type (i.e., low, medium, high energy) (Bergey et al. 2003). Differences in egg characteristics likely are the result of subpopulation adaptations to the

[20] Only seven populations were analyzed using 12 loci: Kennebec, Hudson, James, Albemarle, Savannah, Ogeechee, and Altamaha rivers.

watershed, but the manner in which these adaptations were produced were not determined. The SRT concluded that unique behavioral and physiological traits likely exist for each extant subpopulation of Atlantic sturgeon – except those that share a drainage basin (similar adaptations).

Discreteness Conclusion

The SRT found that it was reasonable to conclude that all of the U.S. Atlantic sturgeon subpopulations could be considered discrete subpopulations. These conclusions are based on the information presented above, which note that Atlantic sturgeon are 1) physically separated from other subpopulations during the spawning season, 2) genetic analysis suggest that each subpopulation is statistically significant different ($P < 0.05$) from one another using both mtDNA and nDNA markers and multiple genetic analysis, and 3) migration behaviors of Atlantic sturgeon both as adults and developing larvae vary among river systems.

2.2.2. Support for Significance

Unique Ecological Setting

The SRT reviewed ecoregion maps for both terrestrial and marine ecosystems to describe habitat, climate, and physiographic differences throughout the range of the Atlantic sturgeon. The Nature Conservancy (TNC) ecoregion maps were chosen by the SRT, as they were the most current maps available depicting ecoregions for both terrestrial and marine systems and can be further examined as Ecological Drainage Units (EDUs) if smaller management units are required (Groves et al. 2002, Olivero 2003, Higgins et al. 2005). Marine ecoregion maps were limited to the United States, as indicated by Marine Ecoregion 3 (Figure 19), which ends near or at the international boundary between the US and Canada. Similarly, the New York Bight DPS consists of two separate terrestrial ecoregions named, the North Atlantic Coast (NAC) (a coastal ecoregion) and the Lower New England (LNE) (an inland ecoregion). These two terrestrial ecoregions were combined because both the Hudson and Delaware rivers transverse both ecoregions. Although the NAC and LNE ecoregion boundaries range from the Delaware River to just west of the Kennebec Estuarine Complex, the SRT concluded that the Gulf of Maine (Cape Cod Bay to the Penobscot River) should be considered a unique ecoregion based on TNC marine ecoregion 3 (Figure 19) and a review of sea surface water temperatures that demonstrate that the GOM is a much colder environment compared to southern regions (Figure 20). The resulting ecoregion map created by SRT correlates well with mtDNA and nDNA genetic trees of Atlantic sturgeon (Figure 15, 16, and 18), and suggests that regional subpopulations are adapted to ecological features that are unique to an ecoregion.

Differs Markedly in its Genetic Characteristics

As described earlier, Atlantic sturgeon population genetics have been extensively studied since the 1990s. These studies have continuously shown that Atlantic sturgeon subpopulations are genetically diverse and significantly different using multiple genetic techniques. However, until recently this genetic information has been unreliable as tissue samples were taken in many cases from subadults (possible strays from other systems). The SRTs most reliable genetic data is restricted to 12 subpopulations.

To further investigate significant relationships among Atlantic sturgeon subpopulations, the SRT used genetic distances and bootstrap values, and assignment test values to help determine subpopulation groupings. As described earlier, assignment or classification tests resulted in 94% accuracy for identifying sturgeon to their DPS with a range of 88 – 96% when using data collected only from YOY and adults (Table 6). Genetic trees produced from only YOY and adult samples were similar among mtDNA and nDNA, and bootstrap values for these trees were relatively high (at least for nDNA) (Figure 16 and 17). Based on the similarities seen between mtDNA and nDNA genetic trees, high bootstrap values and classification rates, the SRT identified five population groupings that were considered to be markedly different: 1) Gulf of Maine 2) New York Bight, 3) Chesapeake Bay, 4) Carolina, and 5) South Atlantic (Figure 15).

Significant Gap in the Range of the Taxon

Determining whether a gap in the range of taxon would be significant if a DPS went extinct is somewhat difficult to ascertain with an anadromous fish such as the Atlantic sturgeon. Atlantic sturgeon are known to migrate great distances between their natal rivers and overwintering areas. Therefore, estuarine and marine populations are comprised of mixed stocks. Despite this extensive mixing of migratory sub-adults and adults, adults are known to return to their natal river to spawn. Therefore, the loss of a DPS would mean the loss of riverine spawning subpopulations, while marine and estuarine habitat may still be occupied by migratory sturgeon from other DPSs. Because gene flow is low among subpopulations, Atlantic sturgeon from other DPSs are not expected to re-colonize systems except perhaps over a long time frame (e.g., greater than 100 years) (Secor and Waldman 1999). Thus, the loss of one or more DPSs is expected to result in a significant gap in the range of the species given that the DPSs as designated are relatively large. The SRT contends that the loss of one or more of these DPSs could negatively impact the species as a whole.

Significance Conclusion

The SRT concluded that it is reasonable to conclude that five population groupings of Atlantic sturgeon within the United States should be considered significant under the DPS policy guidelines. The five groupings are: 1) Gulf of Maine, 2) New York Bight, 3) Chesapeake Bay, 4) Carolina, and 5) South Atlantic. These conclusions are based on the information presented above, which note that Atlantic sturgeon are 1) found in five unique ecological settings, 2) genetic analyses suggest that subpopulations can be easily grouped into five populations with high certainty (94%) and these groupings correlate well with the five unique ecological settings, and 3) due to low gene flow among populations, the loss of one or more these five populations could negatively impact the species as a whole.

Though the SRT is recommending that five DPSs be designated for Atlantic sturgeon, the team also recommends that individual river subpopulations should be considered distinct management/recovery units within the DPS for any future recovery planning, as subpopulations within a DPS are genetically diverse, and it would be prudent to protect these smaller units as well.

3. Analysis of the ESA Listing Factors

The ESA defines an "endangered" species as any species in danger of extinction throughout all or a significant portion of its range and a "threatened" species as any species likely to become endangered throughout all or a significant portion of its range within the foreseeable future. Section 4(b)(1)(a) of the ESA requires that determinations of whether a species is threatened or endangered be based solely on the best scientific and commercial data available and after taking into account those efforts, if any, being made to protect such species. A species may be determined to be endangered or threatened due to one or more of the following five factors described in Section 4(a)(1) of the ESA:

1) The present or threatened destruction, modification, or curtailment of habitat or range;
2) Overutilization for commercial, recreational, scientific, or educational purposes;
3) Disease or predation;
4) The inadequacy of existing regulatory mechanisms; and
5) Other natural or manmade factors affecting its continued existence.

In the following section, each of these five factors is examined for its historic, current, and/or potential impact on Atlantic sturgeon status. It should be noted that current and potential threats, along with current distribution and abundance, determine present vulnerability to extinction. Information about historic threats is included to assist interpretation of historic population trends. The relationship between historic threats and population trends also provides insights that may help to project future population changes in response to current and potential threats.

3.1. The Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Atlantic sturgeon, like all anadromous fish, are vulnerable to a host of habitat impacts because they use rivers, estuaries, bays, and the ocean at various points of their life. Habitat alterations potentially affecting sturgeon include dam construction and operation, dredging and disposal, and water quality modifications such as changes in levels of DO, water temperature, and contaminants.

Loss of habitat and poor water quality have contributed to the decline of Atlantic sturgeon since European settlement; however, the importance of this threat has varied over time and from river to river. Some important aspects of habitat quality, especially water quality, have improved during the last thirty years. Examination of the impact of present or threatened destruction, modification, or curtailment of habitat or range on Atlantic sturgeon is presented. If information was not available specifically for Atlantic sturgeon, information relevant to other sturgeon species is presented. Similarities in sturgeon life history and physiology make these data and analyses applicable, with occasional qualification, to Atlantic sturgeon.

The following sections review the impact of dams, dredging, and water quality on Atlantic sturgeon and their habitat generally. River specific information is presented, as available and applicable, following the more general discussion.

3.1.1. Dams and Tidal Turbines

Dams for hydropower generation and flood control can have profound effects on anadromous species by impeding access to spawning and foraging habitat, modifying free-flowing rivers to reservoirs, physically damaging fish on up- and down-stream migrations, and altering downstream flows and water temperatures. Patrick (*unpublished data-a*) estimated that nationwide, over 50,000 miles of river/lake habitat were blocked by terminal dams (those lowest in the watershed), which includes the area between the terminal dam and the next upstream impediment, along the Atlantic, Pacific, and Gulf coasts. Similarly, about 62% of historical habitat once available to American shad is now impeded by dams (W. Patrick, NMFS, unpublished data-b). A nonrandom subsample (largest impediments) of these terminal dams indicated that the majority (65%) do not offer fish passage (Patrick *unpublished data*). Atlantic sturgeon do not regularly use fish passage devices; only four Atlantic sturgeon have been documented to have passed via a fish lift, as these passage facilities are not designed to accommodate adult-sized sturgeon. Three of the Atlantic sturgeon were found in Lake Molutrie, SC that evidently passed the St. Stephens fish lift. The only other observed Atlantic sturgeon using a fish passage device was recently observed in September of 2006 using the Holyoke Dam fish lift, which is located on the Connecticut River, Massachusetts. However, shortnose sturgeon have been observed frequently (4.7 sturgeon per year between 1975 and 2002) to have passed the Holyoke Dam via its fish lift (Kynard 1996, Gephard and McMeney 2004).

Physical damage and mortality can also occur from anadromous fish migrating through the turbines of traditional hydropower dams on their downstream migration. Though Atlantic sturgeon have not been observed to use fish passage devices, tidal power plants are a potential threat to Atlantic sturgeon migrating up- and down-stream (Dadswell and Rulifson 1994, Dadswell 2006). Tidal power plants use marine turbines, similar to windmill technology, to generate power using the force of both incoming and out-going tides. These marine turbines can strike migrating fish such as adult Atlantic sturgeon, thus causing physical damage or mortality; injuries or mortality can also occur via shear, pressure flux, and cavitation effects on fish during turbine passage (reviewed in Dadswell and Rulifson 1984). Currently, there are two tidal power projects in operation along the range of Atlantic sturgeon, with many more projects being proposed. The Annapolis River tidal power plant (Nova Scotia), built in 1982, was constructed as a demonstration site for marine STRAFLO turbines and consisted of a rock-filled dam housing the turbine and sluice gates (M. Dadswell, Arcadia University, Pers. Comm. 2006). The negative impacts of the Annapolis tidal turbine on Atlantic sturgeon (150 – 200 cm TL) appear to be great, as the probability of lethal strike from the turbine ranges between 40 –80% (M. Dadswell, Arcadia University, Pers. Comm. 2006) and at least three severed, gravid females have been observed below the power plant (Dadswell and Rulifson 1994) (Figure 21). Within the United States, one marine turbine project has been proposed on the East River, New York (Angelo 2005, CBS News 2006). Beginning in November of 2006, an 18-month pilot project using two slow speed tidal turbines were placed in the East River to determine their impacts on marine life. Following the 18-month project four more tidal turbines are to be installed to further test the prototype turbines (CBS News 2006). The energy company, Verdant Power, has plans to expand the project to up to 300 turbines to be located within a one-mile section of the river near Roosevelt Island (Angelo 2005).

In addition to dams impeding anadromous fish migration and associated mortalities, Hill (1996) identified the following potential impacts from hydropower plants: altered DO concentrations and temperature; artificial destratification; water withdrawal; changed sediment load and channel morphology; accelerated eutrophication and change in nutrient cycling; and contamination of water and sediment. The suitability of riverine habitat for Atlantic sturgeon spawning and rearing also likely depends on annual fluctuations in flow, which can be greatly altered or reduced by the presence of dams as has been shown for white sturgeon (*Acipenser transmontanus*) (Beamesderfer and Farr 1997). Activities associated with dam maintenance, such as dredging and minor excavations along the shore, can release silt and other fine river sediments that can be deposited in nearby spawning habitat.

It is difficult to assess the impact of dam construction on Atlantic sturgeon, as the locations of historic spawning areas are not known for many rivers (9 of 36 known). The geomorphology of rivers north of Georgia is often characterized by waterfalls and rapids, which are believed to be impassable to Atlantic sturgeon, and these features tend to be located in the vicinity of the fall line. Therefore, Atlantic sturgeon spawning sites above these areas are rare (Figure 22). A few exceptions are the Roanoke and Hudson rivers that have current and/or historical information suggesting that spawning occurred above the fall line (Kahnle 1998, Reviewed in Armstrong and Hightower 2002). In most cases, the first dam on a river was built at the site of natural falls and rapids. As a result, the SRT concluded that Atlantic sturgeon spawning habitat, for the most part, is unimpeded by dams along the Atlantic Coast. Only rivers with a dam located below the fall line or a subpopulation that spawns above the fall line were impeded. Using GIS tools and dam location data collected by Oakley (2005) as a reference point for river kilometer measurements, historical rivers in which Atlantic sturgeon spawned were mapped to determine the number of miles of available riverine habitat. The SRT assumed that the fall line was the upper boundary of habitat unless otherwise noted in the literature or by expert opinion. The distance from the fall line to the mouth of the river (mainstem only) was calculated in river kilometers, and in many cases, may not match Army Corp of Engineers (ACOE) estimates due to a difference in reference points. Proportionally, however, the estimates should be accurate.

Overall, 91% of Atlantic sturgeon habitat seems to be accessible. Four of the 36 rivers examined have lost more than 25% of their riverine habitat and include: Merrimack, NH/MA (58%); Cape Fear, NC (64%); Santee/Cooper, SC (62%); and St. Johns River, FL (63% loss) (Table 7). Though 91% of the Atlantic sturgeon habitat seems to be available, the quality of the remaining portions of habitat as spawning and nursery grounds is unknown. Therefore, estimates of 100% availability does not necessarily equate to 100% functionality.

Several dams within the Atlantic sturgeon historic range have been removed or naturally breached (Treat Falls Dam on the Penobscot River, ME; Edwards Dam on the Kennebec River, ME; Enfield Dam on the Connecticut River, CT; Quaker Neck Dam on the Neuse River, NC). While there has not been a large loss of Atlantic sturgeon habitat throughout the entire species' range due to the presence of dams, individual riverine systems (e.g., Cape Fear, Santee-Cooper, Merrimack) have been severely impacted by dams, as access to large portions of historical sturgeon spawning habitat have been eliminated or restricted. This may be the primary cause of the extirpation of several subpopulations.[21] Thus, it warrants consideration when assessing the extinction risk of subpopulations that are currently impacted by loss of accessible spawning habitat.

3.1.2. Dredging and Blasting

Riverine, nearshore, and offshore areas are often dredged to support commercial shipping and recreational boating, construction of infrastructure, and marine mining. Dredging activities can pose significant impacts to aquatic ecosystems by removing, disturbing, disposing, and resuspending bottom sediments, modifying substrate and impacting the community structure of benthic macrofauna. Environmental impacts of dredging include the following: direct removal/burial of organisms; turbidity/siltation effects; contaminant resuspension; noise/disturbance; alterations to hydrodynamic regime and physical habitat and actual loss of riparian habitat (Chytalo 1996, Winger et al. 2000). According to Smith and Clugston (1997), dredging and filling impact important habitat features of Atlantic sturgeon as they disturb benthic fauna, eliminate deep holes, and alter rock substrates. Nellis et al. (*in press*) documented similar impacts as dredge spoil was documented to drift 12 km downstream over a 10 year period in the Saint Lawrence River, and those spoils have significantly lower amounts of macrobenthic biomass compared to control sites. Using an acoustic trawl survey, researchers found that Atlantic and lake sturgeon were substrate dependent and avoided spoil dumping grounds (McQuinn and Nellis, *In* Press). Similarly, Hatin et al. (*In press*) tested whether dredging operations affected Atlantic sturgeon behavior by comparing CPUE before and after dredging events in 1999 and 2000. The authors documented a three to seven-fold reduction in Atlantic sturgeon presence after dredging operations began, indicating that sturgeon avoid these areas during operations.

Indirect impacts to sturgeon from either mechanical or hydraulic dredging include destruction of benthic feeding areas, disruption of spawning migrations, and deposition of resuspended fine sediments in spawning habitat. In addition to these indirect impacts, hydraulic dredging can directly harm sturgeon by lethally entraining fish up through the dredge drag-arms and impeller pumps. Dickerson (2005) summarized observed takings of sturgeon from dredging activities conducted by the ACOE; overall 24 sturgeon (2 – Gulf, 11 – Shortnose, and 11 – Atlantic sturgeon) were observed during the years of 1990-2005 (Table 8). Of these 24 sturgeon captured, 15 (62.5%) were reported as dead. Overall take during this time can be partially calculated as 100% of hopper dredges have been observed since 1995 during seasonal restrictions for shortnose sturgeon and sea turtles, with an unknown proportion of hydraulic pipeline and bucket-and-barge dredging operations being observed (Dena Dickerson, USACOE-ERDC, Pers. Comm. 2006). The SRT calculated a minimum take of 0.6 Atlantic sturgeon per year, based simply on hopper dredge takes since 1995 and that dredging efforts were relatively similar among years (USACOE 2006). It should be noted that all Atlantic sturgeon takes associated with dredging projects may not have been observed because seasonal restrictions for

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[21] Within this report a subpopulation is considered a population unit of the species range or its DPS and is sometimes used interchangeably with the term population when referring to specific population units (e.g., Hudson River Population = Hudson River subpopulation)

listed species do not overlap fully with critical periods for Atlantic sturgeon, and also, observers are not required on some rivers that support Atlantic sturgeon as they do not support shortnose sturgeon or sea turtle populations. Dickerson (2005) noted that the largest take of sturgeon species was observed in the Delaware (N =6) and Kennebec (N = 6) rivers. Atlantic sturgeon have also been taken in both hydraulic pipeline and bucket-and-barge operations in the Cape Fear River, NC (M. Moser, University of North Carolina at Wilmington, Pers. Comm. 1998). To reduce the impacts of dredging on anadromous fish species, most of the Atlantic states impose work restrictions during sensitive time periods (spawning, migration, feeding) when anadromous fish are present. NMFS also imposes seasonal restrictions to protect shortnose sturgeon populations (where present) through Section 7 consultations that may have the added benefit of protecting Atlantic sturgeon.

3.1.3. Water Quality

The quality of water in river/estuary systems is affected by those activities conducted directly in the riparian zone and more remotely in the upland portion of the watershed. Industrial activities can result in discharges of pollutants, changes in water temperature and levels of DO, and the addition of nutrients. In addition, forestry and agricultural practices can result in erosion, run-off of fertilizers, herbicides, insecticides or other chemicals, nutrient enrichment and alteration of water flow. The coastal environment is also impacted by coastal development and urbanization that result in storm water discharges, non-point source pollution, and erosion. Secor (1995) noted a correlation between low abundances of sturgeon during this century and decreasing water quality caused by increased nutrient loading and increased spatial and temporal frequency of hypoxic conditions. Using a multivariable bioenergetics and survival model, Niklitschek and Secor (2005) demonstrated that within the Chesapeake Bay, a combination of low DO, water temperature, and salinity restricts available Atlantic sturgeon habitat to 0-35% of the Bay's modeled surface area during the summer. Pulp mill, silviculture, agriculture, and sewer discharge can elevate temperatures and/or increase biological oxygen demand resulting in reduced DO levels that can be stressful to aquatic life. Niklitschek and Secor (2005) also simulated the affects of achieving EPA's DO-criteria for the Chesapeake Bay and water temperature affects on available habitat.[22] It is interesting to note that the EPA adjusted their open water minimum DO-criteria for the Chesapeake Bay (increased from ~2 ppm to 3.5 ppm) to provide protection specifically for sturgeon species, which require higher levels of DO compared to other fish species. Niklitschek and Secor (2005) found that achieving EPA's new DO-criteria, would increase Atlantic sturgeon available habitat by 13% per year, while an increase of water temperature by just 1° C would reduce available habitat by 65%. Similar results may occur in southern rivers where high water temperatures and low DO are a common occurrence during the summer months.

Atlantic sturgeon may be particularly susceptible to impacts from environmental contamination due to their benthic foraging behavior and long-life span. Sturgeon using estuarine habitats near urbanized areas may be exposed to numerous suites of contaminants within the substrate. Contaminants, including toxic metals, polychlorinated aromatic hydrocarbons (PAHs), organophosphate and organochlorine pesticides, polychlorinated biphenyls (PCBs), and other

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[22] Refer to http://www.chesapeakebay.net/wqcoxygen.htm for details on the EPA's DO criteria for the Chesapeake Bay Program.

chlorinated hydrocarbon compounds can have substantial deleterious effects on aquatic life. Effects from these elements and compounds on fish include production of acute lesions, growth retardation and reproductive impairment (Cooper 1989, Sinderman 1994).

Heavy metals and organochlorine compounds accumulate in sturgeon tissue, but their long-term effects are not known (Ruelle and Henry 1992, Ruelle and Keenlyne 1993). Elevated levels of contaminants, including chlorinated hydrocarbons, in several other fish species are associated with reproductive impairment (Cameron et al. 1992, Longwell et al. 1992, Hammerschmidt et al. 2002, Drevnick and Sandheinrich 2003), reduced egg viability (Von Westerhagen et al. 1981, Giesy et al. 1986, Mac and Edsall 1991, Matta et al. 1997, Billsson et al. 1998), reduced survival of larval fish (Berlin et al. 1981, Giesy et al. 1986), delayed maturity (Jorgensen et al. 2003) and posterior malformations (Billsson et al. 1998). Pesticide exposure in fish may affect anti-predator and homing behavior, reproductive function, physiological development, and swimming speed and distance (Beauvais et al. 2000, Scholz et al. 2000, Moore and Waring 2001, Waring and Moore 2004). Moser and Ross (1995) suggested that certain deformities and ulcerations found in Atlantic sturgeon in North Carolina's Brunswick River might be due to poor water quality in addition to possible boat propeller inflicted injuries. It should be noted that the effect of multiple contaminants or mixtures of compounds at sub-lethal levels on fish has not been adequately studied. Atlantic sturgeon use marine, estuarine, and freshwater habitats and are in direct contact through water, diet, or dermal exposure with multiple contaminants throughout their range.

Sensitivity to environmental contaminants varies among fish species and life stages. Early life stages of fish seem to be more susceptible to environmental and pollutant stress than older life stages (Rosenthal and Alderdice 1976). In aquatic toxicity tests (Dwyer et al. 2000), Atlantic sturgeon fry were more sensitive to five contaminants (carbaryl, copper sulfate, 4-nonylphenol, pentachlorophenol, and permethrin) than fathead minnow (*Pimephales promelas*), sheepshead minnow (*Cyprinodon variegatus*), and rainbow trout (*Oncorhynchus mykiss)* - three common toxicity test species - and 12 other species of threatened and endangered fishes. The authors note, however, that Atlantic sturgeon were difficult to test and conclusions regarding chemical sensitivity should be interpreted with caution. Shortnose sturgeon toxicity tests suggested that this sturgeon species had similar sensitivities to that of the fathead minnow (Dwyer et al. 2005). Conversely, ongoing research with shovelnose sturgeon (*Scaphirhynchus platorhynchus*), an inland sturgeon species, suggests that some sturgeon species may be less sensitive to dioxin, the most toxic organochlorine compound, than salmonid species (Tillitt et al. 2005).

The relationship between Atlantic sturgeon contamination and human health has been partially investigated because polychlorinated biphenyls (PCBs) have been detected in Atlantic sturgeon flesh from the Saint Lawrence and Hudson rivers (Sloan 1987). PCBs are known to have long-term deleterious environmental and health effects and are characterized as carcinogenic (Budavari et al. 1989). The U.S. Environmental Protection Agency (EPA) banned the production of PCBs and regulated their disposal because the compound was linked to cancer, liver damage, skin lesions, and reproductive disorders. To protect human health, the U.S. Food and Drug Administration set the upper limit for PCBs in the edible portions of fish and shellfish at 2 µg/g (parts per million) in 1984. Reproductive and developmental effects thresholds for PCBs in fish, however, may be lower or higher than the human health criterion (Niimi 1996, Monosson 2000, Meador et al. 2002). In fish, exposure to PCBs reportedly causes a higher incidence of fin erosion, epidermal lesions, blood anemia, and an altered immune response (Kennish et al. 1992). PCBs probably have the greatest effect on reproduction where PCB residues have been related to mortality and reproductive failure in Baltic flounder – *Platichthys flesus* (Von Westernhagen et al. 1981), charr – *Salvelinus sp.* (Monod 1985), fathead minnows (Post 1987), lake trout – *S. namaycush* (Mac and Swartz 1992), rainbow and westslope cutthroat (*Oncorhynchus clarki lewisi)* trout (Matta et al. 1997), and zebrafish – *Danio rerio* (Billsson et al. 1998).

Another suite of contaminants occurring in fish are metals (mercury, cadmium, selenium, lead, etc.), also referred to as trace metals, trace elements, or inorganic contaminants. Post (1987) states that toxic metals may cause death or sub-lethal effects to fish in a variety of ways and that chronic toxicity of some metals may lead to the loss of reproductive capabilities, body malformation, inability to avoid predation, and susceptibility to infectious organisms. Dietary methylmercury experiments using fathead minnows inhibited gonadal development of females and reduced reproductive success by a factor of three (Hammerschmidt et al. 2002, Drevnick and Sandheinrich 2003). Chronic dietary mercury exposure in Atlantic salmon (*Salmo salar*) parr caused oxidative stress, brain lesions, and altered behavior (Berntssen et al. 2003). Arsenic, lead, cadmium, and selenium were the major inorganic contaminants found in striped bass (*Morone saxatilis*) sampled in the Hudson, Nanticoke, and Potomac rivers (Mehrle et al. 1982). In the same study, the authors found that vertebrae from Hudson River striped bass had lower strength, stiffness, toughness, and ruptured more easily than vertebrae of hatchery striped bass and suggested that contaminants such as PCB, cadmium, and lead could affect survival of larvae and abundance of striped bass.

Dadswell (1975) and Rehwoldt et al. (1978) were the only references found which specifically associated Atlantic sturgeon with any of these contaminants. Dadswell (1975) examined 30 juvenile Atlantic sturgeon collected in the Saint John River estuary, New Brunswick. The mean concentration of mercury was 0.29 ppm of wet weight with a range of 0.06 – 1.38 ppm. Rewoldt et al. (1978) examined a limited number of freshly captured Hudson River fish in 1976 and 1977 along with a number of reference samples from the Hudson River that had been stored in preservation between 1924 and 1953. These tissue samples were analyzed for cadmium, mercury, and lead and compared with other fish species taken from the Hudson River during those time periods. Average values of contaminant levels did not show any chronological relationship, such that Atlantic sturgeon samples from 1924 and 1976 showed little difference for all three metal residues. The 1976-1977 average concentrations (µg/g; ppm, wet weight) in Atlantic sturgeon tissue were as follows: cadmium 0.02, mercury 0.09, and lead 0.16.

As noted above, few references regarding contaminants in Atlantic sturgeon tissue or species-specific potential biological effects were found. However, information is available regarding contaminants in other sturgeon species:

- Gulf sturgeon (*Acipenser oxyrinchus desotoi*) collected from a number of rivers between 1985 and 1991 were analyzed for pesticides and heavy metals (Bateman and Brim 1994). Concentrations of arsenic, mercury, DDT metabolities, toxaphene, polycyclic aromatic hydrocarbons, and aliphatic hydrocarbons were sufficiently high to warrant concern.

- Twenty juvenile Gulf sturgeon from the Suwannee River in Florida exhibited an increase in metals burdens with an increase in fish length (Alam et al. 2000).
- In a California study involving laboratory exposures, white sturgeon larvae had a significantly increased incidence of defects with selenium levels greater than 15 µg/g (R. Linville, UC-Davis. Pers. Comm. 2006).
- Kootenai River white sturgeon exhibited organochlorine levels that could potentially affect reproduction or other physiological functions (Kruse and Scarnecchia (2002a).
- Growth and reproductive impacts were observed in Columbia River white sturgeon, where plasma triglycerides and conditions factors were negatively correlated with total DDT, total pesticides, and PCBs (Feist et al. 2005). In males, plasma androgens and gonad size were also negatively correlated with total DDT, total pesticides, and PCBs.
- Kruse and Scarnecchia (2002b) noted that the mortality of white sturgeon embryos was significantly different between individuals reared in different media (Fuller's earth 12.6% versus river bottom sediment 20.6%), which was related to copper and Aroclor 125 (PCB) concentrations.
- Dioxin and furans were detected in ovarian tissue from shortnose sturgeon caught in the Sampit River/Winyah Bay system (SC). Results showed that four out of seven fish tissues analyzed contained tetrachlorodibenzo-*p*-dioxin (TCDD) concentrations greater than 50 pg/g (parts-per-trillion), a level which can adversely affect the development of sturgeon fry (J. LLIff, NOAA, Damage Assessment Center, Silver Spring, MD, unpublished data).
- Shortnose sturgeon collected from the Delaware and Kennebec rivers had total toxicity equivalent concentrations of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), PCBs, dichlorodiphenyldichloroethylene (DDE), aluminum, cadmium, and copper above adverse effect concentration levels reported in the literature (Environmental Research and Consulting 2002, 2003).
- In a study of white sturgeon from the Columbia River (Webb et al. 2006), mercury concentrations were measured in several types of tissues from legal-size fish (110 – 137 cm FL) and a mature adult female (170 kg, 262 cm FL). Tissue mercury content was correlated with suppressed circulating sex steroids, decreased condition factor and relative weight, and a lower gonadosomatic index in immature male fish. A significant positive linear relationship was determined between age and liver mercury concentrations. Mercury concentration in muscle tissue from the mature adult female (1.094 ppm) exceeded state and Federal action limits.

The EPA published its second edition of the National Coastal Condition Report (NCCR II) in 2004, which is a "report card" summarizing the status of coastal environments along the coast of the United States (EPA 2004). The report analyzes water quality, sediment, coastal habitat, benthos, and fish contaminant indices to determine status. An overall grade of F was given to the Northeast region (Virginia - Maine) where water quality, sediment, benthos, and fish tissues received a grade of D or F (Table 9). The Chesapeake Bay was also analyzed as a separate region within the Northeast and received a score of F in all status indices, except for coastal habitat, which was not evaluated (no coastal habitat). However, the Southeast region (North Carolina - Florida) received an overall grade of B-, which is the best rating in the nation with no indices below a grade of C (Table 9). Areas of concern that had poor index scores were: 1) Hudson River – water quality, sediment, and tissue contaminants, 2) Delaware River – water quality and tissue contaminants, 3) Upper Chesapeake Bay – water quality and sediment, 4) Narragansett Bay – tissue contaminants, 5) Potomac River – sediment, 6) Pamlico Sound – water quality, 7) ACE Basin – water quality, and 8) St. Johns River – sediment. There was also a mixture of poor benthic scores scattered along the Northeast and Southeast region.

3.1.4 River Specific Habitat Information

Gulf of Maine DPS

Penobscot River – Maine

There are two obstructions to Atlantic sturgeon historical spawning habitat in the Penobscot River, Maine. In 1833, the Veazie Dam was constructed on the Penobscot River at rkm 56, blocking 29 km of habitat that was historically accessible to Atlantic sturgeon. Five kilometers downstream of the Veazie, the Treats Falls Bangor Dam also impeded migration upstream during the summer months. The Bangor Dam, however, was breached in 1977 and now allows diadromous fish migration. Thus, there are currently 50 km of tidal and freshwater habitat available for spawning and nursery habitat. Historically, the first natural obstacle to Atlantic sturgeon migration on the Penobscot River may have been the falls at Milford, rkm 71 (L. Flagg, MEDMR, Pers. Comm. 1998). If Atlantic sturgeon were able to ascend the falls at Milford, they could have migrated without obstruction to Mattaseunk (rkm 171). In June 2004, the Penobscot Accord was signed which gave the Penobscot River Restoration Trust, a non-profit corporation established in May 2004, the ability to buy Veazie, Great Works and Howland dams on the Penobscot River over a five year period. If bought, the Trust has the right to decommission and/or remove the Veazie Dam, decommission the Great Works Dam, and install fish passage or remove the Howland Dam. However, these options cannot be initiated until 2007-2010 and sufficient money is garnered to fund all aspects of the project. If the Accord is successfully implemented, large portions of historical habitat once available to Atlantic sturgeon will be opened.

Dissolved oxygen levels reached 0 ppm in the Penobscot River estuary during the summer months in the late 1960s (Hatch 1971). These low DO levels occurred at the freshwater/saltwater interface (salinities 0-10 ppt), which is an important zone for subadult Atlantic sturgeon. Dissolved oxygen levels improved significantly in the late 1970s and 1980s to levels sufficient to support aquatic life coincident with improved point source treatment of municipal and industrial waste, although the substrate is still severely degraded (Squiers 1988), which has decreased the diversity of benthic fauna (USEPA 1994).

The predominant substrate types in the Penobscot River from Winterport to Bucksport, Maine, consist of wood chips, silt/sawdust, and *Mytilus* mussel beds (Metcalf & Eddy 1994). Data on the substrate and benthic communities above Winterport (in the tidal freshwater section) are limited, but it is likely that the mid-estuary and freshwater tidal zones are impacted from organic debris deposits (Metcalf & Eddy 1994). Also, a coal tar deposit has been discovered in the tidal section of the Penobscot River in Bangor, but the impacts on fish and benthic biota are unknown. Notably, the presence of coal tar deposits in the Connecticut River has been linked to tumors and reduced reproductive success (See Connecticut River Section for more information on coal tar, page 43). The former Holtra-Chem facility in Orrington, ME on the Penobscot River was known to use large quantities of mercury in the production of chemicals for subsequent sale to paper mills. A portion of the site remedy includes the removal of mercury hot-spots in the river (MEDEP 2006). Dioxin, likely generated from wastewater discharges from pulp and paper mills and municipal wastewater treatment plants, has been found in fish samples collected in the Penobscot River. Dioxin levels in fish from the Penobscot River have dropped from a high of 7.6 pg/g (parts-per trillion) in 1984 to < 0.1 pg/g in 2004 (MEDEP 2005).

While dredging is somewhat limited in the Penobscot River, eight projects were proposed in 2000 (Fishermen's Voice 2000) and appropriations to dredge the Penobscot Harbor were approved in 2003 (House Bill 107-681, 2003).

In summary, dams on the Penobscot River reduced accessibility of Atlantic sturgeon spawning habitat. Water quality was severely degraded in the Penobscot River for several years but seems to be improving. Further modification for access to historical habitats will likely improve status of Atlantic sturgeon as both spawning and nursery habitats will be reopened.

Estuarial Complex of the Kennebec, Androscoggin, and Sheepscot Rivers – Maine

Historically, the upstream migration of Atlantic sturgeon in the Kennebec River was limited to Waterville, ME, which is the location of Ticonic Falls (rkm 98) (NMFS and USFWS 1998). The Ticonic Falls are located 65 rkm downstream of the fall line (based on reference points provided by Oakley 2005). The construction of Edwards Dam in 1837, downstream of the Ticonic Falls, denied Atlantic sturgeon access to historical habitat in the Kennebec River until 1999 when it was removed. Since its removal, 100% of historic habitat has been opened. Since the removal of the Edwards Dam, shortnose sturgeon have been documented at the Lockwood Dam (rkm 98), indicating that this habitat is being utilized again by a sturgeon species.

In the Androscoggin River, the Brunswick Hydroelectric Dam is located at the head-of-tide at the site of natural falls. Given its limited storage capacity, the Brunswick Dam does not have the capacity to influence river flows and therefore, no minimum flow requirement is necessary. The location of historical spawning grounds on the Androscoggin is unknown, but it is unlikely that Atlantic sturgeon could navigate the natural falls located at Brunswick Dam (NMFS and USFWS 1998). Similarly, within the Sheepscot River Atlantic sturgeon upstream migration is thought to be historically limited to the lower river (rkm 32) just below the head-of-tide dam (rkm 35), which is the first dam on the river; therefore, 100% of the historical habitat (based on river kilometers) is available to Atlantic sturgeon in the Sheepscot.

Historically, the Kennebec River has been dredged along Swan Island, at Gardiner, and from Hallowell to Augusta. The upriver dredging projects are all located in tidal freshwater habitat. No channel maintenance dredging above Bath, where spawning habitat used to be located prior to the removal of Edwards Dam, has been conducted since 1963. In the lower Kennebec River, the ACOE routinely conducts dredging operations to facilitate movement of Navy ships to Bath Iron Works (BIW) in Bath, ME. Maintenance dredging is also conducted by BIW around its docking facilities. Dredging in this region of the river is known to have resulted in sturgeon mortality. In April 2003, a shortnose sturgeon was killed in a closed bucket dredge on the last hour of the last day of dredging (K. Damon-Randall, NOAA, Pers. Comm. 2006). The dredging of the Doubling Point reach of the Kennebec River resulted in the take of five shortnose sturgeon on October 6, 2003, four of which were observed by the endangered species observer. All four sturgeon were removed alive from the hopper and placed in a tub of water. Two of the four fish showed signs of external trauma but showed signs of mobility and respiration. These two fish were released approximately 2.5 nautical miles downriver of the dredge site. One of the fish went straight down and swam away, while the other was last seen trying to swim but was not descending. The other two fish showed signs of more significant trauma and were less active and subsequently died onboard the barge. On October 8, 2003, one shortnose sturgeon was observed in the hopper. This fish was retrieved and placed in an aerated holding tank. The fish was very lively but showed signs of injury. The fish was released at the same release location as the other fish and was last seen swimming and descending to depth. Another two sturgeon (one Atlantic and one shortnose) were found dead on a BIW dock, possibly the result of operations within BIW.

A trawl survey in the Kennebec River near BIW captured subadult Atlantic sturgeon from April 17, 1997, (the start of the sampling project) through November 17, 1997. Neither subadult shortnose nor Atlantic sturgeon were captured from December 1997 through February 1998. However, the researchers did track tagged fish around BIW until ice impeded the researchers' navigation; providing evidence that sturgeon are likely present year-round. Atlantic and shortnose sturgeon were manually tracked in the Bath region of the river in 1998 and 1999. Two Atlantic sturgeon were tracked in October and November 1998, and one was relocated in December 1998 in Merrymeeting Bay (presumably overwintering with shortnose sturgeon). These two fish (along with an additional Atlantic sturgeon) were manually tracked again from April through November 1999. They were observed to move in and out of BIW, up to Swan Island and Chops Point and down to Hospital Point.

State and Federal resource agencies have imposed seasonal restrictions for dredging activities in the Kennebec River. Dredging activities have been restricted to the time period between November 1^{st} and April 1^{st}, which is the time of year when the least number of diadromous fish species would be present, with special emphasis on the Federally-endangered shortnose sturgeon. It is difficult to completely assess the potential impact of dredging on subadult Atlantic sturgeon without knowing if they overwinter in the tidal freshwaters of Merrymeeting Bay or in the estuary below Bath, ME, or leave the river system entirely. There are no Federal navigation projects in the Androscoggin River or Sheepscot rivers.

During the late 1960s and early 1970s, DO levels reached zero ppm in the Kennebec and Androscoggin rivers from the head-of-tide to the mid-estuary during the summer months. The drop in oxygen levels commonly caused fish kills. Dissolved oxygen levels improved significantly in the late 1970s and 1980s, coincident with improved point source treatment of municipal and industrial waste. Although the DO levels were at severely low levels until the late 1970s, a population of shortnose sturgeon managed to persist in the system during this time period. The substrate in the upper freshwater portions of both the Kennebec and Androscoggin rivers was severely degraded by wood chips, sawdust and organic debris until the late 1970s. This accumulation was quickly flushed from the river systems after the cessation of log drives and the construction of water treatment plants.

Dioxin, likely generated from wastewater discharges from pulp and paper mills and municipal wastewater treatment plants, has been found in fish samples collected in the Kennebec and Androscoggin rivers (MEDEP 2005). The levels of dioxin found in fish have declined significantly since sampling was initiated in 1984. The Androscoggin River has had the highest dioxin levels for fish in the state of Maine. Levels of tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) were as high as 20 - 30 pg/g (parts-per-trillion) in fish sampled from the Androscoggin and Kennebec rivers during 1984-1986, before dropping to 0.1 pg/g in 2004 (MEDEP 2005). The discharge of dioxin into Maine river systems has steadily declined since the 1980s. In 1997, the Maine Legislature passed LD 1633, an act to make fish in Maine rivers safe to eat and to reduce color pollution. The LD 1633 established specific enforceable milestones for eliminating dioxin discharges from Maine's kraft mills. The milestones include: non-detectable dibenzo-*p*-dioxin at bleach plants by 1998; non-detectable dibenzofuran at bleach plants by 2000, and compliance with an above/below fish tissue test.

The MEDEP has conducted limited testing for heavy metals, PCBs, and organochlorine pesticides in the tidal waters of the Kennebec River. One shortnose sturgeon collected from the Kennebec River in 2003, as a result of BIW dredging mortality, had total toxicity equivalent concentrations of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), PCBs, dichlorodiphenyldichloroethylene (DDE), aluminum, cadmium, and copper above adverse effect concentration levels reported in the literature (Environmental Research and Consulting 2003). Mercury levels were above those considered safe for human consumption and also exceeded levels reported in the literature as harmful to wildlife in all Maine rivers and streams tested, including the Kennebec River (Sowles et al. 1997). In 1995, PCB levels in both striped bass and bluefish (*Pomatomus saltatrix*) from the Kennebec River were higher than EPA's screening value but much lower than the EPA's national median level (Sowles et al. 1997). Currently, fish consumption advisories are in place for the Androscoggin and Kennebec rivers (MEBOH 2001). No consumption of lobster tomalley (hepatopancreas) due to organochlorine contamination is also advised.

Despite water quality degradation described above, the Kennebec estuarial complex continues to support sturgeon populations. Improvements in habitat quality from the 1980s to the present will likely facilitate recovery of the Atlantic sturgeon subpopulation in this estuary. The removal of Edwards Dam in the Kennebec River has reopened additional access to historic habitat that will likely improve spawning success and accelerate recovery. However, the impacts of dredging projects to Atlantic sturgeon in the Kennebec are a concern. Though time-of-year restrictions likely minimize these impacts, the continued dredging of potential nursery grounds may impede the recovery of this species.

<u>Merrimack River – New Hampshire and Maine</u>

Hoover (1938) identifies Amoskeag Falls (rkm 116) as the historical limit of Atlantic sturgeon in the Merrimack River. The Essex Dam in Lawrence, MA (rkm 49) is the first upstream barrier, blocking the migration of Atlantic sturgeon to 58% of its historically available habitat. Tidal influence extends to rkm 35; however, in the summer months when river discharge is lowest, the salt wedge extends upriver to rkm 16, resulting in approximately 19 km of tidal freshwater and 9 km of freshwater habitat (Keiffer and Kynard 1993; rkm adjusted to correlate with GIS mapping). Based on a detailed description by Keiffer and Kynard (1993), the accessible portions of the Merrimack seem to be suitable for Atlantic sturgeon spawning and nursery habitat.

There has been little dredging activity in the Merrimack in recent years; the only project noted since 1998 was to deepen several sections of the Merrimack River near the town of Haverhill to open up more commercial opportunities in 2005 (Meehan 2005, Russo 2005).

In 2003, the ACOE and municipalities along the Merrimack River completed a watershed assessment of the Merrimack, which notes the lower basin of the river was highly urbanized with high levels of point and non-point sources of pollution (USACOE 2003). Other threats to anadromous fish in the watershed assessment noted impaired DO and pH levels. In 2005, there were two fish consumption public health advisories listed in the Merrimack River for mercury. A comprehensive analysis of biological data has identified the Merrimack River watershed in southeastern New Hampshire as a mercury hot-spot within the region (Evers et al. 2007). In an earlier fish tissue investigation conducted by USFWS (Major and Carr 1991), the following contaminant levels were measured in seven species of Merrimack River fish: mercury 0.20, lead 0.28, cadmium 0.04, chromium 0.29, copper 0.65, chlordane 0.12, DDT 0.16, dieldrin 0.01, and PCBs 1.38 - all in µg/g (ppm), wet weight. Sturgeon were not among the species examined by USFWS.

New York Bight DPS

Taunton River – Rhode Island and Massachusetts

Historic upstream migration of Atlantic sturgeon in the Taunton River is unknown. Currently, Atlantic sturgeon are restricted to the lower 70 km of the river as a result of the Town River Pond Dam, allowing access to 89% of the river. However, there has been no evidence of Atlantic sturgeon spawning in this river in recent years (last 15 years). Though spawning habitat is likely available, it is unlikely that water quality conditions are favorable for supporting nursery habitat as the river suffers from low DO (< 5 mg/L) and high ammonia-nitrogen levels (> 0.2 mg/L) (Taunton River Journal 2006). Surveys conducted in 1970 for American shad noted DO levels as low as 0.3 mg/L and ammonia-nitrogen levels as high as 1.22 mg/L (Taunton River Journal 2006). Low DO and excessive nutrient levels are still observed in the river, but water quality has slightly improved since 1970 (Taunton River Journal 2006). The river passes through several municipalities from which 23 million gallons of treated wastewater is added to the river daily; the majority of which is produced from a single treatment facility in the city of Brockton. In 2003, the EPA noted the Brockton facility was in violation of its discharge permit on many occasions, when it released water with excessive nutrient loads. There are no fish consumption advisories in effect for the Taunton River.

Connecticut River – Massachusetts and Connecticut

Questions exist regarding the historic range of Atlantic sturgeon in the Connecticut River. In all but low flow years, it is likely that Atlantic sturgeon could pass the Enfield rapids prior to dam construction (Enfield Dam), which occurred in three stages between 1829 and 1881 (Judd 1905).

The falls at South Hadley, MA, which is now the site of the Holyoke Dam, are considered the northern limit of sturgeon in this system; however, there is one historical record of an Atlantic sturgeon sighted as far north as Hadley, MA (24 rkm upstream from South Hadley). Since the Enfield Dam has been breached, an additional 90 km of habitat are available, and depending on the interpretation of historical spawning grounds, Atlantic sturgeon either have 100% (Holyoke Dam, South Hadley, MA), or 86% (Hadley, MA) of their historic habitat available. There is a chance that Atlantic sturgeon can reach habitat above the dam via a fish lift located at the Holyoke Dam, where 81 shortnose sturgeon have been observed to pass over the 21 years of the lift operation (Kynard 1996). However, no Atlantic sturgeon have been observed to pass the dam until just recently. On August 31, 2006, one 152.4 cm TL Atlantic sturgeon was observed in the spill way lift.

Water quality on the Connecticut River has improved dramatically in the last 40 years. It is now swimmable and fishable with some downstream exceptions, although there are still fish consumption advisories in Connecticut (T. Savoy, CTDEP, Pers. Comm. 2006). As of 2005, the Connecticut Department of Public Health had two species of fish listed as non-consumptive due to PCB contamination in the Connecticut River.

In the Connecticut River, coal tar leachate has been suspected of impairing sturgeon reproductive success. Kocan et al. (1993) and Kocan et al. (1996) conducted a laboratory study to investigate the survival of shortnose sturgeon eggs and larvae exposed to polycyclic aromatic hydrocarbons (PAHs), a by-product of coal distillation. Only 5% of sturgeon embryos and larvae survived after 18 days of exposure to Connecticut River coal tar (i.e., PAHs), demonstrating that contaminated sediment is toxic to shortnose sturgeon embryos and larvae under laboratory exposure conditions. Also, in 1988, it was observed that one out of every four female shortnose sturgeon which underwent surgical procedures for egg removal (N = 4) could not be spawned as a result of the presence of a tumor, thought to be related to coal tar or other industrial pollution present (B. Kynard, CAFL, Pers. Comm. 2006). Since the discovery of the coal tar deposits and impacts on biota, a significant amount of the coal tar has been removed. A more recent review of the contaminants within the Connecticut River revealed that total mercury and dioxin-like (coplanar) PCBs posed a risk to recreational and subsistence fishers, as well as the fish-eating mammals and birds, suggesting that contaminant levels were relatively high (Hellyer 2006).

Dredging is required about every six to seven years to maintain a Federal Navigation Project in the lower river from Hartford, CT to the mouth of the river. Seasonal restrictions have been implemented in the past to protect shad and Atlantic salmon (W. Neidermyer, USFWS, Pers. Comm. 1998); seasonal restrictions to protect shortnose sturgeon in this area likely benefit Atlantic sturgeon.

<u>Hudson River – New York</u>

The first impediment to migrating Atlantic sturgeon on the Hudson River is the Federal Dam, located at Troy (rkm 280, adjusted for GIS mapping). This dam location is upstream of Catskill (rkm 204), which is the northern extent of Atlantic sturgeon spawning and nursery habitat (Kahnle et al. 1998). The commercial shipping channel is maintained at a depth of 9.75 m (at mean low water) for nearly the entire length of the river to the Port of Albany; however, the section between Haverstraw Bay and Catskill is naturally deep and does not require dredging (D. Mann-Klager, USFWS, Pers. Comm. 1998). Dredge and fill operations have altered the river north of Catskill, but this is upstream from spawning and nursery habitat. There are infrequent dredging operations occurring south of Catskill for maintenance dredging and providing access to the channel (A. Kahnle, NYSDEC, Pers. Comm. 2006). Presently, all historic habitat in the Hudson River, from Haverstraw to Catskill, is accessible to Atlantic sturgeon as spawning and nursery habitat, although the quality or functionality of this habitat is unknown. Numerous studies from the early 1990s to the present have captured gravid adults and numerous year classes of juveniles, which indicates that at least some of the habitat is of functional quality (J. Mohler, USFWS, Pers. Comm. 2006). However, as noted above in section 3.1.1 (Dams and Tidal Turbines), potential foraging and nursery habitat of Atlantic sturgeon could be affected by a tidal turbine power project owned by Verdant Power that is currently testing two tidal turbines near Roosevelt Island, with plans to expand the project to 300 tidal turbines (Angelo 2005, CBS News 2006).

Population expansion in the Hudson River valley increased sewage output to the river, causing habitat impacts. Sewage decomposition produced several areas of inadequate oxygen (oxygen blocks) in the river. Best known was the block present in the Albany pool, located north of the Atlantic sturgeon's spawning and nursery habitat. Other blocks occurred at certain times in the southern stretch of river from the Tappan Zee Bridge south through New York Harbor (Brosnan and O'Shea 1997). Improvements to sewage treatment eliminated the problem near Albany by the late 1970s and the problem near New York City by the middle to late 1980s.

Data from the Saint Lawrence and Hudson rivers reported by Spagnoli and Skinner (1977), showed that average levels of PCBs in all sturgeon tissue sampled were higher than the FDA guidelines (> 2 µg/g; ppm) for edible portions of fish ranging from 6.72 ppm in the Hudson River to 11.89 ppm in the Saint Lawrence River. Belton et al. (1982) reported mean PCB levels in Atlantic sturgeon from the Hudson-Raritan estuary at 2.35 µg/g. In the Hudson River, there was a decline in PCB contamination from 1977-1988 where concentrations ranged from 0.15 – 1.7 µg/g in the muscle tissue, although the average concentration in the brain was 7.92 µg/g (Sloan 1987). Sloan and Armstrong (1988) observed that PCB concentrations were inversely proportional to body size of fish with Atlantic sturgeon PCB levels detected at less than 5 µg/g (Sloan and Armstrong 1988). Overall, PCB concentrations have declined to levels acceptable to EPA guidelines in recent years, but continual monitoring is needed to document the fate of PCB contamination in the river (Sloan et al. 2005). However, fish consumption advisories are still in place that advise against the consumption or reduced consumption of all species captured in the Hudson River between Troy Dam and Catskill due to PCB contamination. Other portions of the river include fish consumption advisories for three species due to mercury, PCBs, and cadmium contamination.

Delaware River – New Jersey, Delaware, Pennsylvania

The portion of the Delaware River and Bay that is available to Atlantic sturgeon extends from the Delaware Bay to the fall line at Trenton, NJ; a distance of 140 rkm. There are no dams within this reach of the river. Thus, 100% of the habitat is accessible, although habitat suitability is unknown due to river augmentation and water quality issues. Fox (2006) reviewed historical records that suggest that Atlantic sturgeon spawned in the Delaware River in two areas: 1) near Pea Patch Island and 2) near Pedrickston, NJ below Philadelphia, PA. However, Pea Patch Island habitat may be unsuitable spawning habitat depending on water flows as salt water often encroaches this area throughout the year, possibly due to hydrodynamic alterations to the river via past dredging operations and water sharing agreements with upstream municipalities (DiLorenzo et al. 1993, G. Murphy, DFW, Pers. Comm. 2006). However, these water diversion dams are managed to provide suitable habitat for trout and are so far upstream that they are not expected to affect sturgeon spawning. A flow analysis has not been conducted because the current location of Atlantic sturgeon spawning is unknown (C. Shirey, DNREC, Pers. Comm. 2005). The navigation channel undergoes maintenance dredging from the mouth of Delaware Bay to just north of Trenton. The Delaware River Fish and Wildlife Management Cooperative has imposed "no work" windows to reduce impacts from dredging on diadromous species. In addition, NMFS has consulted on the impacts of both dredging and blasting projects and has recommended restrictions for shortnose sturgeon, which may also benefit Atlantic sturgeon.

In 2006, Crown Landing, LLC, was approved by the Federal Energy Regulatory Commission (FERC) to construct and operate a Liquefied Natural Gas (LNG) import terminal on the Delaware River (RKM 126) near Logan, New Jersey. This location is suspected to be one of the historical spawning grounds of Atlantic sturgeon (Fox 2006); thus, it is suspected that the LNG terminal will likely threaten the viability of this subpopulation. However, site surveys conducted by the LNG researchers from May 2005 to April 2006, only documented 4 juvenile and 1 adult in the project area, suggesting the area is not utilized currently as a spawning ground.[23] The river is approximately 1.2 miles wide at the terminal location, and the facilities at the terminal will consist of a LNG pier (2,000 ft long) and berth in the Delaware River. The construction of the LNG terminal requires the hydraulic dredging of 1.24 million m^3 in the first year of construction followed by maintenance dredging of 67-97,000 m^3/year. Dredging spoil will be deposited in an upland disposal site, and dredging will be limited to the months of August through December. Crown Landing estimates that LNG shipments will occur approximately once every two to three days and that the Project will receive a maximum of 150 shipments per year. To maintain the stability of the LNG carriers, the carriers will take on ballast water from the Delaware River as they offload LNG. Approximately eight million gallons of water will be pumped into the LNG carriers over a 10-hour period to reach a minimum stability while at the berth, and an additional 5 to 11 million gallons of ballast water will be taken on after undocking just downstream of the berth area. Semi-daily ballast water withdrawals have the potential to entrain or impinge Atlantic sturgeon larvae, but it unknown if this area still supports spawning.

Until recently, poor water quality has been a significant factor for fish utilizing the upper tidal portion of the estuary. Inputs of chemicals and untreated sewage to the river and estuary have been reported for at least 200 years. Coal silt in the upper Delaware River was one of the major pollution problems from 1820-1940. Borodin (1925) and Horn (1957) suggest that pollution from oil and dyes was a factor in the decline of Atlantic sturgeon in the estuary. As late as the early 1970s, levels of DO between Wilmington and Philadelphia routinely dropped below levels that could support aquatic life from late spring through early fall. A portion of the Roebling-Trenton stretch of the river is an EPA Superfund site due to the presence of the Roebling Steel

[23] LNG contracted researchers did not report the type of gear used for sampling, frequency, or effort of sampling; thus this survey does not provide conclusive evidence that spawning does not occur in this area.

plant. The EPA has been considering ways to remove or cap the contamination in the river that resulted from the plant operations.

Since 1990, DO levels have remained above minimum state standards throughout the entire year (R. Green, Delaware DNREC, Pers. Comm. 1998). Other anadromous fish stocks, such as striped bass, American shad (*Alosa sapidissima*), and river herring (*A. pseudoharengus and aestivalis*) are utilizing the mainstem Delaware River for spawning and nursery habitats. The Delaware River striped bass stock has recently been defined as restored, is a significant contributor to the coastal stock, and supports significant in-river recreational and commercial fisheries since water quality has been restored. The Delaware River shortnose sturgeon population has also shown signs of recovery with population levels having increased to over 8,000 fish. Shortnose sturgeon have also been documented well downstream of Philadelphia, which was the downstream limit for this species over the last few decades due to degraded water quality conditions and into Delaware Bay. The restoration of other anadromous species suggests that environmental conditions are now adequate to support growth of the Atlantic sturgeon subpopulation if the fish are allowed to reach maturity and spawn (C. Shirey, DNREC, Pers. Comm. 2005). However, levels of PCBs, dioxins, mercury, and chlorinated pesticides are still elevated, and consumption advisories have been listed for numerous resident and migratory species of fish (Ashley et al. 2004). Two shortnose sturgeon collected during a 2002 mark/recapture study in the Delaware River had elevated levels of cadmium, copper, DDE, PCDD/Fs, and PCBs in gonad or liver tissue (Environmental Research and Consulting 2002). Though dredging is controlled by seasonal restrictions, the continual dredging of spawning and nursery grounds will likely reduce habitat quality through the redistribution of contaminants and further destruction of habitat; thereby, potentially subjecting sturgeon to degraded habitat conditions for longer periods of time.

Chesapeake Bay DPS

Chesapeake Bay (James, York, Rappahannock, Potomac, Susquehanna, and Nanticoke Rivers) – Maryland, Virginia, Pennsylvania

Due to their upriver locations, most dams in the Chesapeake Bay watershed have large freshwater tailways (unobstructed habitat downstream of the dam). Four dams constructed from 1904 – 1932 in the Susquehanna River have impeded diadromous fish migration, although none of these dams are suspected to have impeded Atlantic sturgeon spawning habitat as the lowermost dam (Conowingo) is suspected to be located above the historic spawning grounds (Steve Minkkinen, USFWS, Pers. Comm. 2006). Only two shortnose sturgeon and no Atlantic sturgeon have been noted to pass the fish lift operated at the Conowingo Dam during its years of operation; 1965 – 1966 and 1972 – present.

The Embrey Dam (built in 1910), located above the fall line, on the Rappahannock River may have potentially blocked the upstream migration of Atlantic sturgeon; however, this dam was breached (by explosives) in 2004. Constructed in 1823, the Bosher Dam on the James River impeded upstream diadromous fish migration until a vertical slot fish passage way was installed in 1999.[24] No Atlantic sturgeon have been observed to pass through this fishway (Bushnoe et al. 2005).

During the past 100 years, increased rates of urbanization along with residential and industrial development along the banks of sub-estuaries have continued to contribute to historical trends in sedimentation, deforestation, and pollution (Cooper and Lipton 1994). The period of Atlantic sturgeon population decline and low abundance in the Chesapeake Bay corresponds to a period of poor water quality caused by increased nutrient loading and increased frequency of hypoxia (Officer et al. 1984, Mackiernan 1987, Kemp et al. 1992, Cooper and Brush 1993). It is plausible that overharvesting of Atlantic sturgeon in the 1890s led to the dramatic decline in the fishery, and poor water quality since then has not been conducive to recovery. Secor and Gunderson (1998) showed that juvenile Atlantic sturgeon were less tolerant of summer-time hypoxia than juveniles of other estuarine species. Over the last 50 years, high nutrient inputs have contributed to high spatial and temporal incidence of summer-time hypoxia and anoxia in bottom waters (Taft 1980, Officer et al. 1984, Malone et al. 1993, Boesch et al. 2001). During spring and summer algal blooms, the Chesapeake supports extremely high primary production rates. Blooms accelerate bottom microbial respiration, which results in oxygen depletion in benthic waters. The Bay is especially vulnerable to the effects of nutrients due to its large surface area, volume ratio, relatively low exchange rates, and strong vertical stratification during spring and summer months. Niklitschek and Secor (2005) modeled suitable habitat availability for Atlantic sturgeon in the Chesapeake Bay and results indicated that the system was squeezed or stressed in the summer months as hypoxic conditions consumed 0-35% of the Bay from 1993-2002. Similar trends in low DO have been observed in the lower portions of the York and Potomac rivers (Chris Hager, VIMS, Pers. Comm. 2005).

Since 1984, the Chesapeake Bay Program and its member states (PA, MD, DC, and VA) have instituted programs related to nutrient abatement (Cooper and Lipton 1994, Boesch et al. 2001). Within Chesapeake Bay tributaries, improving conditions for macrobenthos have been observed, perhaps as a result of nutrient abatement programs (Dauer 1995). Furthermore, the survival and growth rates of hatchery-reared Atlantic sturgeon stocked in the Nanticoke River in 1996 provide some evidence of the suitability of nursery habitat. Fish consumption advisories, however, are in effect for at least 10 species in the Chesapeake Bay due to PCB, mercury, and kepone contamination.

However, one of the limiting habitat requirements for Chesapeake Bay sturgeons may be the availability of clean, hard substrate for attachment of demersal, adhesive eggs (Bushnoe et al. 2005, Chris Hager, VIMS, Pers. Comm. 2005). Rubble, cobble, and gravel size rock, as well as shell, forest litter, and submerged vegetation provide substrate for egg attachment. In the Chesapeake Bay's watershed, 18th and 19th century agricultural clear cutting (Miller 1986) contributed large sediment loads that presumably have buried or reduced most sturgeon spawning habitats (reviewed in Bushnoe et al. 2005).

The most significant impacts to Atlantic sturgeon spawning habitat likely occurred in 1843 and 1854 when the James River, which likely supported the largest subpopulation in the Chesapeake

[24] Originally, the James River had two additional impediments downstream of Bosher Dam: Browns Island Dam and Williams Island Dam were breached and notched in 1989 and 1993, respectively.

Bay based on commercial landings, had granite outcropping consisting of large and small boulders (called Rockett's) removed and dredged to improve ship navigation (Holton and Walsh 1995, Bushnoe et al. 2005). Similarly, Drewry's Island Channel had rock removed to improve navigation in 1878 (Holton and Walsh 1995). These granite outcroppings and boulder matrices are the types of habitats that are believed to be ideal spawning habitats for Atlantic sturgeon (Bushnoe et al. 2005). Existing spawning habitat in the Potomac River seems to be intact, although water quality is a major concern in this system.

No dredging is currently conducted within potential Atlantic sturgeon spawning areas in the Rappahannock, Potomac, York, or Nanticoke rivers. There are projects underway to deepen and widen the terminal near Richmond on the James River that may have a negative impact on Atlantic sturgeon spawning in that river. In addition, the James River is dredged on almost an annual basis to allow commercial ocean-going vessels to reach the Richmond terminal (Chris Hager, VIMS, Pers. Comm. 2005). Since 1998, six new permits have been issued for dredging within the James River, and an additional 24 maintenance projects have been approved (L. Gillingham, VMRC, Pers. Comm. 2005). There are dredging moratoriums in place for the Commonwealth of Virginia during the anadromous spawning season, although the ACOE is negotiating to dredge during this moratorium in areas not affecting anadromous fish (Chris Hager, VIMS, Pers. Comm. 2005; Albert Bell, USFWS, Pers. Comm. 2006).

There is evidence, however, that environmental conditions within the entire Chesapeake Bay ecosystem have not degraded to the point at which they can no longer support sturgeon. One year old hatchery sturgeon released in the Nanticoke River in 1996 survived and grew at favorable rates, indicating that the Bay is still able to support juvenile sturgeon (Secor et al. 2000). Also, over 1,100 wild sturgeon have been observed in the Maryland Reward Program during the last 11 years, indicating that sturgeon still use the Bay as an opportunistic place to forage. Overall, the SRT concluded that water quality and habitat degradation are threats to the viability and recovery of Atlantic sturgeon and that mitigation of these stressors would likely improve or accelerate the recovery of this species within the Bay.

Carolina DPS

Albemarle Sound/Roanoke River – North Carolina

The construction of Roanoke Rapids Dam in 1955 on the Roanoke River blocked access to diadromous fish above rkm 207. It is likely that Atlantic sturgeon ascended the Roanoke Rapids, based on locations above the rapids with sturgeon-related names and the capture of sturgeon in fish slides located at Roanoke Rapids as they were coming downstream in the 1800s (reviewed in Armstrong and Hightower 2002). Two additional dams, Gaston and Kerr, are immediately above Roanoke Rapids. It is uncertain how spawning has been affected by these dams as age-0 and 1 juveniles still occur in the Albemarle Sound portion of the system, and therefore, spawning must be continuing on the Roanoke River below the dams or in other Albemarle Sound tributaries. If spawning is limited to the fall line, 100% of Atlantic sturgeon spawning habitat is available as the Roanoke Rapids Dam is located at or near the fall line. If spawning historically occurred above the fall line, experts expect 45 rkm (18%) of habitat or more could be impeded (NMFS 2006).

A fishway prescription for the Roanoke Rapids and Gaston dams was filed in 2006 as a result of Dominion Generation applying for a "major new hydropower license" (NMFS 2006). The fishway prescription will allow for the passage of American shad (*Alosa sapidissima*), river herring (*A. psuedoharengus and A. aestivalis*), and American eel (*Anguilla rostrata*): phase 1 initial truck and trapping; phase 2 permanent truck and trapping; and phase 3 full capacity volitional passage. Atlantic sturgeon were not a management objective in this prescription due to their low population size and lack of safe and effective downstream passage mechanisms for post-spawn adults. However, NMFS reserved its authority to prescribe fishways or other modifications as appropriate in the future for both Atlantic and shortnose sturgeon in the event these circumstances change (NMFS 2006).

Flow, water temperature and oxygen levels in the Roanoke River are also affected by both the Kerr Dam, and the Gaston Dam/Roanoke Rapids facilities that both engage in peaking operations. NMFS, USFWS and other Federal and state fishery management agencies are currently working with the ACOE – Wilmington District, and Dominion Power (operators of the dams) to address environmental concerns through modification of dam operations. Riverine water flow has already been modified during the striped bas spawning season to simulate natural flow patterns; these modifications undoubtedly benefit Atlantic sturgeon. Regardless of the temporary modifications, lower water temperatures resulting from the hypolimnetic discharge from Kerr Dam have caused temporal shifts in the spawning peaks for both American shad and striped bass and likely have had the same impact for other diadromous species, including Atlantic sturgeon.

The ACOE conducts extensive annual dredging operations to maintain navigational access through Oregon Inlet, which is the main corridor into Albemarle Sound. However, dredging in the Sound itself and its major tributaries is relatively minor with the exception of the Atlantic Intercoastal Waterway (AICW). The Roanoke River has not been dredged since the 1940s. The USFWS, NMFS, ACOE, NC Division of Marine Fisheries, and NC Wildlife Resources Commission, all support the in-water moratorium coordinated by the NC Division of Coastal Management. Under this moratorium, work is restricted in certain coastal waters during the spring spawning season (February 1 through June 30) to protect diadromous fishes and also provides nursery ground dredging moratoriums from April 1 through September 30.

Water quality in the Albemarle Sound ecosystem and in its major tributaries is relatively good, due in large part to the fact that most of the watershed is rural and/or forested. Paper mill operations on the Roanoke River at Weldon and Plymouth have caused some localized areas of contamination. While the localized effect of the contaminants within the system to Atlantic sturgeon is unknown, as no tissue samples have been collected or analyzed, fish consumption advisories are in effect for two fish species in the Roanoke River based on dioxin and a general mercury advisory. Fish kills do occur occasionally in the Roanoke River, when high flows from Kerr Dam during the summer are coupled with high ambient temperatures and an influx of swamp water with low DO, creating a large, hypoxic plume within the river. Such events would affect potential Atlantic sturgeon nursery habitat in the lower river.

Pamlico Sound and Tributaries (Tar and Neuse Rivers) – North Carolina

Both the Tar-Pamlico and Neuse rivers, the two major tributaries to Pamlico Sound, are dammed. One hundred percent of the riverine habitat is available to Atlantic sturgeon in the Tar-Pamlico, as the low-head Rocky Mount Dam (rkm 199) is located on the fall line. It is likely that Atlantic sturgeon historically utilized habitat in the Neuse River up to the falls at rkm 378 where a dam (Falls Dam) is now located, although this site is above the fall line. Access to historic habitat was blocked by Quaker Neck Dam at Goldsboro and Milburnie Dam (rkm 349) in the vicinity of Raleigh, NC. Quaker Neck Dam was removed in 1998, and access was restored up to Milburnie Dam (rkm 349). However, if the fall line is an indicator of the upper limit of spawning migration then the Milburnie Dam is above the fall line, and 100% of historic Atlantic sturgeon spawning habitat may be available. The flow regime of Milburnie Dam has been temporarily increased to simulate natural conditions on the Neuse River, but these flow regimes are not permanently established and could be changed in the future.

The ACOE conducts navigational dredging operations in the AICW through Pamlico Sound and up major tributaries to facilitate boating access. All major inlets to Pamlico Sound, including Hatteras, Ocracoke, and Drum, are also dredged. The degree to which dredging operations affect the species in Pamlico Sound and tributaries is unknown; however, all dredging permits in North Carolina incorporate seasonal restrictions for the protection of diadromous species.

Water quality in the Pamlico system, especially in the lower Neuse River, is of serious concern (Paerl et al. 1998, Qian et al. 2000, Glasgow et al. 2001). The lower Neuse River has been the site of many fish kills and much concern in recent years because of outbreaks of a toxic dinoflagellate, *Pfiesteria piscicida*; however, this disease has not been detected in Atlantic sturgeon, and no sturgeon carcasses were found even during severe outbreaks.[25] The entire basin has been designated as nutrient-sensitive, and additional regulatory controls are being implemented to improve water quality. Both the Neuse and Pamlico portions of the estuary have been subject to seasonal episodes of anoxia that significantly affect the quality of Atlantic sturgeon nursery habitat. Concentrated animal feeding operations (CAFOs) are attributed to at least some portion of the current water quality problems in the Pamlico watershed (Mallin and Cahoon 2003). Farms that produce hogs, turkeys, and chickens have proliferated throughout the coastal portion of the basin in the last decade or so, with increases in both aquatic and atmospheric deposition of nitrogenous waste products. North Carolina passed a moratorium in 1997 limiting additional hog operations and is conducting a study of measures to address the problem; this bill was renewed in 1999 and 2003 (a four year cycle). There are three fish consumption advisories (carp, catfish, and largemouth bass) in effect for the Pamlico Sound and its tributaries due to mercury and PCB contamination.

<u>Cape Fear River – North Carolina</u>

The Cape Fear River has three locks and dams between Wilmington and Fayetteville that are located below the fall line; two additional dams, Buckhorn and B. Everette Jordan, are located above the fall line. Atlantic sturgeon movement is blocked at the first lock and dam located in Riegelwood, NC (rkm 90). Other pelagic species can pass over the three locks and dams during

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[25] Atlantic and shortnose sturgeon are rarely found in this system and may be the reason no observations of *Pfiesteria piscicida* have occurred.

high water or may be locked around the low elevation dam; observations at Buckhorn Dam (rkm 292) confirm passage, although it is low. The benthic Atlantic and shortnose sturgeon are not known to pass over these three locks/dams. Over the last 18 years, there have only been two sightings of large adult Atlantic sturgeon (> 181 kg or 400 lbs) at the base of Lock and Dam #1, observed jumping just downstream (R. Hall, ACOE Lock Master, Pers. Comm. 2005). No Atlantic or shortnose sturgeon have been captured upstream of Lock and Dam #1 despite extensive sampling efforts (Moser et al 1998). Although locks are operated during the spring in an effort to provide upstream passage, sturgeon are not known to utilize the locks. Flows on the river are regulated upstream at the B. Everette Jordan Dam; however, the extent to which the flow departs from the historical hydrography has not been evaluated. Current flow regimes do not seem to have peaking hydrographs usually associated with hydropower dams. Historical spawning locations are unknown in the Cape Fear River; therefore, it is assumed that the fall line is the upper limit of spawning habitat. Using the fall line as guide, only 33% of the historical habitat is available to Atlantic sturgeon (96 km of 292 km). In some years, the salt water interface reaches the first lock and dam; therefore, spawning adults in the Cape Fear River, either do not spawn in such years or spawn in the major tributaries of the Cape Fear River(i.e., Black River or Northeast Cape Fear rivers) that are not obstructed by dams.

Dredging operations (including the blasting of rock) on the lower Cape Fear River, Brunswick River and port facilities at the U.S. Army's Sunny Point Military Ocean Terminal and Port of Wilmington are extensive. To protect diadromous fish, restrictions are placed on dredging to avoid sensitive seasons and locations, such as potential spawning habitat (February 1st through June 30th) and suspected nursery grounds (April 1st – September 30th). Dredging activities above Lock and Dam #1 in the Cape Fear River are less common and unlikely to impact Atlantic sturgeon.

Water quality in the Cape Fear River is less than desirable for aquatic life, due largely to industrial development and use, including the Port of Wilmington and numerous industrial point-source discharges. Development of CAFOs in the coastal portion of the Cape Fear River basin has been especially heavy (most concentrated operations of CAFOs occur in the Cape Fear River Drainage within NC) and contributes to both atmospheric and aquatic inputs of nitrogenous contamination possibly causing DO levels to regularly fall below the 5 mg/L state standard (Mallin and Cahoon 2003). In recent years, there have been fish kills observed, usually as a result of blackwater swamps (with low DO) being flushed after heavy rainfall. Fish advisories also exist for two species within the river drainage for mercury contamination.

Winyah Bay (Waccamaw, Great Pee Dee, Black and Sampit Rivers) – South Carolina

Only the Great Pee Dee Rive is dammed in this river system; Blewett Falls Dam is located at or near the fall line (305 km upstream). It is unknown how much of the river was used by Atlantic sturgeon prior to dam construction, but a historic fishery for sturgeon near Winston Salem has been noted and suggests that some portion of the historical spawning habitat is impeded. Access to historic spawning areas seems to be adequate in the Waccamaw, Black and Sampit rivers as these rivers are unimpeded, though habitat quality is unknown.

Winyah Bay and its shipping channel, which includes the salinity regime commonly inhabited by age 1-4 juveniles, are dredged with some regularity for navigation into the Port of Georgetown. In the Bay, a seasonal restriction to protect sea turtles restricts dredging during the summer months.

Industrialization, including paper and steel mills, in the upper portion (Sampit River arm) of Winyah Bay has impacted water quality. Riverine sediment samples contain high levels of various toxins including dioxins (NMFS and USFWS 1998). The effects of these contaminants are unknown, but there are fish consumption advisories for three fish species in the system due to mercury contamination.

<u>Santee-Cooper – South Carolina</u>

The Santee Basin originates in the Blue Ridge Mountains of North and South Carolina and includes a total of 182 separate rivers or named river segments. The Santee Basin is second only to the Susquehanna on the U.S. East Coast in terms of drainage area and volume of flow (Hughes 1994). Major watercourses within the Basin include the Broad, Saluda, Catawba-Wateree, Congaree, and the Santee rivers. The Broad and Saluda rivers merge to form the Congaree River, and the Wateree and Congaree rivers merge to form the Santee River. Based on the historical flow record (1908-1941) the mean annual Santee River inflow was 18,522 cfs, varying from a 7-day low flow average of 6,572 cfs to over 200,000 cfs. The present Santee-Cooper Project diverts a weekly average flow of 4,500 cfs through the Jefferies Hydroelectric Station to the Cooper River, with the remainder of the flow released at the Santee Hydroelectric Station and Spillway, and the ACOE St. Stephen Hydroelectric Project.

The Santee-Cooper Hydroelectric Project, which is owned by the South Carolina Public Service Authority (SCPSA), is located in the coastal plain of the Santee Basin on the Santee and Cooper rivers, South Carolina. The project was constructed in 1938 – 1942 and includes Lake Marion, which is impounded by the Santee Dam (Wilson Dam) on the Santee River at river mile (rm) 87, and Lake Moultrie, which is impounded by the Pinopolis Dam on the Cooper River at rm 48. The project structures consist of the Wilson Dam, Pinopolis Dam, Diversion Canal, Santee Spillway Hydroelectric Station, and Jefferies Hydroelectric Station. The ACOE Re-diversion Project is located on the Re-diversion Canal. It consists of the St. Stephen Hydroelectric Project and St. Stephen fish lift. The SCPSA operates both the Jefferies Hydroelectric Station and the ACOE St. Stephen station.

Although there is no license requirement, the navigation lock at Pinopolis Dam has been operated since the 1950s. This early passage began as a cooperative effort with South Carolina Wildlife Resources Department (now South Carolina Department of Natural Resources), the Fish and Wildlife Service's Bureau of Sport Fisheries and Wildlife, and SCPSA. The purpose of lock passage operations was originally to pass river herring as forage fish for the nationally recognized landlocked striped bass population discovered in the Santee Cooper Lakes in the early 1950s (Stevens 1957). Prior to the Santee Re-diversion Project, annual river herring passage estimates ranged as high as 10 million (Cooke and Leach 2003). It is likely that other diadromous species including American shad, striped bass, sturgeon, and American eel (*Anguilla rostrata*) were passed during those years; however, the hydroacoustic counting methods did not differentiate among species. After re-diversion of the Santee River in 1985-87 and construction of the St. Stephen Powerhouse and Fishway on the Re-diversion Canal, the Pinopolis Lock passage estimates declined substantially but remain important to the overall Santee Basin passage objectives.

The Santee Dam is located on a bypassed reach of the Santee River 37 miles upstream from the confluence of the Re-diversion Canal. Flows exceeding 600 cfs occur only during sporadic unregulated spill events at the Santee Dam Spillway, most frequently during March. Upstream migrations of diadromous fish, including American shad, blueback herring, American eel, and shortnose sturgeon, are documented during the winter and spring spawning season within the bypassed reach, and their upstream migrations are blocked by the dam. Upstream movements of diadromous fish in the bypassed reach are substantial during spill events or during lower flow years when the St. Stephen Hydroelectric Facility is not operating during the spawning runs (Cooke and Leach 2003).

Subsequent to completion of the Santee-Cooper Project, it was discovered that diversion of the Santee River flow into the Cooper River resulted in increased shoaling within Charleston Harbor, necessitating expensive and more frequent dredging. To alleviate the frequency of dredging within the Charleston Harbor, the Cooper River Re-diversion Project was constructed in 1980-1985 by the ACOE to return Santee River flow to the original basin. A re-diversion canal was constructed to divert flow from Lake Moultrie to the Santee River, which is 37 miles downstream from the Santee Diversion Dam. A new hydroelectric project dam, the St. Stephen Hydropower Project, was constructed on the re-diversion canal to replace lost hydropower generation capacity at the Jefferies Station at Pinopolis Dam. Because of sport fishing stakeholder and fishery resource agency concerns over loss of the Pinopolis Lock herring passage after re-diversion of the river flow, a new fishway was constructed at the St. Stephen Dam.

The St. Stephen Hydroelectric Project and Fish Lift were constructed by the ACOE as a part of the Cooper River Re-diversion Project. The Fish Lift is operated by the SCDNR under an agreement with the ACOE. It was primarily constructed to pass blueback herring into Lake Moultrie as forage fish for the stocked reservoir striped bass fishery and to mitigate for the shift in blueback herring runs from the Cooper River to the Santee River. The fish lift currently passes American shad, blueback herring, striped bass, and other non-diadromous fishes; however, the lift primarily attracts upper water column species and is not designed to attract or pass benthic-oriented shortnose or Atlantic sturgeon. Modifications to the fish lift will be necessary to effectively pass all Basin target species (Cooke and Leach 2003, 2005).

Although it is not known to what extent the Santee-Cooper River system was used by Atlantic sturgeon, it is assumed that the fall zone acts as the upper most limit to spawning habitat. Using the fall line as the upper region of habitat, it is estimated that only 41% of the historic habitat is available to Atlantic sturgeon today (the dam is located 211 km upstream from the mouth, the fall line is 516 km upstream from the mouth based on GIS tools). Although a fish lift operates at the dam during the spring, observations of sturgeons in the lift are extremely rare, and there is no record of an adult Atlantic sturgeon being lifted, although three dead Atlantic sturgeon were observed upstream of the lift in Lake Marion, above Wilson Dam in 1995-1997. There is no dredging in the Santee River that would have the potential to affect Atlantic sturgeon habitat. The Cooper River flows into Charleston Harbor, which is one of the busiest ports on the Atlantic Coast and is dredged regularly. The river channel is maintained by dredging all the way to the Pinopolis Dam. No seasonal restrictions are placed on dredging in the Cooper River; however, a restriction is placed on dredging conducted offshore of Charleston Harbor in the shipping channel during the summer months to protect sea turtles. Subadult Atlantic sturgeon form winter aggregations in the shipping channel outside Charleston Harbor. Although water quality is generally good in the harbor and river, sediments in some areas are still contaminated due to previous industrial operations and military facilities. Fish consumption advisories are in effect for three species in this river complex due to mercury contamination.

South Atlantic DPS

ACE Basin (Ashepoo, Combahee, Edisto) – South Carolina

The Ashepoo, Combahee, and Edisto rivers, and St. Helena Sound into which they flow, are among the least developed in the region with generally very good water quality. The area near their confluence has been designated the ACE Basin National Estuarine Research Reserve. There are only two dams on the Ashepoo River, the Cocker Pond and Bennetts Pond dams, which are located near the fall zone and impede nine kilometers of habitat from the dam to the fall line. All other ACE basin streams are not impeded by dams. Subpopulations in this system have received little impact from dredging, dams, or diminished water quality (NMFS and FWS 1998). There are currently three fish consumption advisories present within the ACE Basin for mercury contamination.

Savannah River – South Carolina and Georgia

The New Savannah Bluff Lock and Dam (NSBL&D) at the city of Augusta (rkm 299), is located just a few kilometers below impassible rapids, denying Atlantic sturgeon access to 7% of its historically available habitat (NMFS and USFWS 1998). The NSBL&D has five vertical spillway gates that could allow passage for anadromous fish during the normal spawning season flows in the Savannah River. Under normal spring flows when the gates are open, the headpond and tailwater elevations are often at the same level, and fish may pass upstream over the submerged weirs at each gate opening. Limited passage studies at the NSBL&D have documented significant passage by American shad, river herring, and striped bass for many years. Additionally, a recent study indicates significant numbers of shortnose sturgeon are present at the NSBL&D during the late winter-spring spawning period. While sturgeon passage has not yet been confirmed at the NSBL&D, the limited scope of passage studies conducted to date cannot exclude the possibility of passage by sturgeon. Recent Congressional Acts (the Water Resources Development Act of 2000, P.L. 106-541, and the Omnibus Appropriations Act 2001, P.L. 106-554) have authorized the Savannah District, United States Corps of Engineers (SDCOE) to repair and rehabilitate the NSBL&D to transfer the project to the City of North Augusta and Aiken County, South Carolina. The SDCOE commissioned a study to investigate terms for transfer of ownership of the NSBL&D. The study identified and investigated fish passage configurations that would readily pass many species, including sturgeon. It is highly likely that fish passage will be required as a term and condition when ownership of the NSBL&D

is transferred (S. Bolden, NMFS, Pers. Comm. 2006). Therefore, while the NSBL&D currently may hinder sturgeon passage to the Augusta Canal Hydropower project location, sturgeon passage cannot be discounted. Further, it is probable that once the fishway is installed at the NSBL&D both shortnose and Atlantic sturgeon will have free upstream passage to the Augusta Dam. Also, NMFS believes that vitally important spawning habitat is available in the Savannah River upriver from the NSBL&D and also the Augusta Dam, and the species will likely expand its geographic range to reoccupy these formerly available habitats.

Maintenance dredging, occurring primarily in nursery habitat, is frequent, and substantial channel deepening took place in 1994. A seasonal restriction on dredging operations has been imposed from March 16th – May 31st to protect striped bass in this river system. This spring closure likely benefits Atlantic sturgeon as well (M. Collins, SCDNR, Pers. Comm. 1998).

The Georgia Ports Authority is seeking to expand their port facility on the Savannah River. Within the 1999 Water Resources Act, Congress authorized the deepening of the Savannah Navigation Channel from the current depth of –42 ft to –48 feet mean low water. Hydrodynamic and water quality models have been developed to predict changes in water quality across depth and throughout the channel. Species-specific variables (season, DO, temperature, river flow, depth and slope) have been run through the model to evaluate impacts and predict post-construction habitat conditions. There are concerns that the deepening may negatively alter overall water quality (e.g., salinity and DO), creating inhospitable foraging/resting habitat in the lower Savannah River for sturgeon.

Other activities occurring on the Savannah River include an expansion of Container Berth 8 by Georgia Ports, which requires dredging and pile driving. Expansion of Berth 8 required construction of a commercial pile-supported, concrete berth facility. The location of the berth nearby known over-wintering habitat of juvenile shortnose sturgeon in the Middle River resulted in a pile-driving moratorium.

Plans to expand the Elba Island LNG Terminal near Savannah, Georgia, are currently being reviewed. The proposed expansion includes installation of an additional two 200,000 m^3 LNG storage tanks, six closed-loop submerged combustion vaporizers, and modification of the berthing area to accommodate larger LNG carriers. Activities required for the expansion include pile driving, dredging, and construction barge activities.

The lower Savannah River is heavily industrialized and serves as a major shipping port. Nursery habitat in the lower river has been heavily impacted by diminished water quality and channelization, but effects on juveniles have not been determined. Reduced DO levels and upriver movement of the salt wedge may result from channel deepening. Mercury contamination is also prevalent within the system, with five fish species listed on the fish consumption advisory list.

Ogeechee River - Georgia

Atlantic sturgeon have access to 97% of their historical spawning habitat as the Jordan Mill Pond Dam is located 10 km downstream of the fall line. Downstream nursery habitat is likely compromised during hot, dry summers. This occurs when water flow is minimal and non-point sources of hypoxic waters have a greater impact on the system as potential thermal refugia are lost when the aquifer is lowered. Since 1986, DO levels have dropped to approximately 4 mg/L annually (Ogeechee River Basin Plan 2001). There have been no dredging projects reported in the last 25 years.

Altamaha River - Georgia

The Altamaha River is one of the largest drainage basins east of the Mississippi River (662 km mainstem and major tributaries). Although the two major tributaries are impounded, all dams are well upriver, at or above, the fall line and the probable historic extent of Atlantic sturgeon habitat. The drainage basin is dominated by silviculture and agriculture, with two paper mills and over two dozen other industries or municipalities discharging effluent into the river. Nitrogen and phosphorus concentrations are increasing, and eutrophication and loss of thermal refugia are concerns (see Ogeechee River).

Dredging operations are restricted to maintenance dredging of the Hatch Nuclear Power Plant water intake structures located on the Altamaha River at rkm 180 (rm 112), which is approximately 11 miles northeast of Baxley, in Appling County, Georgia. Plant facilities include the use of a closed-cycle cooling system that takes water from the Altamaha River. The water intake structure is located on the southern bank of the river and is 150 feet long by 60 feet wide. The flow rate of water being taken into the plant has historically averaged 88 cubic feet per second (cfs). The intake structure is covered with trash racks for removal of large debris and a traveling vertical screen of 3/8-inch mesh for removing small debris. The plant discharges water that ranges from 62^o F in winter to 94^o F in summer into the river at a rate of 50 to 58 cfs.

The intake structure requires maintenance dredging about once per year; dredging only occurs during the summer months. Each dredging event requires the use of a hydraulic, clamshell, or dragline type of dredge and will remove approximately 14,000 cubic yards of spoil material. This material is disposed in upland areas.

Other activities conducted at the Hatch plant as a function of operation that may affect sturgeon include impingement of adults or juveniles on the trash racks, entrainment of eggs or larvae in the cooling water intakes, discharge of heated effluents, and dredging operations.

Satilla River – Georgia

No Atlantic sturgeon habitat is lost as a result of dam construction on the Satilla River. Three hundred seventy-six kilometers of habitat exists between the river mouth and the fall line. Water quality conditions seem to be favorable during most of the year within the Satilla River, although low DO (< 5 mg/L) was a common occurrence observed during 1998-1999 water quality surveys (Satilla River Basin Plan 2002). The main sources of low DO concentrations are related to non-point sources, as point sources (i.e., wastewater discharge) have been vastly improved since the 1980s.

St. Mary's River – Georgia and Florida

Over 274 km of Atlantic sturgeon habitat is accessible (100%) between the river mouth and the fall line, and as such, dam construction has not had a significant impact on this river. It seems that the extirpation of the Atlantic sturgeon subpopulation in this system was likely caused by reduced DO levels during the summer in the nursery habitat, probably due to eutrophication from non-point source pollution. Dredging in the system seems to be limited to maintenance dredging of the ICW as needed.

St. Johns River – Florida

Historically, Atlantic sturgeon likely accessed all parts of the St. Johns River, as American shad were reported as far upstream as Lake Poinsett (reviewed in McBride 2000). However, the construction of Kirkpatrick Dam (originally Rodman Dam) at rkm 153 has restricted migration to potential spawning habitat upstream. Spawning may have occurred in the Ocklawha River, a tributary of the St. Johns River, and historic sturgeon habitat may not have included upstream portions of the river (K. Sulak, USGS, Pers. Comm. 2006). Water quality in this system also seems to be degraded, and low DO is a common occurrence during the summer months when water temperatures rise. Dredging commonly occurs within the system and has been linked to the reduction in submerged aquatic vegetation where Atlantic sturgeon likely forage (Jordan 2002) and may have impacted nursery habitat. Although Atlantic sturgeon were likely historically present in this river, it is believed that the subpopulation has been extirpated, and the St. Johns River now only serves as a nursery (NMFS and USFWS 1998).

3.1.5. Summary and Evaluation

Summarizing the preceding review, it is apparent that some Atlantic sturgeon subpopulations are likely affected by anthropogenic impacts to the watershed. These subpopulations include:

- Penobscot River – Wood chip debris reducing benthic habitat quality, mercury hot spots, coal tar deposits.
- Kennebec River – Maintenance dredging on nursery grounds.
- Merrimack River – 58% of historic habitat impeded.
- Connecticut River – Coal tar deposit on suspected spawning grounds.
- Hudson River – Continual dredging of nursery grounds, elevated levels of heavy metal and PCB contamination.
- Delaware River – Continual dredging, LNG operations, dioxin, mercury, PCB, and chlorinated pesticide contamination.
- Chesapeake Bay – Low DO in waters of the Bay during the summer and poor sediment quality.
    - Potomac River – Poor sediment quality.
    - James River – Continual dredging of nursery and spawning grounds, sedimentation.
- Roanoke/Albemarle Sound – Low DO during the summer and hypolimnetic discharges from Kerr Dam.
- Neuse River – Low DO and altered water flows.
- Pamlico Sound – Low DO in the Sound during the summer.

- Cape Fear River – 64% of historic habitat impeded, continual dredging in nursery grounds although there is a dredging moratorium imposed during the spring and summer.
- Santee-Cooper River – 62% of historic habitat impeded, continual dredging in nursery and spawning grounds within the Cooper River.
- Ogeechee River – Low DO during the summer months.
- Satilla River – Low DO during the summer months.
- St. Johns River – 63% of historic habitat impeded, low DO, dredging.

Atlantic sturgeon throughout their range are exposed to a variety of habitat threats including: restricted access to riverine habitat; large portions of degraded habitat, which may result in high levels of tissue contamination and water quality standards that are below fish health standards; and/or poor quality of some benthic habitat. Without substantial mitigation and management to improve the habitat and water quality of these systems, Atlantic sturgeon subpopulations will likely continue to be depressed until suitable habitat and water quality conditions are achieved. This is evident in southern streams that are suspected to no longer support reproducing Atlantic sturgeon subpopulations, such as the St. Mary's and St. Johns rivers. Although these rivers are at the southern range of the species, the degradation of habitat via dredging and water pollution likely prohibit Atlantic sturgeon from recolonizing these systems. The recovery of Atlantic sturgeon along the Atlantic Coast, especially in areas where habitat and water quality is severely degraded, will require improvements in the following areas: 1) elimination of barriers to spawning habitat either through dam removal, breaching, or installation of successful fish passage options; 2) operation of water control structures to provide flows compatible with Atlantic sturgeon use in the lower portion of the river (especially during the spawning season); 3) imposition of restrictions on dredging, including seasonal restrictions and avoidance of spawning/nursery habitat; and 4) mitigation of water quality parameters that are restricting sturgeon use of a river (i.e., DO). Additional data regarding sturgeon use of riverine and estuarine environments is needed.

3.2. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Atlantic sturgeon have been directly harvested with various gears including gill nets, traps, pound nets, otter trawls, harpoons, trammel nets, weirs, stake row nets, and seines (Smith 1985, Van Den Avyle 1984). Many authors have cited commercial over-harvesting as the single major cause of the precipitous decline in abundance of Atlantic sturgeon (Ryder 1888, Vladykov and Greely 1963, Hoff 1980, ASMFC 1990, Smith and Clugston 1997). The ASMFC 1990 FMP stated that recreational hook and line fishing in the U.S. is insignificant but noted an emerging directed sport fishery for Atlantic sturgeon in the Canadian maritimes. There is no evidence that a recreational fishery ever developed in the U.S. for Atlantic sturgeon. General information is presented below on both directed and incidental catch of Atlantic sturgeon and is followed by more specific information on harvest by river system.

3.2.1. Directed Harvest

Harvest records indicate that fisheries for sturgeon were conducted in every major coastal river along the Atlantic coast at one time and were concentrated during the spawning migration (Smith 1985). By 1860, commercial fisheries were established in Delaware, Georgia, Maryland, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, and Virginia (Smith 1990). Records of landings were first kept in 1880 when the U.S. Fisheries Commission started compiling statistical information on commercial fishery landings (ASMFC 1990). Harvest in these early years was heavy, and approximately 3350 mt (7.4 million lbs) were landed in 1890 (Smith and Clugston 1997). The majority of the fishery for a 50-year time period (from 1870-1920) was conducted on the Delaware River and the Chesapeake Bay System with New Jersey and Delaware reporting the greatest landings. Landings reported until 1967 likely included both Atlantic and shortnose sturgeon. Shortnose sturgeon were granted Federal protection in 1967; therefore, harvest has been illegal in subsequent years. During the 1970s and 1980s, the focus of fishing effort shifted to South Carolina, North Carolina, and Georgia, which accounted for nearly 80% of the total U.S. landings (64 mt). Catch between 1990 and 1996 (average 49 mt) was centered in the Hudson River and coastal areas of New York and New Jersey (Smith and Clugston 1997).

The ASMFC 1990 FMP summarized the history of Atlantic sturgeon exploitation but cautioned that one should not infer that the reported historic landings approximated sustainable yields for sturgeon fisheries. Instead, it was hypothesized that the data more likely depict rapid over exploitation leading to stock collapse and recruitment failure. By 1990, six jurisdictions prohibited sturgeon landings: Pennsylvania, Potomac River Fisheries Commission, District of Columbia, Virginia, South Carolina, and Florida. There were two kinds of management measures in states that allowed harvest: seasons and size limits. However, among the states in which harvesting was legal, only Georgia had a size limit which allowed females the opportunity to spawn once before being harvested (ASMFC 1990). The 1990 FMP concluded that the species was capable of sustaining only very modest rates of annual exploitation. It also included the management recommendation that each state should control harvest to increase spawning biomass through one of the following three means: 1) by adopting either a minimum total length of at least seven feet (2.13 m) and instituting a monitoring program that has mandatory reporting of commercial landings; 2) institute a moratorium on all harvest; or 3) if a state did not choose one of these first two options, it could submit alternative measures to the ASMFC Atlantic Sturgeon Plan Review Team for determination of conservation equivalency. By 1996, closures of the Atlantic sturgeon fishery had been instituted in all Atlantic Coast states except for Rhode Island, Connecticut, Delaware, Maryland, and Georgia, all of which adopted a seven-foot (2.13 m) minimum size limit. New York and New Jersey opted for the third choice under the 1990 FMP and instituted a five foot (1.5 m) minimum size limit with seasonal restrictions, quotas, mandatory reporting, and extensive monitoring, until 1996 when the fisheries were closed by the state.

In 1996, a review of the 1990 FMP concluded that the standard seven foot (2.13 m) minimum size mandated in the FMP protected only about 50% of the spawning females and about 80% of the spawning males in the stock. The review further concluded that the five foot (1.5 m) minimum size permitted in New York and New Jersey probably resulted in recruitment overfishing. The 1996 review document noted that New York had exceeded its set quota for both 1994 and 1995 but stated that both New York and New Jersey had committed to further restrictions that would help restore the Hudson stock.

In reviewing historical records of catch and stock abundances, Smith (1985) pointed out that Atlantic sturgeon was in need of immediate protection throughout much, if not all, of its range and suggested that the best strategy might be a total moratorium on exploitation of the species. The 1996 FMP review stated that the 1990 FMP for Atlantic sturgeon would not lead to the recovery of the East Coast stocks and therefore, should be amended. Recommendations in the plan review included a complete moratorium on harvest until 20 year classes were established (20-40 years), enhanced monitoring programs, specifications on the role of cultured fish in stock enhancement and restoration programs, and monitoring and commitment to reduce bycatch if necessary. The plan was adopted in early June 1998. A Canadian commercial fishery still exists, although it is highly regulated by size restrictions, seasonal closures, limited entry in some portions, and quotas.

Despite the fact that the fishery has been closed coastwide since 1995 and in certain states prior to then (NC, 1991; SC, 1985), poaching of Atlantic sturgeon continues and is a potentially significant threat to the species, but the present extent and magnitude of such activity is largely unknown. Instances of documented poaching have occurred since the previous Status Review, several of them very recent, indicating that poaching is contributing to Atlantic sturgeon mortality, and should be considered along with bycatch in other legal fisheries as a factor in assessing present threats. Poaching has been documented by law enforcement agencies in Virginia, South Carolina and New York. In Virginia, Marine Resources Commission law enforcement agents with the Virginia Marine Police, in collaboration with the National Marine Fisheries Service Division of Law Enforcement, arrested commercial fishermen who had killed approximately 95 Atlantic sturgeon from the James and Poquoson rivers, VA, during 1998-1999. The fish documented were purchased by undercover operatives, and the operation was terminated in order to preclude further loss of sturgeon (J. Croft, Virginia Marine Police, Pers. Comm. 2007). Virginia Marine Police indicated that the black market in Virginia continues to currently exist, with fishermen referring to sturgeon as “Canadian bacon.” In South Carolina, Department of Natural Resources law enforcement officers apprehended one individual with a two to three-foot Atlantic sturgeon in a cooler, in late 2006. The fish had been caught in a channel net set for catching shrimp. A commercial fisherman advised U.S. Fish and Wildlife Service staff that at least one other Atlantic sturgeon was killed and filleted for consumption, and also reported that sturgeon are illegally taken and sold during the American shad fishery (M. Sasser, Waccamaw National Wildlife Refuge, Pers. Comm. 2006). In New York, officers of the Department of Environmental Conservation recently arrested a commercial fisherman who had two Atlantic sturgeon in his possession. The fisherman advised the officers that there is a black market for Atlantic sturgeon (G. Colvin, NYDEC, Pers. Comm. 2007). These cases suggest that poaching of Atlantic sturgeon is regularly ongoing, is contributing to mortality, and is likely slowing the rate of recovery that otherwise would occur.

3.2.2. Bycatch

Insight into the extent to which Atlantic sturgeon are caught as bycatch in commercial fisheries and the percent released alive can be obtained from examining: 1) landing records for states without directed sturgeon fisheries, 2) tagging and recapture studies, 3) log books completed by fishermen, 4) the reward program instituted by the USFWS and the state of Maryland, 5) USFWS Coastal Tagging Database, and 6) NMFS observer program. While these data sets cannot provide a complete assessment of Atlantic sturgeon bycatch, these data allow us to gauge the severity of bycatch as a threat to the species. It would be desirable to know the effects of bycatch on each spawning subpopulation, but this would require the following data: 1) the size of the subpopulation in each river; 2) the proportion of sturgeon in each river caught as bycatch as affected by season and area of a fishery, gear type, and fishing effort; 3) the origin of fish captured; 4) the effort level in each of those fisheries; and 5) the mortality rate of sturgeon caught by each gear type. These data do not exist for most spawning subpopulations; however, bycatch of Atlantic sturgeon has been reported in many different fisheries conducted in rivers, estuaries, the nearshore ocean, and the EEZ. Since Atlantic sturgeon spend portions of their lives in all of these habitats, they are subject to incidental capture at greater rates than non-anadromous species. Relative importance of commercial bycatch in the Northeast from rivers, estuaries, territorial ocean waters, and the EEZ can be inferred from tagging and recapture data reported by Delaware DFW tagging studies (Shirey et al. 1997). Atlantic sturgeon from 65-165 cm (TL) were tagged (1,700) in the lower Delaware River from 1991-1997. Atlantic sturgeon recaptures came from commercial fisheries ranging from Maine to North Carolina. The majority of recaptures (61%) came from ocean waters within 4.8 km of shore, 20% of the recaptures came from rivers and estuaries, 18% from the EEZ, and 1% were captured at unreported locations. Similarly, Stein et al. (2004b) examined bycatch of Atlantic sturgeon using the NMFS sea-sampling/observer 1989-2000 database. The bycatch study identified that the majority of recaptures occurred in five distinct coastal locations (Massachusetts Bay, Rhode Island, New Jersey, Delaware, and North Carolina) in isobaths ranging from 10 to 50 m, although sampling was not randomly distributed. Similar results were reported in the Atlantic Coast Sturgeon Tagging Database (USFWS); noting most recaptures occurred off the coast of New Jersey, at the mouth of the Chesapeake Bay, within the Chesapeake Bay, and the eastern portion of the Albemarle Sound, NC (Eyler et al. 2004).

The season in which a fishery is conducted determines whether it can potentially intercept Atlantic sturgeon and if the sturgeon intercepted will survive (i.e., temperature-related mortalities). Stein et al. (2004b) showed that bycatch was the lowest in the ocean during the summer months (July – September); however, bycatch of Atlantic sturgeon in inland waters likely increases during the summer months (as evident from USFWS Tagging Program Data; greatest catches occur in May and June). Adults migrating to spawn can be intercepted within rivers in the spring in the southern portion of the range and later in the summer in the northern portion. Juveniles can be intercepted in rivers and estuaries when emigrating from nursery habitat or year-round. Fisheries conducted within rivers and estuaries may intercept any life stage, while fisheries conducted in the nearshore and ocean may intercept migrating juveniles and adults.

Target Fisheries of Concern

As mentioned previously, Stein et al. (2004b) examined the bycatch of Atlantic sturgeon using the sea-sampling/observer database (1989-2000) operated by NMFS. Overall, 30 directed fisheries were examined (Table 10). The five greatest bycatch rates were observed in the weakfish-striped bass (*Cynoscion regalis – Morone saxatilis*) fishery (0.1667 catch/monitor trip), followed by northern kingfish (*Menticirrhus saxatilis*), American shad, southern flounder (*Paralichthys lethostigma*) and red hake (*Urophycis chuss*). It should be noted, however, that the NMFS observer database does not have equal coverage among fisheries or months of sampling; thus, bycatch rates can be heavily biased and error rates can be large. For an example, during the years of 2000 – 2004 the NMFS Observer Program (NEFO) observed 71 fisheries, of these fisheries only 18 had more than 100 days-at-sea effort; effort in the other 53 fisheries averaged 20 days-at-sea. Though bias can occur from using the NMFS observer database, similar results were found in the Atlantic Coast Sturgeon Tagging Database where wild Atlantic sturgeon bycatch was observed in the striped bass fishery (43%), followed by flounder (*Paralichthys sp.)* (13%), shad (*Alosa sp.*) (8%), and other unidentified fish (8%) (Eyler 2006).[26] In South Carolina and Georgia, the American shad gill net (52%) and shrimp trawl (39%) fisheries were responsible for the majority of Atlantic sturgeon recaptures in a multi-year tagging program (Collins et al. 1996). While these fisheries have the greatest rate of bycatch, they may not have high associated mortality rates associated; thus, an analysis of primary gear used, season, and length of season are important variables in understanding Atlantic sturgeon mortality in these fisheries.

Since 2000, some Federally targeted fisheries have been modified (i.e., monkfish) or essentially eliminated (i.e., American shad ocean drift net fishery and spiny dogfish fishery) (ASMFC TC 2006), which suggests that these estimates are inapplicable for contemporary fisheries. The ASMFC Atlantic Sturgeon Technical Committee held a meeting on February 1 – 3, 2006, in Norfolk, Virginia to determine how these changes affected bycatch mortality (ASMFC Technical Committee 2006). Based upon the NMFS Observer Program Database, the ASMFC TC concluded:

1) Bycatch losses principally occur in sink-net fisheries, but may be occurring in substantial numbers in trawl fisheries.
2) Absolute number of dead Atlantic sturgeon in sink-net fisheries were similar between the periods 1995-2000 (average = 25/yr) and 2001-2004 (average = 32/yr). This trend, however, must be interpreted with caution because observer coverage varies year to year and across fishery types.
3) Mortality rates for the sink-net fishery are influenced by soak-time.
4) Until the bycatch rate matrix from Stein et al. (1999) can be modified, it is not possible to estimate absolute numbers of Atlantic sturgeon taken as bycatch.
5) Any estimate of bycatch from the NMFS observer dataset will be an underestimate because bycatch is under reported in state waters and no observer coverage exist South Atlantic (NC – FL) US Federal waters.

[26] The Atlantic Coast Sturgeon Tagging Database also contains records on 675 hatchery-reared Atlantic sturgeon.

Gear Effects

Gill nets

Survival of Atlantic sturgeon caught incidentally in gill nets is variable depending on water quality and the manner in which the gear is set and the length of time it is left before being tended (Table 11). Overall, bottom set gill nets incur the greatest mortality of Atlantic sturgeon, compared to other gill nets or types of gear (Stein et al. 2004b). The greatest observed mortality was from gill nets utilized for the monkfish fishery that were set for eleven days and averaged 70% mortality. Common soak times of two to three days averaged 36-50% mortality (NMFS Observer Database). The NEFO also observed high mortality rates in fisheries targeting Atlantic cod (30%). The smallest mortality rate was observed for trawl and pound net fisheries that had 0-0.2% mortality (Stein et al. 2004b, NEFO 2000-2004 data).

Stein et al. (2004b) examined bycatch and mortality of Atlantic sturgeon captured in the sea-sampling/observer program conducted from 1989 – 2000. Overall, 25,035 lbs of Atlantic sturgeon were captured in coastal waters from North Carolina to Maine while observers were onboard.[27] Eighty-four percent of these captures came from sinking gill nets. Only 357 lbs (1%) of sturgeon were captured in drift gill nets that were used in the bluefish and American shad ocean fisheries. Mortalities ranged from 10% to 22% in the drift and sink gill net fisheries, respectively. Stein et al. (2004b) estimated the annual bycatch of Atlantic sturgeon from the sink and drift net fisheries. The sink net fishery captured between an estimated 60,000 – 225,000 lbs of Atlantic sturgeon annually (1986-2000), increasing from 60,000 lbs in 1986 to 150,000 lbs in 2000. Sink net landings likely peaked at an estimated 225,000 lbs in 1996. Despite only 357 lbs of Atlantic sturgeon being observed in the drift net fisheries, these fisheries are evidently prolific, as estimates of annual Atlantic sturgeon catch ranged between 1,000 – 150,000 lbs annually, averaging around 50,000 lbs. Unlike the sink net fishery, the drift net fishery did not increase over the time, but rather remained relatively constant.

The Atlantic Coast Sturgeon Tagging Database has recorded that over 5,000 wild sturgeon have been tagged that were incidentally captured during the period of 1992-2003 (Eyler 2006). Three hundred and sixty eight of these tagged fish have been recaptured, some multiple times. Sixty-two percent of the recaptures came from anchored gill nets; other gear types interacted less with Atlantic sturgeon. The striped bass fishery intercepted the majority of these tagged Atlantic sturgeon using anchored gill nets (64%), drift gill nets (19%), and unspecified gill nets (12%). The NMFS sea-sampling program observed 433 Atlantic sturgeon captures between 2000 – 2004. Of these 433 sturgeon captured, 91% were taken in fixed gill nets, and the mortality rate was 30%. The remainder of the fish was captured in drift gill and purse nets, and trawls, and no mortalities were recorded.

Bycatch information in the Chesapeake Bay system is available primarily for the Maryland portion of the Bay from the reward programs conducted by the USFWS and the state of Maryland. All of the wild captures in this program (N = 1,133) were caught as bycatch from commercial gears. Most captures in Maryland and Virginia were from drift gill nets and pound nets. Since the USFWS reward program was restricted to live captures, few dead sturgeon were

[27] During the period of 1989-1997, some fisheries were targeting Atlantic sturgeon.

reported. It is likely, however, that rates of mortality were low. The gill net fishery, where most mortality is expected, occurs during months when water is cold; thereby, increasing survival of sturgeon caught as bycatch. Most captures in warm water months occurred in pound nets, which are presumed to have zero mortality.

The NCDMF initiated an observer program in April 2004 to monitor bycatch in the Albemarle and Pamlico Sounds. Overall, 42 sturgeon have been observed (April 2004 – December 2005). The majority of those captured were reported in larger mesh gill nets (> 5in stretched mesh) (B. Price, NCDMF, Pers. Comm. 2006). Twelve individuals were captured in the Pamlico Sound, averaging approximately 600 mm TL. Thirty individuals were captured in the Albemarle Sound, averaging 600 mm TL. Two of the Albemarle captures were YOY (< 410 mm TL). Overall, bycatch mortality was relatively low at 12% (5 deaths), with the majority of deaths occurring during the summer (June, April, August).[28]

Most Atlantic sturgeon tagged and recaptured by the Delaware DFW occurred in gill nets (78%), and mortality in anchored gill nets was 10% (C. Shirey, Delaware DFW, Pers. Comm. 1998). Collins et al. (1996) reported a mean mortality rate of 16% and a 20% injury rate of sturgeon caught in staked shad gill nets fished in Winyah Bay in 1994, 1995, and 1996. Atlantic sturgeon were tagged in the Altamaha River, Georgia in 1986-1992 (Collins et al. 1996), with most recaptures (52%) coming from American shad gill net fisheries in Georgia, and the majority of the remainder coming from the shrimp trawl fishery (39%). Somewhat larger rates of mortality have been reported in the Cape Fear River, where a monthly gill net survey has been conducted by the University of North Carolina at Wilmington (UNCW) and NCDMF personnel since 1990. Using 5.5 inch stretched mesh sink gill net and 24 hr soak times, mortality rates ranged from 25% during the periods of 1990 – 1998 and 37% from 2000 – 2004. Greatest mortality rates occurred during the summer months (June-August) where 34 of 69 (49%) sturgeon caught died.[29] In the Mid-Atlantic region, Atlantic sturgeon are caught as bycatch in gill nets and trawls targeting a variety of species including, dogfish, flounder, shad, striped bass, weakfish, and monkfish. Mortality of those taken in gill nets is greater than in trawls, especially in anchored nets fished for extended periods (1-2 days) (C. Shirey, Delaware DFW, Pers. Comm. 1998). Atlantic sturgeon bycatch in Delaware Bay typically occurs from March into May and is associated with the fixed gill net fisheries for a variety of species: primarily American shad, striped bass, weakfish, and white perch. Bycatch mortality, as reported by the Delaware Bay fishers, is low. Of ten Atlantic sturgeon reported captured in anchored gill nets, only one was reported as dead. Many fishery managers believe that Atlantic sturgeon bycatch and mortality are vastly underreported along the Atlantic coast (W. Patrick, NMFS, Pers. Comm. 2006).

Trawls

There are regional differences in how trawl fisheries operate and tow their gear. Trawl duration is generally shorter in northern areas (Maine to North Carolina) and longer from South Carolina and south. Bycatch survival is greater in the colder water temperatures of the north, but in the south, survival of sturgeon is likely to be enhanced by use of various bycatch reduction devices. The ASMFC Stock Assessment assumed a coast-wide value of 5% mortality in trawl fisheries

[28] Other mortalities occurred in January and March.
[29] Soak times are reduced to 4 hr sets during the summer.

(ASMFC 1998b). Stein et al. (2004b) reported no immediate Atlantic sturgeon mortality when captured in trawls over an 11-year period (1989-2000) where over 3,000 lbs of Atlantic sturgeon were captured from North Carolina to Maine. This is similar to NEFO data for the period of 2000-2004 that showed 0.2% Atlantic sturgeon mortality in fish and shrimp otter trawls. All Atlantic sturgeon captured by trawls during the 19 years of Cooperative Winter Tagging Cruises survived (N = 146, 1988 – 2006); however, all tows were 30 minutes or less in duration and all occurred during winter when water temperatures were low (Laney et al. *In prep*).

Observers on vessels in the trawl fisheries ranging from Maine to Maryland in 1990-1994 observed a mean bycatch rate of less than 0.05 kg per day (Kennelly 1996). McKiernan and King (1996) reported no captures of Atlantic sturgeon from 36 sea-days of monitoring trawlers north of Cape Cod during July through November 1996. Observations during the fall and winter of 1997 from Maryland through Massachusetts (both territorial seas and EEZ) found no Atlantic sturgeon in eight sea-days on trawlers. However, observers from the sea-sampling/observer program recorded the capture of 3,784 lbs of Atlantic sturgeon between 1989 and 2000 (Stein et al. 2004b). Estimates of annual landings of Atlantic sturgeon from trawl fisheries were between 100,000 – 200,000 lbs of Atlantic sturgeon yearly, with a peak capture in 1996 where as much as 625,000 lbs were landed. This is similar to sinking and drift gill net fisheries that averaged 100,000 lbs and 50,000 lbs each year, respectively (Stein et al. 2004b).

The trawl fishery accounted for 15% of the recaptures that occurred from Maine to North Carolina in Delaware DFW's 1997 study. Survival in trawl nets was estimated to be 100%. Atlantic sturgeon were tagged in the Altamaha River, GA during 1986-1992, and 39% of the recaptures were from the shrimp and whelk trawl fisheries in Georgia (Collins et al. 1996). One trawl recapture came from North Carolina. Turtle excluder device (TED) and bycatch reduction device (BRD) requirements may reduce Atlantic sturgeon bycatch in Southeast trawl fisheries.

Despite over 3,000 lbs of Atlantic sturgeon being captured in the ocean trawl fishery (as observed in the sea-sampling program) and other surveys also showing relatively large trawl bycatch rates, mortality of Atlantic sturgeon captured by trawls seems to be low, with most surveys reporting 0% mortality. However, these studies do not include post capture mortality or studies of mortality from trawl fisheries conducted in the south where tow times are longer and water temperatures are higher. Overall, trawls do not seem to pose a significant threat to Atlantic sturgeon.

<u>Pound Nets</u>

Some captures were reported in pound nets during the USFWS reward program in the Chesapeake Bay. Survival in pound nets is estimated to be 100% (Kahnle et al. 1998).

3.2.3. Projected Impacts of Bycatch

Because of the data limitations noted above, effects of bycatch at the species level are not readily available. Although there is not an estimate of bycatch mortality for Atlantic sturgeon range-wide due to the lack of data, bycatch mortality can be calculated for areas such as the Hudson

River, Mid-Atlantic and New England ocean fishery (Stein et al. 2004b), and Georgia/South Carolina American shad fishery (Collins et al. 2000b).

To estimate the effects of Atlantic sturgeon bycatch on the Hudson River subpopulation, the ASMFC Stock Assessment Team revised its yield and egg-per-recruit model to identify an F_{50} value for bycatch of the Hudson River stock (ASMFC 1998b).[30] The F_{50} is the fishing rate at which a cohort produces 50% of the eggs that it would produce with no fishing effort. Most fishery models use a less conservative target fishing level at the F_{30} or F_{20} level. The more conservative choice of F_{50} for Atlantic sturgeon is justified by their late age at maturity and because they are periodic spawners (Boreman 1997). The resulting estimate was F_{50} – bycatch = 0.03. This can roughly be interpreted to mean that, in the absence of a directed fishery, 3% of the subpopulation can be removed as bycatch mortality each year, while allowing the subpopulation to remain stable or recover. Mortality rates of 10-40%, 10% and 0% were applied to recaptures in gill nets, trawls, and pound nets, respectively. Resulting estimates of mortality (u) caused by reported bycatch ranged from a high of 0.3% - 1.25% during 1991-1992 to a low of 0.09-0.37% during 1995-1996. This estimate of bycatch mortality is considered to be a lower bound estimate because it assumes a 100% reporting rate of tagged fish, zero tag loss, zero tag-induced mortality, zero delayed mortality, and also ignores sublethal effects. Acknowledging that these levels are lower bound rough estimates, they are well below the F_{50} (3%), and the estimated natural mortality rate of 7% (Kahnle et al. 1998).

However, the ASMFC Technical Committee derived different results in 2006. The ASMFC TC determined that the majority of sink-net fisheries were located within the New York Bight, which is dominated by Hudson River Atlantic sturgeon stock (Waldman et al. 1996, ASMFC TC 2006). Based upon a likely range of Hudson River abundances ranging from 8,000 – 15,000 (Hattala and Kahnle unpublished data), and scenarios of contribution rates of the Hudson River stock to sink-net bycatch numbers (25-100%) the ASMFC TC found:

1. The bycatch observed by Stein et al. (2004), but not yet known for the recent period, is of an amplitude that would substantially curtail recovery of the Hudson River subpopulation.
2. Subpopulations smaller than the Hudson River will experience a higher relative rate of bycatch losses, depressing their recovery rates to a larger degree than the Hudson River subpopulation.
3. Considerable uncertainty exists in how individual subpopulations are impacted by bycatch due to lack of information on constituent population abundances and the degree to which they are taken in regional coastal fisheries.

Collins et al. (2000) investigated the bycatch and mortality rate of Atlantic sturgeon captured in the South Carolina and Georgia American shad gill net fishery (includes stake and drift nets). Two Winyah Bay (South Carolina) commercial fishermen were accompanied in 1994-1995 to estimate the mortality and condition of Atlantic sturgeon captured in the staked gill nets targeted for American shad. Using data collected from these fishermen, extrapolations show that 158 Atlantic sturgeon were captured each year in the American shad fishery in Winyah Bay proper.

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[30] A relatively good relationship with fishers during this period resulted in better estimates of bycatch than currently reported.

The bycatch mortality was 16%, with another 20% of the Atlantic sturgeon damaged in some manner, resulting in the annual bycatch mortality of 25 fish/year and 32 injuries/year.

The Altamaha River (Georgia) was surveyed to determine the magnitude of Atlantic sturgeon bycatch in that river during the American shad fishing season. Overall, 744 sturgeon (both species) were captured in the American shad fishery during the years of 1982-1983. Assuming trends from 1986-1992 Altamaha sturgeon catch data were similar to those in 1982 and 1983, it is expected that 89% (N = 662) of the catch consisted of Atlantic sturgeon. Also assuming 10% mortality (Stein et al. 2004b) as the fishery is dominated by drift gill nets, it is estimated that 33 Atlantic sturgeon [(662 * 0.10) / 2 years = 33 sturgeon] would die each year from the fishery. These data present evidence that bycatch mortality of Atlantic sturgeon in the American shad fishery, at least in South Carolina and Georgia, ranged between 25-33 Atlantic sturgeon/fishery/year.

3.2.4. Scientific Utilization and Recreational Impacts

Overall, scientific collections do not seem to be significantly affecting the status of Atlantic sturgeon as the SRT found few projects directly targeting Atlantic or shortnose sturgeon: 1) Altamaha River tag-recapture study, 2) a Hudson River juvenile index (FWS), 3) sampling program within Long Island Sound, 4) LNG terminal sampling on the Delaware River, 5) the Maryland Reward Program, 6) South Carolina diet study, 7) South Carolina recruitment index study, 8) distribution and abundance study in the Penobscot River, and 9) Delaware River juvenile and subadult monitoring program.

- The Altamaha River tag-recapture study has been underway since 2004 and is funded by NMFS until 2009. Atlantic and shortnose sturgeon are captured by large mesh gill net, trammel nets and trawling. In 2004 and 2005, over 2,000 adult and juvenile Atlantic sturgeon were captured by the principal investigator, with no mortalities (Doug Peterson, UGA, Pers. Comm. 2006).

- From October 2003 to November 2005 in the Hudson River, a total of 562 juvenile Atlantic sturgeon were captured in gill nets, measured, tagged, spine sampled, and released as part of a relative juvenile abundance study performed by the USFWS and NYSDEC (Sweka et al. 2006). No mortalities were observed during the course of the study (Jerre Mohler, USFWS, Pers. Comm. 2006).

- Research efforts directed at Atlantic sturgeon for tagging and food habits studies in Long Island Sound with both trawls and gill nets have resulted in the collection of 219 Atlantic sturgeon through 2005 (T. Savoy, CTDEP, Pers. Comm. 2006). No mortalities took place. Sampling within the Connecticut River (primarily with gill nets) resulted in the collection of 112 Atlantic sturgeon from 1988 through 2004. Seven mortalities (6%) took place up through 2004 as a result of gill net collections where nets excessively entangled fish for various reasons.

- A one-year survey to document the occurrence and distribution of juvenile sturgeon in the Delaware River in the vicinity of Oldmans Creek was initiated in May of 2005. Sampling for juvenile sturgeon was performed using trammel nets and small mesh gill nets. As of December 2005, only 4 juvenile Atlantic sturgeon had been captured, with no mortalities reported (G. Murphy, DFW, Pers. Comm. 2006)

- Within the Chesapeake Bay, the USFWS has been funding the Maryland Reward Program since 1996, which pays fishers $25 for hatchery-reared and $100 for wild sturgeon if the specimen is alive so that they can be measured, weighed, tagged, and released by USFWS personnel. Although sturgeon are sometimes held for long periods of time (days) and restrained by rope in some instances, there are only a few mortalities reported for the reward program.

- In a one-and-a-half year study (ongoing) of Atlantic sturgeon diets in the Savannah and Edisto rivers, approximately 250 subadult and adult sturgeon were lavaged (a non-lethal method of removing stomach contents) to determine diets.[31] No mortalities have occurred (M. Collins, SCDNR, Pers. Comm. 2006).

- For the past 10 years, South Carolina has conducted an annual survey targeting juvenile, especially age-1, Atlantic sturgeon in the Edisto River. The goal of the survey is to develop an index of abundance to estimated year class strength. Annual catches are usually on the order of magnitude of 100 fish, with no mortalities reported (M. Collins, SCDNR, Pers. Comm. 2006).

- A study was initiated in spring 2006 to assess the distribution, abundance and movements of adult and subadult Atlantic sturgeon in the Penobscot River system in Maine. A secondary goal of the study is to assess similar aspects of the ecology of shortnose sturgeon or other diadromous species of concern, where such activities are synergistic with the primary approaches. To date, 62 shortnose sturgeon have been captured and tagged (three mortalities,) and seven Atlantic sturgeon have been captured and tagged (two mortalities) and three have been tagged. This study is ongoing and will continue for at least one additional year.

- The state of Delaware monitors juvenile and subadult Atlantic sturgeon abundance in the lower Delaware River using small mesh gill nets, in addition to tagging and habitat utilization studies. Only one mortality has been observed during >1,700 captures.

Scientific studies directed at other species also have the potential to intercept sturgeon on a sporadic basis and may result in Atlantic sturgeon mortalities, as these studies are not specifically designed to capture and release live sturgeon. It is not possible for the SRT to identify all of these studies. However, the following are some of the studies which are known to the SRT and have the potential to take Atlantic sturgeon:

- The Cape Fear River Survey has been operating continuously since 1997. The objective of the survey is to document relative abundance of fish species within the river, especially sturgeon, using large mesh gill nets (5 in stretched meshed) and electrofishing. Prior to 2002, the gill net survey was conducted by UNCW and intercepted 88 Atlantic

[31] Only 12 of the 250 sturgeon examined were adults, which were collected from the Edisto River.

sturgeon, of which 22 (25%) were killed. The greatest mortality occurred during periods of highest water temperature (Moser et al. 1998). Since 2002, this survey has been continued by the NCDMF, and they have reported mortality rates of 37% overall. Similar to earlier findings, mortality was highest during the summer months (June-August), averaging 49% (34 of 69 sturgeon died) (F. Rohde, NCDMF, Pers. Comm. 2006).

- The Pamlico Sound Independent Gill Net Survey has been conducted since 2001, targeting striped bass and all other finfish species using an array of gill net mesh sizes. Overall, 14 sturgeon have been captured, with 0 mortalities reported. [F. Rohde, NCDMF, Pers. Comm. 2006).
- The Albemarle Sound Independent Gill Net Survey has been conducted since 1990, also targeting striped bass and other finfish species using an array of gill net mesh sizes. As of October 2005, 842 sturgeon had been captured with 67 mortalities (8%) (F. Rohde, NCDMF, Pers. Comm. 2006).
- The NMFS-USFWS Winter Tagging Cruise has been conducted since 1988, which is generally conducted in the nearshore Atlantic Ocean from Cape Lookout, NC to Cape Charles, VA. The trawl survey targets striped bass and as a result also captures a large variety of other species. From 1988 to 2006, 146 juvenile Atlantic sturgeon were captured, ranging from 0 to 23 fish captured per year. There have been no mortalities.
- Overall, there have been 54 Atlantic sturgeon captured in the Northeast Trawl survey from 1984 to 2004. No mortalities have been reported.
- The Connecticut Department of Environmental Protection Marine Fisheries Division has been monitoring abundance and distribution of finfish and selected invertebrates since 1984 with a stratified random trawl survey (three bottom types, four depth intervals). A total of 355 Atlantic sturgeon have been collected from 1984 through 2004, with no apparent mortalities from the trawl.

Of these projects described above, only the Cape Fear River Survey seems to have a high rate of mortality that could be affecting the status of that subpopulation. To reduce mortality, however, NCDMF has reduced soak times when water temperatures are above 30° C (F. Rohde, NCDMF, Pers. Comm. 2006). Given the relatively low numbers of mortalities identified in the majority of these studies, it does not seem that scientific sampling poses a significant threat to Atlantic sturgeon.

3.2.5. River Specific Overutilization Information

<u>Gulf of Maine DPS</u>

<u>Maine Rivers</u>

Maine had one of the earliest sturgeon fisheries with export back to England taking place as early as 1628. Commercial sturgeon landing statistics (shortnose and Atlantic sturgeon) are generally only available from the late 1800s. Landings peaked in the late 1800s and early 1900s and collapsed by the 1920s. Although there is the occasional story of anglers foul hooking large sturgeon, there was never a directed recreational fishery for this species. Regulations were passed in 1992 to make it illegal to take, catch, or possess Atlantic sturgeon in the state of Maine.

Penobscot River - Maine

Historical accounts of the Penobscot River are very limited; however, Atlantic sturgeon were utilized by native Americans. When there was substantial fishing effort for Atlantic salmon and American shad in the Penobscot River in the early 1800s there was no mention of a large sturgeon fishery. This suggests that there may not have been a large run of Atlantic sturgeon on the Penobscot River at the time.

Estuarial Complex of the Kennebec River - Maine

In 1628, the estuarial complex of the Kennebec River probably supported the largest fishery for Atlantic sturgeon in the State of Maine. This fishery occurring at the head-of-tide on the Androscoggin River persisted intermittently until 1675 (Wheeler and Wheeler 1878). Atkins (1887) described the Kennebec fishery as being an important intermittent fishery, which flourished into the 18th and early part of the 19th centuries. The last major landings on the Kennebec occurred in 1849 when 160 tons of sturgeon were landed (Atkins 1887).

There are no major commercial fisheries occurring in the estuarial complex of the Kennebec and Androscoggin rivers, but there are limited gill net fisheries for menhaden, alewives, blueback herring, sea herring, and mackerel. The use of purse, drag, and stop seines, and gill nets, with the exception of those that do not exceed a maximum stretch of 87.5 mm, are prohibited. If the nets are fixed or anchored to the bottom, they have to be tended continuously and hauled in and emptied every two hrs. There has been no reported or observed bycatch of Atlantic sturgeon.

From 1977-2000, a total of 20 mortalities of subadult Atlantic sturgeon occurred in the MEDMR gill net sampling program out of a total catch of 117 subadults. The relatively large mortality rate of subadult Atlantic sturgeon has been noted by other researchers (Collins et al. 1996, Stein et al. 2004b). Kieffer and Kynard (1993) attributed the large mortality rates of subadults captured in gill nets to the presence of dense dermal ossifications, which prevented the net strands from sliding beyond the operculum, and thus, restricting ventilation.

Merrimack River – New Hampshire and Maine

Jerome et al. (1965) stated that the Merrimack River had a very important Atlantic sturgeon fishery during colonial days and that it lasted until the late 1800s. In the early 1600s, the Merrimack River was known as one of the two best sturgeon fishing areas in the colonies. In 1882, Massachusetts passed a law enacting a minimum 30 cm (12 inch) stretched mesh for taking sturgeon. In 1887, only two tons were taken by 'visiting fishermen,' and it was generally considered that the fishery was eliminated.

Currently, there is an inshore permit fishery (for finfish) that occurs; however, these permits restrict gear to 100 foot drift gill nets that must be attended at all times. No overnight sets are allowed (K. Creighton, MAFWE, Pers. Comm. 2006). There are also offshore fisheries for dogfish, cod, and striped bass, which are susceptible to take sturgeon as bycatch, although mortality is relatively low (K. Creighton, MAFEW, Pers. Comm. 2006).

New York Bight DPS

Taunton River – Rhode Island and Massachusetts

Currently, there is an inshore permit fishery that occurs; however, these permits restrict gear to 100 foot drift gill nets that must be tended at all times. No overnight sets are allowed (K. Creighton, MA FWE, 2006). There are also offshore fisheries for dogfish, cod, and striped bass that are known to take Atlantic sturgeon as bycatch, although mortality is relatively low (K. Creighton, MA FWE, 2006).

Connecticut River – Massachusetts and Connecticut

Reported landings are only available since 1989. Prior to a Connecticut harvest moratorium in 1997, licensed fishermen were limited to a catch of three Atlantic sturgeon per day or per trip, whichever was the longer period of time. This was further restricted in 1992 with an increase in the minimum size from 122 cm to 213 cm TL. Recreational angler catches have been documented but are not generally thought to be a significant source of mortality for Atlantic sturgeon in Connecticut waters. Several other catches are known or suspected, but all Connecticut catches are dominated by immature or juvenile sturgeon.

Bycatch may occur in commercial fisheries, but legal possession of Atlantic sturgeon was prohibited in freshwaters of the state of Connecticut in 1973 and from Long Island Sound in 1997. Bycatch is known to take place in the commercial shad fishery that operates in the lower Connecticut River from April-June with large mesh gill nets (14 cm minimum stretched mesh).

Scientific monitoring for shortnose sturgeon and other species has resulted in the capture of 131 Atlantic sturgeon in the Connecticut River and 360 in Long Island Sound since 1984. Seven mortalities (6% in Connecticut River) have occurred, but scientific monitoring is thought to be a minor source of mortality. Collection of sturgeon for research purposes requires a scientific collector's permit and an annual report of the collections made.

Hudson River – New York

Atlantic sturgeon of the Hudson River Estuary have supported subsistence or commercial fishing since colonial times. Atlantic sturgeon were known to be taken occasionally by hook and line, but the recreational fishery was considered negligible in New York and New Jersey. Reported commercial landings of Atlantic sturgeon are available for New York from 1880-1996. Until 1980, most landings were from the Hudson River. After 1980, landings occurred from both the Hudson River and along Long Island. Largest annual landings of the time series (231 mt) occurred in 1898, after which landings quickly dropped to 15 mt or less per year and remained at low levels through the early 1980s. Fishing has been an important factor affecting abundance of Atlantic sturgeon in the Hudson River estuary for most of this century. In 1985, following the closure of the Atlantic sturgeon fishery in South Carolina, effort and harvest increased substantially in both New York and New Jersey to satisfy market demand. The commercial fishery harvested different sturgeon life stages in the river and ocean. The Hudson River fishery targeted adults during their spawning run. The ocean fishery along Long Island and New Jersey caught a few non-spawning mature adults but targeted juveniles, most of which were immature coastal migrants.

Consistent with the ASMFC FMP for Atlantic sturgeon, New York began to monitor harvest in 1990 and also initiated a population modeling study to determine acceptable levels of harvest from the Hudson River stock. In 1993-1995, New York regulated the Atlantic sturgeon fishery with size limits, seasons, area closures, and quotas derived from preliminary population modeling. As more data became available, it became apparent that the Hudson River stock was being overfished. In 1996, New York implemented a harvest moratorium, and New Jersey instituted a zero quota.

The American shad gill net fishery in the Hudson River Estuary incidentally captures sub-adult Atlantic sturgeon (< 1m). Atlantic sturgeon bycatch was greatest in the early 1980s and steadily decreased until the mid-1990s, and since then has begun to increase slightly. It is likely that the drop in abundance of juveniles in the late 1980s was in response to accumulated removals of older immature and mature fish from the subpopulation starting in the mid-1980s. Atlantic sturgeon are still recovering from fishing efforts in the late 1980s and early 1990s as apparent from current CPUE abundances of approximately two, which are at least one-fourth of that from 15 years ago (CPUE ~ 8) (CPUE = number per $yd^2 * hrs * 10^{-3}$ of net fished). Similarly, as noted above in Section 3.2.3, the ASMFC TC determined that sink-net fisheries operating in the New York Bight alone have the potential to curtail the recovery of the Hudson River subpopulation (ASMFC TC 2006).

Delaware River – New Jersey, Delaware, Pennsylvania

Landings data in the Delaware Estuary are available from 1880 through the present, with the greatest landings of 3,350 mt occurring in 1888. Overfishing was the most likely cause of the dramatic decline in landings and presumably in abundance of Delaware River Atlantic sturgeon in the early 1900s. No landings were reported after 1993 (1,524 kg), and the directed fishery was closed on April 1, 1998.

Recaptures from approximately 1,700 immature fish tagged by the Delaware DFW in the lower Delaware River from 1991-1997 occurred over a wide range of commercial gears in estuaries and the near-shore ocean from Maine through North Carolina (C. Shirey, Delaware DFW, Pers. Comm. 1998). Lowest survival of sturgeon captured as bycatch occurred in gill nets (87%). Overall, almost 90% of Atlantic sturgeon caught as bycatch were reported to be released alive. Current commercial fisheries in the Delaware Bay gill net fishery include striped bass, American shad, white perch, Atlantic menhaden, and weakfish. The majority of these landings occurs in March and April, but bycatch mortality of sturgeon during this period is typically low (C. Shirey, DNREC, Pers. Comm., 2005).

Chesapeake Bay DPS

Chesapeake Bay and Tributaries (Potomac, Rappahannock, York, James, Susquehanna, Nanticoke) – Maryland, Virginia, Pennsylvania.

During the late 1800s, the Chesapeake Bay supported the second greatest caviar fishery in the eastern United States (Murawski and Pacheco 1977). In the early 1900s, the subpopulation collapsed. Depletion of spawning stocks of Atlantic sturgeon in the Chesapeake Bay and elsewhere is often attributed to a period of high exploitation occurring in the late 1800s (Murawski and Pacheco 1977; Secor and Waldman 1999). Juvenile and subadult Atlantic sturgeon are routinely taken as bycatch throughout the Chesapeake Bay in a variety of fishing gears, including gill nets, pound nets, and fyke nets. Of the hundreds of sturgeon held for examination in the Maryland and Virginia reward programs, only a few fish were determined to be in poor physical condition, although it is important to note that the program was designed to examine live specimens for the reward to be granted (J. Skjeveland and A. Spells, USFWS, Pers. Comm. 1998).

Low rates of sturgeon bycatch mortality were also reported for striped bass gill nets (0-8%) and American shad staked gill nets (4%) within the Chesapeake Bay (Hager 2006). A multitude of other estuarine fisheries exist within the Chesapeake Bay, but these fisheries are not expected to have large rates of bycatch mortality either.

Carolina DPS

Albemarle and Pamlico Sound – North Carolina

Data on Atlantic sturgeon bycatch in the Albemarle and Pamlico Sound come from three sources 1) NCDMF independent gill net surveys (IGNS) that were initially designed to monitor striped bass, 2) NCDMF Observer Program and 3) NC Sea Grant Fishery Resource Grant project that examined sturgeon bycatch in the flounder fishery (White and Armstrong 2000). The Albemarle and Pamlico IGNS used identical gear, which consisted of sinking and floating gill nets ranging from 2.5-10 inch stretched mesh and 439 m long. Only a few fish have been captured in the Pamlico Sound gill net survey since 2000, although 842 Atlantic sturgeon were captured in the Albemarle Sound between 1990-2005. The size range of the fish captured in the Albemarle Sound was from 153 to 1000 mm FL and averaged 472 mm FL. Atlantic sturgeon were entangled in stretched mesh ranging from 2.5 – 9.0 inches, but the majority (76%) were captured in mesh sizes of 2.5-4.5 inches stretched mesh. These mesh sizes are similar to those used by shad/herring and the flounder fisheries.

The NCDMF Observer Program sampled both the Albemarle and Pamlico Sound monthly from April 2004 to December 2005. Thirty Atlantic sturgeon were observed in the Albemarle Sound, and 12 Atlantic sturgeon were observed in the Pamlico Sound. The majority of these observations occurred in large mesh gill nets (> 5 in mesh), where only six trips were made in the small mesh gill net fishery. Overall, Atlantic sturgeon averaged 600 mm TL and ranged from 355 to 820 mm TL. Only two of these individuals were YOY and they were captured in the Albemarle Sound. Overall, five (12%) observed mortalities were reported, occurring in June 2004 and April, August, January, and March 2005.

Similarly, the sturgeon bycatch and mortality in the Albemarle Sound flounder fishery included the capture of 131 Atlantic sturgeon in flounder gill nets fished from 1998-2000 by a single fishermen (White and Armstrong 2000). Of the 131 Atlantic sturgeon captured, no mortalities were reported, although four individuals were noted as having minor injuries. Other fisheries (spiny dogfish, ocean shrimp, flounder, and American shad) in the Albemarle and Pamlico Sound and Cape Fear River reported catches of zero to two sturgeon per fishery per year, including flounder fisheries. These data indicate that underreporting of sturgeon bycatch is occurring at extreme levels in this area. Additional fisheries also exist that could accidentally capture sturgeon in North Carolina including: spot (*Leiostomus xanthurus*), white perch (*Morone americana*), yellow perch (*Perca flavescens*), catfish (*Ictalurus sp.),* striped bass, and river herring.

Cape Fear River – North Carolina

A gill net survey conducted in the Cape Fear River by UNCW personnel noted that twenty-five percent of sturgeon intercepted (22 of 88 caught) were killed. The gill nets were set one day, checked the second, and retrieved on the third. The greatest mortality occurred during periods of highest water temperature (Moser et al. 1998). Since 2002, this survey has been continued by the NCDMF, and they have reported mortality rates of 37% overall. Similar to earlier findings, mortality was greatest during the summer months (June-August), averaging 49% (34 of 69 sturgeon died) (F. Rohde, NCDMF, Pers. Comm. 2006). There are no estimates of bycatch in fishery dependent surveys.

Winyah Bay (Waccamaw, Great Pee Dee, Black, Sampit) – South Carolina

During the mid-1970s, nearly 50% of all U.S. landings of Atlantic sturgeon came from this area (Smith and Dingley 1984). However, the fishery was almost entirely restricted to coastal waters outside the Bay, making it impossible to assign landed fish to a particular subpopulation. The fishery in South Carolina was closed in 1985. The Bay is currently fished by gill net fishers targeting American shad. This fishery in the Bay has an estimated bycatch of 158 Atlantic sturgeon per year of which 16% die (25) and another 20% are injured to some degree (Collins et al. 1996). Shad fishers also operate within the rivers, but neither effort nor average numbers of Atlantic sturgeon encountered are known. Poaching of adult Atlantic sturgeon has been reported from the Winyah Bay area in recent years. Carcasses of large females have been found with the ovaries (caviar) removed.

Santee and Cooper Rivers – South Carolina

The mouth of Santee River is just south of Winyah Bay and has the largest shad landings in the Southeast (D. Cooke, SCDNR, Pers. Comm. 2006) likely resulting in similar mortality and injury of sturgeon captured in the Winyah Bay shad fishery. Upriver bycatch levels are unknown. The Cooper River also has an active hook and line shad fishery, because gill nets are restricted (D. Cooke, SCDNR, Pers. Comm. 2006).

South Atlantic DPS

ACE Basin (Ashepoo, Combahee, Edisto) – South Carolina

There was a directed commercial fishery for Atlantic sturgeon in this system prior to the 1985 fishery closure. The commercial sturgeon fishery operated in the lower and middle portions of both the Combahee and Edisto rivers. Commercial shad fisheries captured some juvenile Atlantic sturgeon, but most fishermen operate upriver from the areas of greatest abundance during that time of year. The shrimp trawl fishery in St. Helena Sound also captures juveniles, as evident from tag returns.

Port Royal Rivers (Broad and Cosawatchie) – South Carolina

Although a few commercial sturgeon fishers apparently operated in this area prior to 1985, the landing of only one Atlantic sturgeon has been recorded (Smith and Dingley 1984). Little, if any, shad fishing takes place in this system. It is not known whether there is any significant bycatch in the shrimp trawl fishery in this area.

Savannah River – South Carolina and Georgia

During 1989-1991, the commercial shad gill net fishery's bycatch included more endangered shortnose sturgeon than juvenile Atlantic sturgeon, which is considered unusual. Collins et al. (1996) reported that two commercial fishermen collected 14 fish over the period of 1990-1992, averaging seven Atlantic sturgeon/fisher/year. It seems that abundance within the Savannah River is extremely low, as evident from low bycatch and reported captures over the last 15 years. Thus, bycatch may be an issue if abundance is low and fishing effort is high.

Ogeechee River – Georgia

Bycatch in the shad fishery is a concern because evidence suggests that this Atlantic sturgeon subpopulation is stressed and that complete recruitment failure has occurred in some years. Bycatch mortality in the estuarine and lower river shad fishery is of particular concern, but no estimates of take are available.

Altamaha River – Georgia

Juvenile Atlantic sturgeon tagged (N = 1,534) in this river were recaptured primarily by shad gill nets (52%) and shrimp trawls (39%) (Collins et al. 1996). Estimated annual total bycatch of Atlantic sturgeon in the shad gill net fishery in the tidal portion of the river during 1982-1983 averaged 372 sturgeons (both species) (Collins et al. 1996). Percent mortality was not determined in the drift gill nets and was probably minimal. Juvenile Atlantic sturgeon from this river are relatively abundant in comparison to other rivers in the region, so a large percentage of the individuals in winter mixed-stock aggregations on the shelf are likely from this river. Most sturgeon occurring as shrimp trawl bycatch are from mixed-stock aggregations.

Assuming a 10% bycatch mortality rate from drift nets (Stein et al. 2004b), it is expected that 33 Atlantic sturgeon are taken each year as bycatch mortality. This estimate was made in the early 1980s, and it is likely that bycatch has increased as the sturgeon subpopulation has increased.

Satilla River – Georgia

Shad fishing effort is low in this river due to an apparently depleted shad population. However, because the Atlantic sturgeon subpopulation is depleted and highly stressed, any bycatch mortality could have an impact on the subpopulation.

3.2.6. Summary and Evaluation

Commercial fisheries for Atlantic sturgeon in the late 1800s led to significant reductions in population size. Population sizes were further reduced by overfishing during the 1970s through the early 1990s. In 1990, the ASMFC adopted an FMP, which made management recommendations to the coastal states for greater reduction of exploitation. In early 1998, a complete moratorium on possession of Atlantic sturgeon was implemented both in state and Federal waters, which eliminated the threat of both directed catch and bycatch incentives to retain Atlantic sturgeon. Furthermore, Amendment 1 to the ASMFC's FMP formalizes the moratorium as a mandatory compliance measure in all jurisdictions, and it can not be lifted for a spawning stock until 20 protected year classes of mature females are established. Since then, there has been some circumstantial evidence that the moratorium is allowing some recovery as the length of Atlantic sturgeon captured off North Carolina (a mixed stock) has been increasing since 1986, averaging 800 mm TL in 1986 and 1100 mm TL in 2003 (Laney et al. *In prep*). In the same survey, Atlantic sturgeon measuring greater than 1200 mm TL were first captured in 1997, which could possibly be the result of reduced fishing pressure.

Atlantic sturgeon are caught as bycatch in various commercial fisheries along the entire U.S. Atlantic Coast within inland, coastal, and Federal waters. While Atlantic sturgeon caught incidentally can no longer be landed, bycatch could still be a threat if they are injured or killed in the act of being caught. Bycatch mortality rates range between 0-51%, with greatest mortality occurring in sink gill nets. Mortality associated with bycatch has been estimated as high as 1400 deaths a year during the years of 1989 – 2000 in the ocean fisheries ranging from North Carolina to Maine (Stein et al. 2004b). These estimates are no longer considered applicable to contemporary fisheries due to changes in fishery practices and amount of effort (ASMFC TC 2006). However, the ASMFC TC reevaluated the impacts of bycatch on Atlantic sturgeon in 2006 and determined: 1) that bycatch losses principally occur in sink-net fisheries still and 2) the number of observed dead Atlantic sturgeon in sink-net fisheries was similar between the periods of 1995-2000 and 2001-2004[32]. The ASMFC TC also note that any estimate of bycatch from the NMFS ocean observer dataset will be an underestimate because bycatch is under reported in state waters and no observer coverage exist in South Atlantic (NC – FL) US Federal waters. Inland American shad gill net fisheries in two southern locations (Winyah Bay and Altamaha River) were estimated to capture 530 sturgeon, of which 58 Atlantic sturgeon likely die as a result of being captured.

Overall, these estimates suggest that bycatch could have a substantial impact on the status of Atlantic sturgeon, especially in rivers or estuaries that do not currently support a large subpopulation (< 300 spawning adults per year). Atlantic sturgeon are considered to be more

[32] This trends, however, must be interpreted with caution because observer coverage varies year to year and across fishery types (ASMFC TC 2006).

sensitive to fishing mortality as they are a long-lived species, have an older age at full maturity, have lower maximum fecundity values, and 50% lifetime egg production occurs later in life than other coastal species with no fishing mortality (Boreman 1997). Efforts should be made to better quantify data on bycatch levels and fishing effort to determine if specific river population estimates are valid for other river subpopulations as bycatch rates are vastly underreported (ASMFC 2005). This information will also allow more refined estimates of bycatch and potential impacts on the rate of recovery of individual river subpopulations.

There is no evidence that mortality associated with scientific research poses a significant threat to the species or to individual river subpopulations. However, bycatch mortality on the Cape Fear River, NC suggests that methods such as setting gill nets overnight as a method to capture Atlantic sturgeon should be used sparingly and under the appropriate conditions (e.g., water temperature, DO concentrations). There is no evidence that recreational fishing poses a threat to Atlantic sturgeon as the species is not a target of recreational fishers in the United States.

3.3. Competition, Predation, and Disease

3.3.1. Competition and Predation

Atlantic sturgeon are benthic predators and may compete for food with other bottom-feeding fishes and invertebrates including suckers (*Moxotoma sp*.), winter flounder (*Pleuronectes americanus*), tautog (*Tautoga onitis*), cunner (*Tautagolabrus adspersus*), porgies (Sparidae), croakers (Sciaenidae), and stingrays (*Dasyatis sp*.) (Gilbert 1989). Specific information concerning competition between Atlantic sturgeon and other species over habitat and food resources is scarce. There are no known exotic or non-native species that compete directly with Atlantic sturgeon. There is a chance that species such as suckers or other bottom forage fish would compete with Atlantic sturgeon, but these interactions have not been elucidated.

The relationship between the Federally endangered shortnose sturgeon and the Atlantic sturgeon has recently been explored. Shortnose sturgeon are sympatric with Atlantic sturgeon throughout most of their range. Larger, adult shortnose are suspected to compete for food and space with juvenile Atlantic sturgeon in rivers of co-occurrence (Pottle and Dadswell 1979, Bain 1997). Haley and Bain (1997) found that while shortnose and Atlantic sturgeon overlap in their use of the lower estuary, the overall distribution of the two species differed by river kilometers, providing evidence that Atlantic and shortnose sturgeon partition space within the Hudson River despite co-occurrence in channel habitats. This finding is consistent with Kieffer and Kynard (1993) who found that subadult Atlantic and adult shortnose sturgeon in the Merrimack River, MA were spatially separate except for brief use of the same saline reach in the spring. Kahnle and Hattala (1988) conducted late summer-fall bottom trawl collections in the lower Hudson River Estuary from 1981-1986 and found that most shortnose sturgeon occupied rkm 55-60 in water depths of greater than six meters. Even though there was overlap in river miles, there was separation by water depth. In Georgia, the distributions of adult shortnose and juvenile Atlantic sturgeons overlap somewhat, but Atlantic sturgeon tend to use more saline habitats than shortnose sturgeon (G. Roger, formerly Georgia DNR, Pers. Comm. 1998).

Juvenile shortnose sturgeon apparently avoid competition for food with Atlantic sturgeon in the Saint John River, Canada by spatial separation, but adult shortnose may compete for space with similar-sized juvenile Atlantic sturgeon (Dadswell et al. 1984). Haley and Bain (1997) analyzed stomach contents of Atlantic and shortnose sturgeon in the Hudson River using gastric lavage and found clear differences in their diets. Polychaetes and isopods were primary foods retrieved from Atlantic sturgeon while amphipods were the dominant prey obtained from shortnose sturgeon.

Very little is known about natural predators of Atlantic sturgeon. The presence of bony scutes are likely effective adaptations for minimizing predation of sturgeon greater than 25 mm TL (Gadomski and Parsley 2005). Documented predators of sturgeon (*Acipenser sp*.) include sea lampreys (*Petromyzon marinus*), gar (*Lepisosteus sp.*), striped bass, common carp (*Cyprinus carpio*), northern pikeminnow (*Ptychocheilus oregonensis*), channel catfish (*Ictalurus punctatus*), smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreus*), grey seal (*Halichoerus grypus*), fallfish (*Semotilus corporalis)* and sea lion (*Zalophus californianus*) (Scott and Crossman 1973, Dadswell et al. 1984, Miller and Beckman 1996, Kynard and Horgan 2002, Gadomski and Parsley 2005, Fernandes 2006, Wurfel and Norman 2006). In contrast to these findings, Moser et al. 2000 tested whether flathead catfish (*Pylodictus olivaris*) preyed on shortnose sturgeon (30 cm) in a controlled system, and despite sturgeon being the only prey available none were consumed. However, Gadomksi and Parsely (2005) tested at what size white sturgeon were preyed upon by channel catfish, northern pikeminnow, walleyes, and prickly sculpins (*Cottus asper*). Their results found that channel catfish (mean TL = 472 mm), northern pikeminnow (mean TL = 464 mm), and prickly sculpin (mean TL = 126 mm) fed on juvenile sturgeon of an average size of 121 mm TL, 134 mm TL, and 50 mm TL, respectively. Oddly, similar size walleye (~470 mm TL) rarely fed on white sturgeon, but juvenile walleye (mean TL = 184 mm) consumed sturgeon with a mean size of 59 mm TL. Gadomski and Parsley (2005) suggest that these findings indicate that predation could play an important role in sturgeon recovery. Similarly, Brown et al. (2005) concluded that the "…introduction of [flathead catfish] has the potential to adversely affect ongoing anadromous fish restoration programs and native fish conservation efforts in the Delaware and Susquehanna basins." The same concern has been stated by fishery management agencies for south Atlantic river basins where flathead catfish are firmly established and have reached significant biomass, significantly altering native fish assemblages and biomass in the process. There is, however, no current evidence that predation rates on Atlantic sturgeon are elevated above "natural" levels.

3.3.2. Disease

Little information is available on diseases of Atlantic sturgeon. Since disease-related mortality is primarily documented in aquaculture facilities rather than in wild populations (Post 1983), the absence of large-scale controlled propagation of Atlantic sturgeon limits availability of disease information.

Appy and Dadswell (1978) examined Atlantic sturgeon from the Saint John River estuary, New Brunswick, Canada for parasites. They documented the presence of trematodes (flatworms), including *Nitzchia sturionis* on the gills of juveniles, *Derogenes varicus* in the esophagus, and *Deropristis hispida* in the spiral valve of the adult Atlantic sturgeon. The nematode (roundworm) *Truttaedacnitis sphaerocephala* and the acanthocephalan (thorny-headed worm) *Echinorhynchus* "gadi" complex were reported in the spiral valve of adults. In the same investigation, an arthropod, *Dichelesthium oblongum*, was observed in the gill cavity of an adult Atlantic sturgeon. The digenetic trematode, *Deropristis hispida* was also reported causing Distomiasis disease in Atlantic sturgeon taken from Raritan Bay, NJ (Murawski and Pacheco 1977). Another case involving a *Nitzchia sturionis* infestation was reported in 2006, this time from an adult held in captivity, which was captured from the main stem of Chesapeake Bay. In the 1995 field collection of Hudson River broodstock by the USFWS-NEFC, Lamar, PA, one adult sturgeon was found harboring *Argulus* sp. This ectoparasite is fairly common on juvenile Atlantic sturgeon in Georgia and South Carolina (M. Collins, unpublished data). However, Hoffman (1967) states that parasites are always present in natural populations, and fish are infected by a considerable range of species. Epizootics caused by parasites do not normally occur unless some environmental event alters the equilibrium between the parasites and the free-living community.

The Fish Health Unit-NEFC maintains files from 65 diagnostic cases dealing with Atlantic sturgeon captured in the wild and held at the NEFC. Files are also maintained on their hatchery-reared offspring. The majority of cases involved fish from the NEFC, Fish Technology Section, in Lamar, PA, while two cases involved fish received from the Harrison Lake National Fish Hatchery in Charles City, VA and one from Maryland. The data comprise details on disease assays conducted on 17 captive adults, 65 juveniles and subadults, 125 yearlings, 80 fingerlings, and 200 fry sampled since 1991. The common fish fungus *Saprolegnia* species was diagnosed on fish in seven cases and on Atlantic sturgeon eggs during incubation. External protozoan parasite infestations reported from the skin and gills include *Chilodonella*, *Ichthyobodo* (Costia), *Trichodina* and *Colponema* species. Internally, *Hexamita* species was observed in the intestinal tract. Numerous bacteria were also isolated from these cases. The following list comprises those species of bacteria that have been known to cause disease in other fish species and have been implicated as a possible cause of disease in a particular diagnostic case: *Streptococcus* sp.; *Vibrio* sp.; *Aeromonas hydrophila*; S*erratia liquqefaciens*; *Vibrio anguillarum*; *Flavobacterium columnare* (*Flexibacter columnaris*); *Aeromonas salmonicida*; and *Pasteurella haemolytica*. An unknown anomaly involving overinflation of the swim bladder in 0+, 2, and 3-year old cultured Atlantic sturgeon led to equilibrium problems and eventual death for many of these fish. Nutritional deficiencies were suspected, but no conclusive diagnosis was made (Fish Health Section case history records, 1991-1997). Overinflated swim bladders in age 0+ progeny cultured from eggs taken from Saint John River adults has also been observed (M. Litvak, University of New Brunswick, Pers. Comm. 1998). An unidentified systemic fungus infection was observed histologically through many organs of fingerling Atlantic sturgeon which were subjects in a feeding experiment (V. Blazer, Leetown Science Center, Pers. Comm. 1998). *Edwardsiella tarda* was isolated from Atlantic sturgeon fingerlings within ten days of a shipment in Florida, in 1999. Affected fish had not been handled well during shipment and may have been subject to high water temperatures while in transit due to flight delays en route. Mortality from this epizootic approached 50 % of the population (R. Francis-Floyd, Florida Sturgeon Culture Risk Assessment Workshop, 2000 Proceedings).

At the USFWS Bear's Bluff Hatchery, South Carolina, shortnose sturgeon that were collected several years ago as broodstock have been exhibiting some signs of stress from an unknown vector. The symptoms have been present since the hatchery received the shortnose broodstock, and only appear during the fall when shortnose sturgeon exhibit lesions on their body. The larger broodstock fish become lethargic, while offspring sometimes die. Hatchery officials have sent tissue samples of the lesions to two different labs, each have noted that the health issue is related to a virus, but each lab cited a different virus as the cause. In at least one year following the lab experiments, however, viruses were not detected and thus the symptoms could have been related to bacteria. Overall, the hatchery officials do not know what is causing the problem, but they do think it related to the environment conditions within Bears Bluff lab, because the sturgeon do not exhibit the same symptoms at a separate hatchery facility.

Atlantic sturgeon were also experimentally challenged with white sturgeon (*Acipenser transmontanus*) herpesvirus type-2 (WSHV-2). Waterborne exposure produced mortality, as well as clinical signs of infection, including hemorrhagic lesions and ulcers on both dorsal and ventral surfaces and particularly around the mouth (R. P. Hedrick and T. S. McDowell, University of California at Davis, Pers. Comm. 1998).

Susceptibility of Atlantic sturgeon to another west coast virus, the white sturgeon iridovirus (WSIV), is suspected but has not been demonstrated. WSIV is of concern because it is assumed to be carried by wild sturgeon and has been shown to cause significant mortalities in cultured sub-yearling white sturgeon (LaPatra et al. 1994). Transfers of carrier fish from the West Coast to the East Coast could create serious consequences for future Atlantic sturgeon aquaculturists and may pose a significant threat to East Coast populations of wild sturgeon if they, in fact, are shown to be susceptible to the virus.

LaPatra et al. (1995) demonstrated that a rhabdovirus, infectious hemotopoietic necrosis virus (IHNV), can be carried by white sturgeon. IHNV is one of the most lethal diseases of salmonids, but currently the disease is confined to the western United States. While LaPatra et al. (1995) states no mortality has been reported in sturgeon exposed to IHNV, there is concern among fish health biologists that any movement of sturgeon carrying the IHNV virus to the East Coast could spread the disease to salmonid populations with potentially devastating consequences.

The potential spread of fish pathogens from one geographic area to another is possible. Currently, there are several regulations or documents that apply to movement of fish or fish eggs from one area within the United States or for import into the United States from other countries. Included among them are: 1) 50 Code of Federal Regulations, Part 16 – Salmonid Importation Regulations; 2) the Lacey Act (18 U.S.C.); 3) the USFWS Health Policy (713 FW 1-4); 4) North Atlantic Salmon Conservation Organization (NASCO) – Protocols for the Introduction and Transfer of Salmonids (NAC [92]24 and NAC [94]14); 5) Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES); 6) laws promulgated by individual states; and 7) the ESA (16 U.S.C.). Although 50 CFR-Part 16, the USFWS Health Policy, and the NASCO Protocols control movement of salmonid fish and eggs and require fish health inspection prior to shipment, they offer no protection from pathogens that might be transferred to Atlantic sturgeon populations from movement of infected fish or eggs of non-salmonid species. All sturgeon species worldwide were afforded CITES protection on April 1, 1998, and Atlantic sturgeon received protection in 1975. However, CITES permitting requirements for moving sturgeon from one country to another do not have a fish health component (M. Maltese, USFWS, Pers. Comm. 1998). The ESA might be used to prevent non-listed sturgeon species from being moved from one geographic area to another or to require disease certification prior to movement, but it would be difficult to show why such action would be necessary to protect a listed sturgeon species given the current state of knowledge concerning Atlantic sturgeon disease or disease susceptibility. The Lacey Act makes it unlawful to import, export, sell, acquire, or purchase fish, wildlife or plants taken, possessed, transported, or sold: 1) in violation of U.S. or Indian law or 2) in interstate or foreign commerce involving any fish, wildlife, or plants taken, possessed or sold in violation of state or foreign law. There are no Federal laws regulating the movement of infected fish or eggs or requiring fish health inspections of non-salmonid species.

The potential for non-indigenous pathogens emanating from aquaculture facilities is being addressed by the ASMFC. Section 3.6.2 of Amendment 1 to the Interstate Fishery Management Plan for Atlantic Sturgeon recommends that public aquaculture facilities should be certified as disease-free. The Amendment further recommends that member states submit annual reports on the status of aquaculture operations and disease-free certification.

Protection of Atlantic sturgeon from non-indigenous pathogens would have to come from state laws, but because laws among the states along the eastern seaboard vary widely, they offer no real protection for the species over its entire range. For example, some states require a permit before any fish can be imported across their borders, while others require a permit only if a species is on their exotic species list (sturgeon are generally not on those lists). Also, some states do not regulate what fish might be reared by aquaculturists but require a permit only if the fish are to be stocked, and others have no restrictions. Permit requirements by the states are aimed principally at preventing introduction of non-native species and generally do not involve a fish health component.

Infection could conceivably arise from white sturgeon or other sturgeon species sold as pets in the aquarium trade and subsequently released into the wild. White sturgeon have been imported into North Carolina and possibly other East Coast states and sold in the aquarium trade. It is unclear whether a ban imposed by a fishery management agency on importation of a species would apply to the pet industry.

3.3.3. Summary and Evaluation

As benthic feeders, Atlantic sturgeon may compete with other bottom-feeding fishes and invertebrates for food, but there is no evidence of abnormally elevated interspecific competition. A potentially competitive relationship between shortnose and Atlantic sturgeon in the Hudson River is the only one studied in any detail. Results indicate that while shortnose and Atlantic sturgeon may overlap in their use of channel habitats, there are differences in their distribution by river kilometers, by depth, and the two species exhibit clear differences in diet.

While concerns have been raised regarding the potential for increased predation on juvenile Atlantic sturgeon by introduced flathead catfish (Brown et al. 2005 and others), Atlantic sturgeon subpopulations seem to be coexisting with flatheads in the Cape Fear River, NC, and Altamaha River, GA (where flatheads have been present for many years), at least in the absence of any directed fisheries for Atlantic sturgeon. Gadomski and Parsley (2005), however, have shown that catfish and other species do prey on juvenile sturgeon; thus, further research is warranted to determine at what level, if any, flatheads and other exotic species prey upon juvenile Atlantic sturgeon and to what extent such predation is affecting the sturgeon subpopulations.

While some disease organisms have been identified from wild Atlantic sturgeon, they are unlikely to threaten the survival of the wild populations. Disease organisms commonly occur among wild fish populations, but under favorable environmental conditions, these organisms are not expected to cause population-threatening epizootics. There is concern that non-indigenous sturgeon pathogens could be introduced, most likely through aquaculture operations. Due to this threat of impacts to wild populations, the ASMFC recommends requiring any sturgeon aquaculture operation to be certified as disease-free.

The aquarium industry is another possible source for transfer of non-indigenous pathogens or non-indigenous species from one geographic area to another, primarily through release of aquaria fish into public waters. With millions of aquaria fish sold to individuals annually, it is unlikely that such activity could ever be effectively regulated. Definitive evidence that aquaria fish could be blamed for transmitting a non-indigenous pathogen to wild fish (sturgeon) populations would be very difficult to collect (J. Coll and J. Thoesen, USFWS, Pers. Comm. 1998).

3.4. Existing Regulatory Authorities, Laws and Policies

As a wide-ranging anadromous species, Atlantic sturgeon are subject to numerous Federal (U.S. and Canadian), state and provincial, and inter-jurisdictional laws, regulations, and agency activities. Following is a list of the most important laws and government policies affecting Atlantic sturgeon and its habitat.

3.4.1 International Authorities

<u>Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)</u>

To ensure that commercial demand does not threaten their survival in the wild, many animal and plant species are protected through a system of permits by this international treaty that regulates trade in listed species. The full species *Acipenser oxyrinchus* has been listed under CITES Appendix II since 1975 (50 CFR 23.23). Appendix II includes species that may become threatened with extinction if trade is not regulated. Appendix II specimens require an export permit from the country of origin or re-export. Such permits are issued as long as the exportation is not detrimental to species' survival and the specimens were legally acquired. The USFWS Office of Management Authority administers CITES in the U.S. and processes any applications for Atlantic sturgeon export permits.

<u>Canadian Authorities</u>

Jurisdiction for sturgeon fisheries in Canada rests with the Canadian Department of Fisheries and Oceans (DFO) in the Maritime Provinces and with the provincial government in Quebec (B. Jessop, DFO, Pers. Comm. 1998).

Maritime Provinces

As of 2006, there were eight commercial licenses for directed Atlantic sturgeon harvest in the Maritimes, eight on the Saint John River, New Brunswick and one on the Shubenacadie River, Nova Scotia (R. Bradford, DFO, Pers. Comm. 2006). There are no sturgeon licenses in the Gulf of Saint Lawrence areas of New Brunswick, Nova Scotia, or Prince Edward Island, although small amounts of bycatch are reported (less than 0.3 tons per year in the last 10 years). Licenses are non-transferable and terminate with the death of the existing licensee, and new licenses are not available. Each license authorizes specific amounts of gear, with the nine New Brunswick licensees authorized a total of 2800 meters of gill net, while the single Nova Scotia licensee is authorized two set gill nets of unspecified length. The legal minimum mesh size is 33 cm (13 inches), the minimum size limit for fish harvest is 120 cm (48 inches), and the season is closed from June 1-30 to protect spawning fish. Retention of sturgeon bycatch has been prohibited throughout the Maritime Provinces since 1995 (B. Jessop, DFO, Pers. Comm. 1998).

Quebec

The Quebec Ministere de l'Environnement et de la Faune regulates the Saint Lawrence River Atlantic sturgeon fishery. A total harvest quota of 6,000 fish (approximately 60 mt) has been in effect since the spring of 1997, along with a size limit of 100-150 cm TL. Harvest quotas are enforced by issuing a specified number of tags to each commercial fisherman. The fishing season runs from May 1 – September 30, and all fishing zones are in brackish waters of the estuary (F. Caron, Quebec Ministere de l'Environnement et de la Faune, Pers. Comm. 1998).

3.4.2 U.S. Interstate/Federal Authorities

Atlantic States Marine Fisheries Commission (ASMFC) and Enabling Legislation

Authorized under the terms of the Atlantic States Marine Fisheries Compact, as amended (P.L. 81-721), the purpose of the ASMFC is to promote the better utilization of the fisheries (marine, shell, and anadromous) of the Atlantic seaboard "by the development of a joint program for the promotion and protection of such fisheries, and by the prevention of the physical waste of the fisheries from any cause."

Given management authority in 1993 under the Atlantic Coastal Fisheries Cooperative Management Act (16 U.S.C. 5101-5108), the ASMFC may issue interstate FMPs that must be administered by state agencies.[33] If the Commission believes that a state is not in compliance with a coastal FMP, it must notify the Secretaries of Commerce and Interior. If the Secretaries find the state not in compliance with the management plan, the Secretaries must declare a moratorium on the fishery in question. To date, this has only happened once when a state was not found in compliance with the striped bass coastal FMP.

[33] ASMFC was given management authority earlier in 1984 under the Atlantic Striped Bass Management Act, but authority was limited to that fishery. The Atlantic Coastal Fisheries Cooperative Management Act of 1993 and amendments gave ASMFC management authority for other interstate coastal species.

In 1998, the ASMFC amended the 1990 Atlantic Sturgeon Management Plan and established a moratorium for Atlantic sturgeon commercial fishing until 20 year classes of adults were established, thus closing the fishery for 20 – 40 years. Since the closure of the fishery, some subpopulations have shown signs of possible recovery while others have not.

Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA)

Authorized under the terms of the ASMFC Compact, as amended (P.L. 103-206), the Secretary of Commerce can implement EEZ regulations that are compatible to ASMFC FMPs in the absence of an approved Magnuson-Stevens FMP. Also, funding is provided to ASMFC, Atlantic Coast states, NMFS, and USFWS to conduct activities that are supportive of ASMFC FMPs. As mentioned previously, effective May 27, 1999, NMFS prohibited the take of Atlantic sturgeon in the EEZ. This rule followed the closure of the state waters under the ASMFC moratorium on the Atlantic sturgeon fishery.

Magnuson-Stevens Act (16 U.S.C. 1801 et. seq.)

This Act provides regional fishery management councils with authority to prepare plans for the conservation and management of Federally-managed fisheries in the EEZ, including the establishment of necessary habitat conservation measures. Essential Fish Habitat (EFH), including freshwater habitats for anadromous species, may also be delineated for species with approved Federal FMPs. Federal FMPs, approved by regional fishery management councils (which are different from the ASMFC), focus on management in the EEZ (3-200 miles) rather than state waters. An alternative mechanism for restricting harvest in the EEZ exists through NMFS' regulations based on recommendations in an ASMFC-approved FMP. Federal fishery management plans prepared under this statute must establish standardized reporting methodologies to assess the amount and type of bycatch occurring in the fishery and include conservation and management measure that, to the extent practicable, minimize unavoidable bycatch and bycatch mortality.

The Magnuson-Stevens Act was reauthorized on October 11, 1996 and again in 2006. The 1996 reauthorization directed the Regional Fishery Management Councils (Councils) and the Secretary of Commerce to describe and identify EFH in fishery management plans, including identification of adverse impacts from both fishing and mechanisms to enhance EFH. Although EFH is identified only for species managed under a Federal FMP, Councils are required to comment on any activity that is likely to substantially affect the habitat of an anadromous fishery resource under its authority. An anadromous fishery resource under a Council's authority is defined as an anadromous species that inhabits water under the Council's authority at some time during its life. The South Atlantic Fishery Management Council has decided to include a description of essential fish habitat for both anadromous and catadromous species in its Habitat Plan, which includes Atlantic sturgeon habitat.

The 2006 reauthorization sought to preserve and strengthen the Councils by establishing Council training programs, clarifying MSAs conflicts of interest and recusal requirements, and ensured that Council members and Scientific and Statistical Committees (SSC) disclose any financial conflicts of interest. The MSA reauthorization also mandated the use of allowable catch levels to prevent overfishing and preserve sustainable harvest; established national guidelines for limited access privilege programs; improved the uniformity of decision making for FMPs and aligns them with National Environmental Policy Act processes; improved data collection for better management; increased the role of science in decision making processes by defining roles of the SSC; and strengthened leadership in international conservation and management activities.

Lacey Act 1981 (16 U.S.C 3371-3378)

In addition to foreign, Federal, or tribal prohibitions, the Lacey Act makes it a Federal crime to import, export, and engage in interstate transport of any fish or wildlife taken in violation of a state law. By providing for Federal prosecution of state fish and wildlife laws and more stringent penalties, the Lacey Act further deters interstate transport of illegally-possessed Atlantic sturgeon.

Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531-1543)

The Endangered Species Act provides for the conservation of plant and animal species Federally listed as threatened or endangered. Atlantic sturgeon, as an unlisted species, may derive benefits from the Federal agency consultation requirements for the endangered shortnose sturgeon, where their ranges and conservation needs coincide. For example, restrictions imposed on ACOE dredging activities to protect shortnose sturgeon may also provide some protection to Atlantic sturgeon (R. St. Pierre, USFWS, Pers. Comm. 1998). To predict impacts from a proposed activity, Federal agencies may agree to fund studies to learn how a threatened or endangered species uses an area. In rivers, such as the Tar-Pamlico, Neuse, and Roanoke rivers in North Carolina, where only Atlantic sturgeon are documented to occur, no indirect protection via the ESA is afforded (S. Bolden, NMFS, Pers. Comm. 2006). Also, Atlantic sturgeon may not benefit from seasonal dredging restrictions to protect shortnose sturgeon spawning as spawning seasons for the two species do not coincide (T. Squiers, MEDMR, Pers. Comm. 1998).

Federal Power Act (FPA) (16 U.S.C. 791-828) and amendments

This Act, as amended, provides for protecting, mitigating damages to, and enhancing fish and wildlife resources (including anadromous fish) impacted by hydroelectric facilities regulated by FERC. Applicants must consult with state and Federal resource agencies who review proposed hydroelectric projects and make recommendations to FERC concerning fish and wildlife and their habitat, e.g., including spawning habitat, wetlands, instream flows (timing, quality, quantity), reservoir establishment and regulation, project construction and operation, fish entrainment and mortality, and recreational access. Section 10(j) of the Act provides that licenses issued by FERC contain conditions to protect, mitigate damages to, and enhance fish and wildlife based on recommendations received from state and Federal agencies during the licensing process. With regard to fish passage, Section 18 requires a FERC license to construct, maintain, and operate fishways prescribed by the Secretary of the Interior or the Secretary of Commerce. Under the Act, others may review proposed projects and make timely recommendations to FERC to represent additional interests. Interested parties may intervene in the FERC proceeding for any project to receive pertinent documentation and to appeal an adverse decision by FERC.

While the construction of hydroelectric dams contributed to some historic losses of Atlantic sturgeon spawning habitat, only a few new dams have been constructed in the range of this species in the last 50 years. The lack of successful fish passage devices for Atlantic sturgeon and the degradation of upstream habitat due to impoundment of the former free-flowing river, limit opportunities for this species to benefit from FPA fishway requirements during the re-licensing of existing hydroelectric dams.

Anadromous Fish Conservation Act (16 U.S.C. 757a-757f) as amended

This law authorizes the Secretaries of Interior and Commerce to enter into cost sharing with states and other non-Federal interests for the conservation, development, and enhancement of the nation’s anadromous fish. Investigations, engineering, biological surveys, and research, as well as the construction, maintenance, and operations of hatcheries, are authorized. Surveys for Atlantic and shortnose sturgeon in New Hampshire (T. Squiers, MEDMR, Pers. Comm. 1998), tag and release studies in Delaware Bay (C. Shirey, Delaware DFW, Pers. Comm. 1998), and research on juvenile Atlantic sturgeon in the ACE Basin, SC (M. Collins, SC DNR, Pers. Comm. 1998) are examples of work funded by NMFS under this law. Research on other species conducted under this act has yielded data on Atlantic sturgeon; for example, striped bass studies in New York have furnished information on juvenile Atlantic sturgeon (A. Kahnle, New York State DEC, Pers. Comm. 1998).

Fish and Wildlife Coordination Act (FWCA) (16 U.S.C. 661-666)

The FWCA is the primary law providing for consideration of fish and wildlife habitat values in conjunction with Federal water development activities. Under this law, the Secretaries of Interior and Commerce may investigate and advise on the effects of Federal water development projects on fish and wildlife habitat. Such reports and recommendations, which require concurrence of the state fish and wildlife agency(ies) involved, must accompany the construction agency’s request for congressional authorization, although the construction agency is not bound by the recommendations. Typical FWCA recommendations for maintenance dredging include construction “windows” to avoid times and locations where Atlantic sturgeon may be spawning.

The FWCA applies to water-related activities proposed by non-Federal entities for which a Federal permit or license is required. The most significant permits or licenses required are Section 404 and discharge permits under the Clean Water Act and Section 10 permits under the Rivers and Harbors Act. The USFWS and NMFS may review the proposed permit action and make recommendations to the permitting agencies to avoid or mitigate any potential adverse effects on fish and wildlife habitat. These recommendations must be given full consideration by the permitting agency but are not binding.

Federal Water Pollution Control Act, and amendments (FWPCA) (33 U.S.C. 1251-1376)

Also called the "Clean Water Act," the FWPCA mandates Federal protection of water quality. The law also provides for assessment of injury, destruction, or loss of natural resources caused by discharge of pollutants.

Of major significance is Section 404 of the FWPCA, which prohibits the discharge of dredged or fill material into navigable waters without a permit. Navigable waters are defined under the FWPCA to include all waters of the United States, including the territorial seas and wetlands adjacent to such waters. The permit program is administered by the ACOE. The EPA may approve delegation of Section 404 permit authority for certain waters (not including traditional navigable waters) to a state agency; however, the EPA retains the authority to prohibit or deny a proposed discharge under Section 404 of the FWPCA.

The FWPCA (Section 401) also authorizes programs to remove or limit the entry of various types of pollutants into the nation's waters. A point source permit system was established by the EPA and is now being administered at the state level in most states. This system, referred to as the National Pollutant Discharge Elimination System (NPDES), sets specific limits on discharge of various types of pollutants from point source outfalls. A non-point source control program focuses primarily on the reduction of agricultural siltation and chemical pollution resulting from rain runoff into the nation's streams. This control effort currently relies on the use of land management practices to reduce surface runoff through programs administered primarily by the Department of Agriculture.

Like the Fish and Wildlife Coordination and River and Harbors Acts, Sections 401 and 404 of the FWPCA have played a role in reducing discharges of pollutants, restricting the timing and location of dredge and fill operations, and affecting other changes that have improved Atlantic sturgeon habitat in many rivers and estuaries over the last several decades. Examples include reductions in sewage discharges into the Hudson River (A. Kahnle, New York State DEC, Pers. Comm. 1998) and nutrient reduction strategies implemented in the Chesapeake Bay (R. St. Pierre, USFWS, Pers. Comm. 1998).

Rivers and Harbors Act of 1899

Section 10 of the Rivers and Harbors Act requires a permit from the ACOE to place structures in navigable waters of the United States or modify a navigable stream by excavation or filling activities.

National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321-4347)

NEPA requires an environmental review process of all Federal actions. This includes preparation of an environmental impact statement for major Federal actions that may affect the quality of the human environment. Less rigorous environmental assessments are reviewed for most other actions, while some actions are categorically excluded from formal review. These reviews provide an opportunity for the agency and the public to comment on projects that may impact fish and wildlife habitat.

Coastal Zone Management Act (16 U.S.C. 1451-1464) and Estuarine Areas Act

Congress passed policy on values of estuaries and coastal areas through these Acts. Comprehensive planning programs, to be carried out at the state level, were established to enhance, protect, and utilize coastal resources. Federal activities must comply with the individual state programs. Habitat may be protected by planning and regulating development that could cause damage to sensitive coastal habitats.

Federal Land Management and Other Protective Designations

Protection and good stewardship of lands and waters managed by Federal conservation agencies, such as the Departments of Defense and Energy (as well as state-protected park, wildlife and other natural areas), contributes to the health of nearby aquatic systems that support important Atlantic sturgeon spawning and nursery habitats. Relevant examples include the Great Bay, Rachel Carson's and ACE Basin National Estuarine Research Reserves, Department of Defense properties in the Chesapeake Bay, and many National Wildlife Refuges.

Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA), Titles I and III and the Shore Protection Act of 1988 (SPA)

The MPRSA protects fish habitat through establishment and maintenance of marine sanctuaries. This Act and the SPA regulate ocean transportation and dumping of dredge materials, sewage sludge, and other materials. Criteria that the ACOE uses for issuing permits include considering the effects dumping has on the marine environment, ecological systems and fisheries resources.

Framework for the Management and Conservation of Paddlefish and Sturgeon Species in the United States

Prepared in 1993 by the National Paddlefish and Sturgeon Steering Committee (including representatives of the USFWS, several state agencies, the private aquaculture community, and academia), this document proposed a framework for the conservation of eight species of paddlefish and sturgeon (including both *Acipenser oxyrinchus* sub-species). The document carries no regulatory force but is intended to foster partnerships among agencies and organizations with an interest in the conservation of sturgeon species. Strategies include research on life history, population characteristics, and habitat requirements; development and coordination of culture and stocking protocols; habitat protection; mitigation of threats from over-harvest; public information and education; and national coordination of conservation efforts.

3.4.3. State Authorities

As noted under discussion of interstate authorities above, all fifteen states, the District of Columbia, and the Potomac River Fisheries Commission have closed their directed fisheries and prohibited landings of Atlantic sturgeon. Prohibitions on sturgeon landings in at least six of these jurisdictions (Pennsylvania, District of Columbia, Potomac River Fisheries Commission, Virginia, South Carolina, and Florida) pre-date 1990. At least four states presently list the

Atlantic sturgeon under state statutes for the recognition and/or protection of rare species. Atlantic sturgeon are listed as endangered in Massachusetts and as threatened in Rhode Island, Connecticut, and Pennsylvania (Northeast Nongame Technical Committee 1996). Protections afforded under the Massachusetts Endangered Species Act include a ban on take in rivers and within the three-mile offshore limit, as well as prohibitions on possession (T. French, Massachusetts DFW, Pers. Comm. 1998). Similar protections are provided under the Connecticut statute: the Connecticut DEP is required to review any project that requires a state permit and may affect Atlantic sturgeon (J. Victoria, Connecticut DEP, Pers. Comm. 1998). Recognition of their vulnerable status is the primary protection afforded to threatened species under the Rhode Island endangered species statute (C. Raithel, Rhode Island DFW, Pers. Comm. 1998). Pennsylvania law forbids taking, catching, killing, possessing, importing or exporting from the Commonwealth, selling, offering for sale any threatened species without a special permit (A. Shields, Pennsylvania Fish and Game Commission, Pers. Comm. 1998).

A variety of state laws may be employed by authorities to reduce threats of accidental release and transmission of diseases into wild Atlantic sturgeon populations from non-indigenous and cultured Atlantic sturgeon. For example, Georgia state law requires wild animal licenses that could be conditioned to prevent escapement for fish held in a system from which water may be discharged. Georgia state regulations also authorize state agencies to prohibit importation of fish or fish eggs that might spread diseases harmful to endemic fish populations (Shipman 1998).

In addition to laws focusing directly on harvest and other population management practices, state and local governments implement a wide variety of laws and regulations that effect the habitat of Atlantic sturgeon. These include laws effecting development in sensitive watersheds, forest practices, waste water discharges, and other activities. Efficacy of these laws to protect sturgeon habitat may be extremely variable and depends on the standards imposed, the types of activities and land areas and water designations by states, such as the designations of Significant Tidal Habitat on the Hudson River in New York and of Primary Nursery Areas in North Carolina contribute to Atlantic sturgeon habitat quality (A. Kahnle, New York State DEC, Pers. Comm. 1998).

3.4.4. Summary and Evaluation

Current regulatory mechanisms have effectively removed threats from legal, directed harvest in the U.S. as well as incentives for retention of bycatch. Formal adoption of a long-term coast-wide moratorium by the ASMFC occurred in June 1998. As requested by ASMFC, the EEZ was also closed by NMFS in 1999. Atlantic sturgeon fisheries in Canada are almost exclusively located at, or above, estuarine reaches of the rivers, and there is currently no evidence that sturgeon of U.S. origin migrate into Canadian rivers in great numbers.[34] Therefore, it is unlikely that Canadian fisheries pose a meaningful threat to fish of U.S. origin.

State and Federal agencies are actively employing a variety of legal authorities to implement proactive restoration activities for this species, and coordination of these efforts is being furnished through the ASMFC. Due to existing state and Federal laws, water quality and other habitat conditions have improved in many riverine habitats, although many systems still have

[34] Only one of 99 Atlantic sturgeon tagged in the Kennebec was returned in Canadian waters.

DO and toxic contaminants issues and habitat quality continues to be affected by dredging and/or alternating natural flow conditions. Remediation of continuing habitat deficiencies will require improved understanding of Atlantic sturgeon habitat needs, the factors adversely affecting habitat, and aggressive implementation of aquatic habitat protection measures.

3.5. Other Natural or Manmade Factors Affecting its Continued Existence

3.5.1. Impingement and Entrainment

The withdrawal of water directly from a river or water body for commercial uses may negatively impact the recovery of Atlantic sturgeon, as larvae, YOY, or small juveniles may become impinged on intake screens or entrained.[35] These impacts can be especially severe when intake structures are located in or near spawning grounds where smaller life stages of fishes are less active (i.e. drift) and are susceptible to intake flows (Carter and Reader 2000). Along the range of Atlantic sturgeon, most, if not all, subpopulations are at risk of possible entrainment or impingement in water withdrawal intakes for commercial uses, municipal water supply facilities, and agricultural irrigation intakes. For example, in North Carolina, over two billion gallons of water per day were withdrawn from the Cape Fear, Neuse, Tar, and Roanoke rivers in 1999 by agriculture (39 Million Gallons a Day (MGD)) and non-agricultural (1,982 MGD) industries (NCDNR 2006). However, the impacts of water withdrawal are dependent on the species, time of year, location of the intake structure, and the strength of the intake current; thus, it is hard to provide general impact estimates as each site is unique. Currently, there are only three surveys that have shown the impacts of water withdrawal on Atlantic sturgeon: 1) Hudson River Utility Surveys, 2) Delaware River Salem Power Plant survey, and 3) Edwin I. Hatch Nuclear Power Plant:

- The Hudson River has six power plants located between river km 34 – 74, which overlaps with known nursery grounds for Atlantic sturgeon larvae and early juveniles (located at rkm 43 – 100). Of the six power plants located in this area, the Danskammer, Roseton, Lovett, and Indian Point pose the greatest risk to Atlantic sturgeon, as the Bowline Point is located farther downriver and withdraws water from a collection pond. Intensive surveys (24 hr/day, four to seven days/week, and 10 – 12 weeks/year during the spring) conducted from 1972- 1998 examining entrainment and impingement of fish species only reported eight entrained sturgeon (larvae) and 63 impinged shortnose sturgeon (majority 200 – 700 mm) (Applied Science Associates 1999).[36] Entrained sturgeon species only occurred at the Danskammer Point Plant where four shortnose larvae and four unidentified sturgeon yolk sac larvae were observed during the spring in 1983 and 1984. Impingement of sturgeon occurred most often at the Danskammer Point Plant, averaging 4.2 – 5.2 impinged fish per year, followed by Indian Point (1.5 – 2.3 fish/year), Roseton (1.5 – 1.8 fish/year), Bowline Point (0 – 0.9 fish/year) and Lovett Point (0 fish per year). During the periods of 1989 to 1996, a total of five shortnose sturgeon was impinged

[35] Impingement is the entrapment of an organism on a water intake structure due to negative pressure (e.g., held against an intake filter screen). Entrainment is when the organism is entrapped within the intake structure.
[36] Only a few of these power plants conducted impingement and entrainment surveys throughout the period of 1972-1998, others conducted survey until take was found to be insignificant or intake structures were modified to reduce take.

(0.6/year) from the Roseton and Danskammer plants. Other plants (Bowline Point and Lovett) reported zero impingements during this period or were not sampled (Indian Point 1991-1996 no sampling).

- The Salem power plant located on the Delaware River/Bay has the potential to take sturgeon species via impingement or entrainment. During the years of 1991 – 1999, a total of eight shortnose sturgeon were reported as impinged. These fish were all juveniles greater than 400 mm TL.

- The Edwin I. Hatch Nuclear power plant (HNP) is located 11 miles north of Baxley, Georgia. The Plant uses a closed-loop system for main condenser cooling that withdraws from, and discharges to the Altamaha River via shoreline intake and offshore discharge structures. Preoperational drift surveys were conducted weekly from February through May in 1973 and every six weeks from June through December 1973. Cataostomids, cyprindis, and centrarchids were the dominant ichthyoplankton families collected. Only two *Acipenser* sp. larvae were collected during the drift surveys. Entrainment samples at HNP were collected for the years 1975, 1976, and 1980. Samples were collected weekly during 1975 and 1976, and monthly in 1980. No *Acipenser* sp. were observed in the entrainment survey (Sumner 2004).

Though most rivers have multiple intake structures which remove millions of gallons a day during the spring and summer months, it is believed that the migratory behavior of larval sturgeon allows them to avoid intake structures for the most part, since migration is active and occurs in deep water (Kynard and Horgan 2002). Effluent from these facilities can also affect subpopulations, as some facilities release heated water that acts as a thermal refuge during the winter months, but drastic changes in water temperature have the potential to cause mortality.

3.5.2. Ship Strikes

Dredging provides safe passage for commercial shipping and recreational boat traffic. With the increase in boating traffic, the potential for sturgeon to be struck by boats is greater, and this seems to happen commonly. Without surveys in place, ten adult Atlantic sturgeon were found in the Delaware River in 2004, six in 2005, and six to date in 2006 that were evidently struck by a passing ship or boat (Kahnle et al. 2005, Murphy 2006) (Figure 23). This observation is not unique as four to eight sturgeon are reported each spring to DFW, and these fish are usually 120 cm to 240 cm in length. Based on the external injuries observed, it is suspected that these strikes are from ocean going vessels and not smaller boats, although at least one fisher reported hitting a large sturgeon with his small craft (C. Shirey, DNREC, Pers. Comm. 2005). Similarly, five sturgeon were reported to have been struck by commercial vessels within the James River, VA in 2005, and one strike per five years is reported for the Cape Fear River. Subpopulations may be affected by these incidental strikes. It is unknown what the overall impact of boat strikes is to Atlantic sturgeon subpopulations, but in small subpopulations (< 300 spawners/year) the loss of any spawning adults could have a substantial impact on recovery. Locations that support large ports and have relatively narrow waterways seem to be more prone to ship strikes (e.g., Delaware, James, and Cape Fear rivers).

3.5.3. Artificial Propagation and Atlantic Sturgeon

Artificial propagation of Atlantic sturgeon for use in restoration of extirpated subpopulations or recovery of severely depleted wild subpopulations has the potential to be both a threat to the species and a tool for recovery. If conducted both in accordance with published guidelines and protocols (ASMFC 2006) and as part of a planned recovery program, artificial propagation may increase population numbers. Artificial propagation for commercial purposes can also be beneficial or detrimental to the species. Providing a cultured product to the market can remove the need to legally and illegally harvest wild stocks. However, aquaculture can make enforcement of a ban on possession of wild stock more difficult by enabling the disguising of poached wild animals as captive-produced. For example, enforcement of a ban on possession of wild stock becomes problematic if possession of cultured stock is permitted. Culture can also introduce the potential for disease or genetic impacts to wild stocks.

Historically, there have been six individuals or organizations that have performed artificial propagation of Atlantic sturgeon and achieved some degree of success. The first recorded propagation of the species was done on the Hudson River in 1875 by Seth Green and Aaron Marks of the New York State Fish Commission. By combining gametes removed from ripe fish during the spawning migration, about 100,000 fry were hatched over a two-week period as reported in the book: <u>Fish Hatching and Fish Catching</u> (Green 1879). Workers reported difficulty in simultaneously obtaining ripe fish of both sexes.

John Ryder (1890) studied Atlantic sturgeon and the sturgeon industry on the East Coast of the United States. He also performed culture experiments on the Delaware River, near the extreme eastern end of the Chesapeake and Delaware Canal, at the suggestion of the U.S. Commissioner of Fish and Fisheries, Professor Marshall McDonald. Ryder described in great detail the process of obtaining gametes, fertilizing, and incubating Atlantic sturgeon eggs. He gave detailed observations that fertilized eggs quickly tended to adhere to nearly any object contacted, including clumping to each other. His success was limited by several fungal infestations of eggs (~95%), which were incubated in floating wooden boxes containing a screen on which the sticky eggs had been spread. Ryder recommended disinfection of incubation water to reduce fungus and increase incubation success.

Further accounts of experimentation with sturgeon hatching on the Delaware River were reported by Bashford Dean (1894), an instructor in biology at Columbia University, NY. Dean incubated eggs in a floating case containing parallel screen-covered trays placed at different locations across the river channel and found that eggs incubated in strong currents and saltier water with less silt were practically exempt from fungus over a five day period. No account was given of the number of larvae hatched or their fate.

Nearly 100 years later, Smith et al. (1980) performed hormone-induced spawning and culturing of Atlantic sturgeon captured in the Atlantic Ocean off the Winyah Bay, SC jetties. Captured broodstock were transported to Orangeburg National Fish Hatchery, SC, where injections of sturgeon pituitary glands were administered to induce gonad maturity and enable collection of viable gametes. Attempts to manually strip eggs were not successful, but through an abdominal incision, 20,000-30,000 eggs were obtained. Workers found that diatomaceous earth was extremely efficient in preventing egg clumping and that eggs could be incubated in McDonald hatching jars where they were kept rolling slightly by circulating water. Despite these improvements over early culture attempts, eggs became fungus-covered in three days. Formalin treatments were then administered to minimize the infection. Hatching was completed by 140 hrs and resulted in the production of about 100 fry, some of which survived for 130 days. Various types of food were offered to the young fish, but they were predominantly fed a beef liver-salmon mash mixture beginning at 11 days post-hatch.

In 1981, an Atlantic sturgeon was again spawned in South Carolina and approximately 11,000 fry were hatched (Smith et al. 1981). They were fed live brine shrimp and liver-salmon mash mixture, and 10,000 fry were placed into an earthen pond for culture. Shortly thereafter, all pond-stocked fish succumbed to a high pH level caused by a phytoplankton bloom. A few of the remaining fish, which were not stocked in the pond, survived for 204 days and reached lengths of about 18 cm.

In 1991, the USFWS-NEFC, Lamar, Pennsylvania began a program to capture, transport, spawn, and culture Atlantic sturgeon. This program was in response to recommendations by the ASMFC in the 1990 FMP (ASMFC 1990) and Special Report No. 22: Recommendation Concerning the Culture and Stocking of Atlantic Sturgeon (ASMFC 1992). The first successful spawn at NEFC was achieved in 1993 using ripe Hudson River broodstock captured by commercial fishermen. The broodstock were transported six hrs by truck to NEFC's facility and given injections of luteinizing hormone releasing hormone analog (LHRHα) according to the schedule used for white sturgeon (as suggested by Conte et al. (1988)). Experiments were performed on incubation temperature and egg disinfection techniques, and approximately 13,000 fry were hatched using McDonald-style hatching jars. Experiments were also performed to identify favorable diets for first-feeding fry and fingerlings (Mohler et al. 1996). Approximately 175 individuals from that year class and others are currently being maintained at NEFC for use in a future broodstock.

Subsequent propagation attempts in 1994, 1995, 1996, and 1998 were also successful with as many as 160,000 fry being hatched in one year. These culture trials have resulted in much needed information relative to propagation and biology of this species, including favorable feed rations and rearing temperature (McPeck 1995), as well as other rearing parameters (Mohler et al. 2000; Jodun et al. 2002). Aside from experience in spawning and culturing propagated fish, knowledge of long-term holding of captive wild fish was obtained. Mohler and Fletcher (1999) found that mature males captured from the Hudson and Delaware rivers in 1991 could be maintained for at least six years in captivity and induced to produce viable milt. The work at Lamar resulted in the publication of the Culture Manual for the Atlantic sturgeon (Mohler 2004).

Artificial propagation of Atlantic sturgeon also took place at the University of New Brunswick, Canada in 1997 and 1998. Saint John River broodstock were collected and induced to provide viable gametes using LHRHα as the spawning hormone. Eggs were taken by manual stripping, in addition to making a small incision in the genital opening to facilitate manual stripping of eggs. Approximately 40,000 fry were hatched in September 1997 with about 10,000 surviving five months later (M. Litvak, University of New Brunswick, Pers. Comm. 1998).

Since NEFC's first successful spawning in 1993, many requests were made for excess progeny both inside and outside of the Department of the Interior. These requests were filled only under the condition that a study plan be submitted to NEFC for review by the Center Director and biologists. Study plans were required to include provisions that escapement of cultured sturgeon into the wild would be prevented, except where experimental stockings were conducted consistent with Federal and state regulations, and they should include a rigorous evaluation component. Accordingly, over 29,000 artificially propagated juvenile sturgeon have been shipped to 20 different organizations including Federal and state agencies, universities, public aquaria, and independent researchers. Some examples of research or education/outreach performed by outside organization using NEFC-produced juvenile sturgeon are: 1) swimming performance and velocity preference of larvae (ACOE); 2) tracking, recapture, growth, and survival of juveniles released in to the Chesapeake Bay (MD DNR); 3) growth and feeding efficiency of juveniles at various temperatures/salinities/oxygen levels (Chesapeake Biological Lab); 4) salinity tolerance and stress (Conte Anadromous Fish Lab); 5) polyculture of sturgeon and catfish to control proliferative gill disease (University of Georgia); 6) susceptibility of Atlantic sturgeon to white sturgeon herpesvirus (University of California-Davis); 7) mark/release study in the Hudson River (New York State DEC); 8) susceptibility of Atlantic sturgeon to *Aeromonas salmonicidia*, the causative agent of furunculosis in fish (Leeton Science Center); 9) public display in aquaria (New York City Aquarium, NY and Maritime Center, Norwalk, CT) and 10) movements and habitat use studies in the Hudson River (NYS DEC).

MDNR has been rearing sturgeon since 1995 with the intention of developing a captive spawning population for use in restoring extirpated subpopulations in Maryland. This program is being developed using the guidance provided by ASMFC. Approximately 75 fish are currently maintained in the captive brood population. Genetic analysis indicates low levels of relatedness and high potential for genetically responsible production and stocking. Restoration activities include captive broodstock culture, laparoscopy to identify sex and maturation, development of a genetically sound broodstock management plan, development of stocking and marking strategies, implementation of coast-wide standardized data collection, habitat assessment and target tributary identification. Research in progress includes development of sperm cryopreservation techniques, feed training of captive wild fish, larval nutrition studies and investigation of streamside culture techniques to mitigate imprinting concerns. Planned future research includes habitat evaluation, sex identification and maturity assessment. Habitat will be evaluated through telemetry monitoring of released sentinel fish and side scan sonar analysis. Sex identification and maturity will be investigated using hormone assays and ultrasound procedures, respectively.

<u>Commercial Aquaculture</u>

Currently, there are six known commercial aquaculture activities involving Atlantic sturgeon in Canada (N = 2), North Carolina (N = 1), and Florida (N = 4). The Canadian Caviar Company raises Atlantic sturgeon for purposes of selling the flesh and caviar. This company has also provided fry to academia for research purposes. The Canadian Sturgeon Conservation Center – New Brunswick is seeking buyers for Atlantic sturgeon fingerlings produced in 1997 from Saint John River wild broodstock (P. Soucy, Canadian Sturgeon Conservation Center – New Brunswick, Pers. Comm. 1998). No well-established commercial source for domestic or wild broodstock currently exists for the species. As a result of successful spawning of Hudson River

Atlantic sturgeon from 1993-1998, NEFC is currently rearing five year-classes of domestic fish. These fish could potentially be used as broodstock for aquaculture operations provided that there is no risk to wild fish. Aquaculturists in Florida, North Carolina, South Carolina, New York, and New Brunswick, Canada have contacted NEFC and expressed interest in initiating commercial production of Atlantic sturgeon.

In 2006, La Paz Aquaculture Group was approved by North Carolina state resource agencies and ASMFC to produce Atlantic sturgeon for flesh and caviar sales. However, their first year of production was halted because remnant storms from Hurricane Katrina destroyed their fry stock that was being raised in Canadian aquaculture facilities. In late 2005, the La Paz Group requested that their permit allow the production of Siberian sturgeon (*Acipenser baerii*) instead so that production could begin in 2006. In 2006, the production of Siberian sturgeon was approved by NC state resource agencies, and Siberian sturgeon eggs were supplied by AquaTech Inc, an Austrian supplier, to North Carolina State University. In August 2006, ASMFC re-evaluated the La Paz permit, and the Board voted to draft an addendum to allow La Paz to acquire Atlantic sturgeon from multiple Canadian aquaculture companies (previously restricted to one company), allowing them to resume Atlantic sturgeon culture. The eggs will initially be raised there under nursery conditions. The juveniles will be transferred to the LaPaz aquaculture facility, near Lenior, NC to be grown out. Resource managers who reviewed the permit found the LaPaz facility to pose little threat to Atlantic sturgeon or shortnose populations due to the facility location (far inland), use of a recirculating system and land application of any discharge (K. Nelson, NCWRC, Pers. Comm. 2006).

In 2001, the Canadian Caviar Company shipped 18,000 Atlantic sturgeon sac fry to the University of Florida. These fry were used to conduct early larval and feeding trials. Survivors of these experiments were transferred to four aquacultural businesses: 1) Evan's Fish Farm – Pierson, FL; 2) Watts Aquatics – Tampa, FL; 3) Hi-Tech Fisheries of Florida – Lakeland, FL; and 4) Rokaviar – Homestead, FL.

Evan's Fish Farm is a commercial food fish farm. The farm experienced a catastrophic systems failure in 2004 and currently has five Atlantic sturgeon on its premises. The farm intends to use these remaining sturgeon as broodstock and would like to acquire more Atlantic sturgeon. Watts Aquatics went out of business, and it is unknown what happened to the Atlantic sturgeon this farm received. Hi-Tech Fisheries of Florida is a commercial fish farm. It currently has around 300 Atlantic sturgeon which have been transferred to a quarry, and the company is in the process of evaluating stock size and health condition. Rokaviar is a commercial food fish farm. Originally, this business received 100 sturgeon, but due to a malfunction with the life support systems, the company now holds 20 Atlantic sturgeon.

All of these facilities are periodically screened for disease by an Institute for Food and Agricultural Science (IFAS) veterinarian. None have reported diseases. All facilities are above the 100-year flood plain and have zero discharge, where tank culture or quarry culture is utilized (Roberts and Huff 2004). These facilities may sell meat, fingerlings, and caviar in accordance with state, Federal, and international laws.

Commercial culture of other sturgeon also has the potential to impact wild Atlantic sturgeon. White sturgeon escaped from an aquacultural facility in Georgia in the early 1990s, and there have been at least two reports of white sturgeon captured by hook and line 150 miles downstream in the Mobile Basin in Alabama (M. Spencer, Georgia DNR, Pers. Comm. 1998). While this particular incident is unlikely to impact Atlantic sturgeon, it illustrates the potential for escapement of non-native sturgeon from aquacultural facilities that could have negative impacts on Atlantic sturgeon through competition for food and habitat, hybridization, and the spread of fish pathogens. For example, surveys of European sturgeon stocks have revealed a dramatic decline (eight fold decrease) in native European sturgeon (*Acipenser sturio*) but a dramatic increase (two to 33 fold increase) in non-native species such as the Siberian sturgeon (Arndt et al. 2000, Arndt et al. 2002). This dramatic increase in non-native captures was believed to be related to escapements from commercial aquaculture facilities. Amendment 1 to the ASMFC's Atlantic sturgeon FMP recommends that states may authorize aquaculture if conducted in accordance with ASMFC Special Report No. 22. Recommendations in the report state, "If non-native or hybrid sturgeon are permitted within a state, they should be restricted to culture operations where escapement and reproduction can and will be controlled."

3.5.4. Summary and Evaluation

Of these other natural and manmade factors assessed, few were considered to be major threats to the viability of Atlantic sturgeon populations. The vast withdrawal of water from rivers that support Atlantic sturgeon subpopulations was considered to be threat; however, data are lacking to determine the overall impact of this threat on sturgeon subpopulations, as impacts are dependent on a variety of factors (e.g., the species, time of year, location of the intake structure, and strength of the intake current). The observation of multiple suspected boat strikes in the Delaware and James rivers was considered to be a major threat to these subpopulations. The majority of mortalities observed in these rivers from potential boat strikes have been of large adult Atlantic sturgeon. As noted earlier in the bycatch section of this report, it is presumed that most extant Atlantic sturgeon subpopulations consist of less than 300 spawning adults, and the loss of only a few adults (~10) impedes the recovery of a subpopulation based on an F_{50} value of 0.3 (Boreman 1997). Lastly, the use of the artificial propagation of Atlantic sturgeon was also a concern to SRT members, as both stock enhancement programs and commercial aquaculture can have negative impacts on a recovering subpopulation (e.g., fish disease, escapement, out-breeding depression). In order to circumvent these potential threats, stock enhancement programs follow culture and stocking protocols approved by the ASMFC. Commercial aquaculture facilities are expected to maintain disease-free facilities and have safe guards in place to prevent escapement of sturgeon into the wild. While in at least one instance, cultured Atlantic sturgeon have gone unaccounted from a commercial aquaculture facility in Florida, this is not considered to be a significant threat.

4. Conservation and Restoration Options

4.1. Aquaculture

The Atlantic sturgeon FMP (ASMFC 1998A) contains many management recommendations, including one that encourages development of aquaculture techniques for breeding and rearing

Atlantic sturgeon and evaluating use of cultured sturgeon for stock restoration. With regard to potential use of cultured sturgeons, the ASMFC established an aquaculture subcommittee in 1995 to develop a breeding and stocking protocol in 1996, which was most recently updated in 2005 and approved in 2006 (ASMFC 2006). Specific recommendations in this protocol are:

6) Planning, Monitoring and Reporting – agencies must provide detailed proposals to the ASMFC Sturgeon Technical Committee for review and recommendation. The plan will also require annual monitoring of the status of the population, the effects of stocking, and possible interactions with shortnose sturgeon.
7) Habitat Quality and Population Surveys – prior to large scale stocking programs being implemented, areas targeted for stocking will be evaluated for the presence-absence of extant populations, determination of relative habitat quality and quantity, and possible human impacts.
8) Tagging of hatchery fish – all hatchery fish should be tagged, including broodstock. Tagging should be standardized.
9) Source of Broodstock – when possible, broodstock should be taken from natal rivers in which stocking will occur. When natal broodstock is not available, nearby sources should be used.
10) Number of spawners – broodstock collections and progeny production should meet genetic criteria for maximizing effective population size of broodstock while achieving an inbreeding rate less than 1%, preferably 0.5%.
11) Fate of Post-Spawn Broodstock – broodstock should typically be spawned only once and returned to its natal stream.
12) Fate of Progeny – excess progeny may be used for research purposes, educational exhibits, euthanized or provided to private aquacultural interests. Any excess progeny released into the wild for research or study purposes must be approved in advance by ASMFC.

Assessments of Atlantic sturgeon genetics identified strong stock structure, large genetic diversity, and low gene flow rates which suggest very slow natural recolonization potential. While stock rebuilding based solely on elimination of harvest avoids genetic risks associated with inter-stock transfer (cross stocking) and inbreeding, which may occur in hatchery-based programs, natural restoration of some stocks may take decades to centuries (Waldman and Wirgin 1998, St. Pierre 1999). These authors recommended the following be included in a restoration plan:

1) Develop clearly defined stock-specific restoration goals;
2) Conduct at least minimal stock specific demographic assessment;
3) Initiate extended stocking programs where Atlantic sturgeon are extirpated but maintain genetic variation among and within stocks;
4) If stocks show continuing decline, initiate extended supplemental stocking programs, but only after genetic risk analysis indicates that benefits outweigh hazards;
5) For viable stocks, allow populations to rebuild naturally by eliminating fishing pressures; and

6) Develop monitoring programs and regularly evaluate progress with adaptive management.

Before undertaking a large-scale program of using cultured fish for restoration stocking, the criteria identified above should be fully considered, and the following questions should be addressed. First, it must be determined with an acceptable level of probability whether genetically distinct river or region-specific stocks exist in waters still inhabited by Atlantic sturgeon. It is not considered sound fisheries management to superimpose progeny from one subpopulation onto another if significant genetic differences exist between the two, as the potential for out-breeding depression can occur.

Second, the difficulty in acquiring sufficient number of male and female broodstock required for a biologically sound breeding protocol (one designed to prevent loss of genetic diversity within subpopulations identified for restoration stocking) must be overcome. The difficulties in obtaining sufficient numbers of broodstock was illustrated in 1997 where capturing efforts of broodstock on the Hudson River, which included 164 gill net sets over a period of 22 tides, resulted in the capture of no females and 42 males (J. Fletcher, USFWS, Pers. Comm. 1998). From June 2-16, 1998, 131 gill net sets captured 87 adult Atlantic sturgeon, including three females. Realizing the scarcity of broodstock, NEFC decided in 1993 to rear a number of individuals from fry to adults from each successful hatchery spawn. As a result, five year classes of domestic Atlantic sturgeon comprising at least 20 genetically distinct families and numerous wild captives are currently being reared at NEFC and could be used in future artificial propagation efforts if deemed appropriate. Under the 2006 ASMFC Breeding and Stocking Protocol for Cultured Atlantic Sturgeon, broodstock can be collected from four sources: 1) recently captured ripe adults collected on or near the spawning grounds, 2) non-spawning adults which have been conditioned in captivity for spawning, 3) wild juveniles which have been reared to adult size in captivity for spawning or 4) juveniles which have been purchased from a commercial producer.

Three experimental releases provide some insight into the feasibility of using cultured Atlantic sturgeon as a management tool in wild stock replenishment. The first release of 4,929 fingerling fish took place in the Hudson River on October 31, 1994; the second release of 3,275 yearling fish took place on July 8, 1996, in the Nanticoke River, which is a tributary to the Chesapeake Bay, MD; and the third release of 210 subadults occurred in 2004 in the Hudson River. These studies are discussed below in more detail.

Hudson River 1994

With assistance from NEFC, the NYSDEC stocked 4,929 3-month old Atlantic sturgeon within the known nursery area of the Hudson River in October 1994. These fish were of Hudson River origin, averaged about 103 mm TL and all received left pelvic fin clips and coded wire tags (Northwest Marine Technologies, Seattle, WA) injected under the first dorsal scute.

The Cooperative Fish and Wildlife Research Unit at Cornell University in Ithaca, NY was contracted by the Hudson River Foundation to conduct long-term studies of abundance and distribution of adult and juvenile Atlantic sturgeon and shortnose sturgeon in the Hudson River.

Using anchored gill nets, Cornell researchers sampled 57 sites in a 150 km reach of the middle Hudson River and collected 29 yearling Atlantic sturgeon between June and mid-December 1995. Most age-1 fish were taken near the salt-freshwater interface near the sturgeon stocking area. Of the 29 yearling sturgeon collected in 1995, 15 (52%) were hatchery fish (identified by wire tags and fins clips). These fish grew an average of 335 mm FL and were distributed over 92 km of river. Wild yearlings were larger, averaging 441 mm, and were collected in a narrower but overlapping 45 km reach of the river.

With a known number of marked (stocked) fish, mark-recapture methodology was used to estimate population size of wild age-1 Atlantic sturgeon. Assuming 100% stocking survival of hatchery reared fish, the population estimate of 4,313 age-1 wild fish (95% confidence interval of 1,917-10,474) indicated that natural production in the Hudson River was very weak in 1994 (Peterson et al. 2000). Cornell researchers repeated their 1995 sampling methods during July-September 1996 and caught only eight juvenile Atlantic sturgeon in the presumed age-1 and age-2 year classes. Seven of these were cultured fish from the 1994 release and averaged 454 mm FL and 617 grams.

Cornell researchers continued to study the distribution and abundance of juvenile Atlantic sturgeon in the Hudson River in 1997. Seasonal aggregations were located using sonic tagged fish captured in early spring. From July-October, the greatest concentrations of both wild and hatchery fish were observed in a 20 km reach between North Haverstraw Bay and West Point. A total of 156 juveniles was collected using targeted gill netting in North Haverstraw Bay, and more than 50% (82 fish) of these were hatchery fish (greater than 3 years old). While survival and migration rates of these cultured fish are unknown, they are still smaller than the wild fish. Cold water rearing conditions best explain the smaller size of stocked fish.

Chesapeake Bay 1996

Maryland DNR requested cultured sturgeon from NEFC for an experimental stocking in the Nanticoke River, which is a tributary on the eastern shore of the Chesapeake Bay. Although a relatively small drainage, the Nanticoke once supported spawning sturgeon, but none have been seen there in over 15 years. The purpose of this experimental stocking was to learn more about habitat needs and preferences, growth and survival rates, feeding habits, seasonal distribution and movements throughout Chesapeake Bay.

In July 1996, 3,275 yearling Atlantic sturgeon of Hudson River origin (1995 year-class) were stocked into the Nanticoke River at two sites located 36 and 50 km above the river mouth. Because the fish were reared in different water temperatures, two size groups were represented (I: 6-15 cm; II: 22-36 cm). All fish were injected with coded wire tags under the third dorsal scute and sturgeon from the larger size group (II) were also tagged with streamer tags. Maryland DNR, USFWS, Virginia Marine Resources Commission and the private Chesapeake Bay Foundation pooled their funds to offer a reward for any sturgeon caught by commercial fishermen in waters of the Chesapeake Bay and held alive for examination. Notices of the reward, $25 for hatchery fish and $100 for others, were posted throughout the Bay along with a toll-free telephone number.

Between 1996 and 2000, 462 hatchery Atlantic sturgeon were colleted, the majority of which were captured in the first two years (Secor et al. 2000). Within eight months post-release, streamer tagged fish more than doubled in size to an average TL of 668 mm. These fish were spread throughout Maryland waters of the Chesapeake Bay, from Baltimore Harbor to the lower Potomac River, with heavy concentrations below the Bay Bridge near Cove Point. Several tagged fish were taken in Virginia (see below), and two were recovered in neighboring North Carolina.

It appears that growth and survival of stocked sturgeon was excellent indicating that the Bay is capable of supporting yearling and juvenile sturgeon. Their rapid dispersal may indicate it is unlikely that these yearlings imprinted to the Nanticoke River. It was recommended that future stockings involve younger fish of Chesapeake origin (e.g., James River fish), similar to the 1994 release in the Hudson River.

The Virginia reward program ran from February through early November 1997 and reported 202 total fish including 169 from the James River (13 hatchery fish), 6 from the York River (three hatchery), and 15 from the Rappahannock River (seven hatchery). Many of the fish taken in autumn months were less than 500 mm TL, suggesting that some natural reproduction occurs in the lower Bay, particularly in the James River. The Virginia reward program was reactivated for a few days in February 1998, and an additional 71 wild juvenile Atlantic sturgeon were reported from the James River (A. Spells, USFWS, Pers. Comm. 1998). Tissue samples from small sturgeon taken in Maryland and Virginia were archived for future genetic analysis to confirm whether one or more discrete Chesapeake Bay sub-populations exist. Subsequent analysis in 2002 indicated that samples from the James River were unique and statistically different from all other subpopulations. In both this and the previously-described experimental stocking, long-term evaluation is needed to determine whether stocked fish have imprinted to the watershed of release and will eventually help to rebuild depleted subpopulations through successful reproduction (Mohler 2000).

Hudson River 2004

In 2004, FWS released 210 subadults of Hudson River origin into the Hudson River. These fish averaged 875 mm TL and were offspring from the 1994-98 year classes, which were held at the Lamar aquaculture facility. Since 2004, 18 sturgeon have been reported (9% recapture rate). The majority of these fish were recaptured in the Hudson River; others were recaptured off the coast of North Carolina (K. Hattala, NYSDEC, Pers. Comm. 2006).

4.2. Summary and Evaluation

Recent experiments demonstrate the technical feasibility of culturing Atlantic sturgeon. While the technology exists, a role for culture has yet to be fully defined in the overall effort to manage, protect, and recover Atlantic sturgeon. As the ASMFC develops restoration goals on a river-by-river basis, they should evaluate whether cultured stocks play a role in restoration. Any proposal for culture of Atlantic sturgeon, for commercial or stocking purposes, should also be evaluated by the ASMFC Atlantic Sturgeon Technical Committee for compliance with applicable protocols

(ASMFC 2006, Waldman and Wirgin 1998), consistency with best management practices to minimize or avoid risk to wild stocks, and compatibility with programs for wild stock.

5. Current Conservation Efforts and PECE Analysis

Current conservation efforts underway to protect and restore Atlantic sturgeon must be evaluated under the Policy for Evaluation of Conservation Efforts (PECE), under the authority of the ESA. This policy is designed to determine whether any conservation efforts that have been recently adopted or implemented, but not yet proven to be successful, will result in recovering the species to the point at which listing is not warranted or contribute to forming a basis for listing a species as threatened rather than endangered (68 FR 15101). The purpose of PECE is to ensure consistent and adequate evaluation of future or recently implemented conservation efforts identified in conservation agreements, conservation plans, management plans, and similar documents when making listing decisions. The policy is expected to facilitate the development by states and other entities of conservation efforts that sufficiently improve a species' status so as to make listing the species as threatened or endangered unnecessary.

In 2003, the Services published guidelines for evaluating conservation efforts that have not yet been implemented or have not yet demonstrated effectiveness when making listing decisions under the ESA. The policy established two basic criteria: 1) the certainty that the conservation efforts will be implemented and 2) the certainty that the efforts will be effective. The first criterion, implementation, requires a high level of certainty that the resources necessary to carry out the conservation effort are available, ensures that the implementing agency has the authority to carry it out, determines if the regulatory or procedural mechanisms are in place to carry out the efforts, and that there is a schedule for completing and evaluating the efforts. The second criterion, effectiveness, requires the conservation effort to describe the nature and extent of the threats to the species to be addressed and how these threats are reduced by the conservation effort, determine if the conservation effort has established specific conservation objectives, determine if the conservation effort identifies the appropriate steps to reduce threats to the species, and evaluate whether the conservation effort includes quantifiable performance measures to monitor for both compliance and effectiveness. Overall, the PECE analysis ascertains whether the formalized conservation effort improves the status of the species at the time a listing determination is made.

The SRT determined that the following conservation efforts required further analysis under PECE: the ASMFC FMP, Roanoke Rapids and Gaston Dams fishway prescriptions, James River restoration plan, Hudson River estuary management plan, multi-state conservation program (ME, NH, MA), and Penobscot Accord.

5.1. ASMFC Management Plan 1998

The content of the 1998 Amendment to the ASMFC FMP for Atlantic sturgeon is presented in the section discussing regulatory authorities. The Amendment includes a stock rebuilding target of at least 20 protected mature age classes in each spawning stock, which is to be achieved by imposing a harvest moratorium. The Amendment requires states to monitor, assess, and annually report Atlantic sturgeon bycatch and mortality in other fisheries, although bycatch reporting is widely accepted as being underreported or not reported at all. The Amendment also requires that states annually report habitat protection and enhancement efforts. Finally, each jurisdiction with a reproducing subpopulation should conduct juvenile assessment surveys (including CPUE estimates, tag and release programs, and age analysis). States with rivers that lack a reproducing sturgeon subpopulation(s) but support nursery habitat for migrating juveniles should also conduct sampling. The Amendment strengthens conservation efforts by formalizing the closure of the directed fishery, and by banning possession of bycatch, eliminating any incentive to retain Atlantic sturgeon. Additional elements of the Amendment related to habitat, stock assessment, and stocking are designed to offer the species wider protection beyond closing a directed fishery and thereby, improve its chances for recovery.

5.2. Roanoke Rapids and Gaston Dams Fishway Prescriptions

In 2006, a final fishway prescription was completed for the Roanoke Rapids and Gaston dams, as a result of the owner (Dominion Generation) applying for a "major new license" (NMFS 2006). The fishway prescriptions have three phases of implementation for the passage of American shad (*Alosa sapidissima*), river herring (*A. psuedoharengus and A. aestivalis*), and American eel (*Anguilla rostrata*): phase 1 - initial truck and trapping; phase 2 - permanent truck and trapping; and phase 3 - full capacity volitional passage. Atlantic sturgeon were not a management objective in this prescription due to their small population size and lack of safe and effective downstream passage mechanisms for post-spawn adults. However, NMFS reserved its authority to prescribe fishways, or appropriate modifications for fishways, for Atlantic sturgeon in the event these circumstances change (NMFS 2006).

5.3. James River Atlantic Sturgeon Restoration Plan

In 2005, state and private partners began work to create a James River Atlantic Sturgeon Restoration Plan. The plan outlines several restoration goals to help preserve and recover the James River Atlantic sturgeon subpopulation. These goals include:

1) Identify essential habitats, assess subpopulation status, and refine life history investigations in the James River.
2) Protect the subpopulation of James River Atlantic sturgeon and its habitat.
3) Coordinate and facilitate exchange of information on James River Atlantic sturgeon conservation and restoration activities.
4) Implement the restoration program.

The plan also describes several milestones for reaching their goals, those of most interest to this review include:

A) Identify essential habitats and protect them using regulatory and/or incentive programs.
B) Develop and implement standardized population sampling and monitoring programs.
C) Develop population models.
D) Develop an experimental culture of James River Atlantic sturgeon.

E) Reduce or eliminate incidental mortality.
F) Identify and eliminate known or potentially harmful chemical contaminants that impede the recovery of James River sturgeon.
G) Maintain genetic integrity and diversity of the wild and hatchery-reared stocks.
H) Designate and fund a James River Atlantic sturgeon restoration lead office.

Though finalized, the plan has not been formally approved by regulatory agencies. However, portions of the plan have already been implemented including the collection of YOY and adult tissue samples for genetic analysis; electronic tracking of sturgeon to determine preferred habitat use and spawning locations; collecting spine samples to establish age distributions; and establishing a long-term YOY index survey (A. Spells, USFWS, Pers. Comm. 2007).

5.4. Hudson River Estuary Management Action Plan

A Hudson River Estuary Management Action Plan was adopted by the NYSDEC in May 1996. The goal of this Plan is to protect, restore and enhance the productivity and diversity of natural resources of the Hudson River estuary to sustain a wide array of present and future human benefits. Multiple projects have been initiated as a response to this Plan and include:

1) Coastal sampling.
2) Juvenile Atlantic sturgeon sonic tracking project.
3) Broodstock sonic tagging, PIT tagging to determine broodstock movements and spawning locations.
4) New York long-term juvenile abundance survey.

5.5. Multi-State Conservation Program (Maine/New Hampshire/ Massachusetts)

Three states, Maine, New Hampshire, and Massachusetts, have applied for and have received funding under NMFS' new Proactive Species Conservation Program grant. The project is entitled "Multi-State Collaborative to Develop and Implement a Conservation Program for Three Anadromous Fish Species of Concern in the Gulf of Maine," and includes the following proposed research on Atlantic sturgeon within the Kennebec River:

- Use acoustic biotelemetry (deploy acoustic array) to identify essential Atlantic sturgeon habitat in the Kennebec River/Androscoggin River complex.
- Conduct a mark-and-recapture study using PIT tags to estimate subpopulation size and external Carlin tags to investigate movements beyond the estuary. Investigate non-traditional population estimation methods because of spawning periodicity of adult sturgeon.
- Obtain tissue samples for sturgeon to conduct genetic analysis and determine stock structure.

5.6. Penobscot Accord

In June 2004, the Penobscot Accord was approved and gave the Penobscot River Restoration Trust, a non-profit corporation established in May 2004, the ability to buy Veazie, Great Works and Howland dams on the Penobscot River over a five-year period. If purchased, the Trust has the right to decommission and/or remove the Veazie Dam, decommission the Great Works Dam, and install fish passage or remove the Howland Dam. However, these options cannot be initiated until 2007-2010. If the Accord is successfully implemented, large portions of historical habitat once available to Atlantic sturgeon will be reopened. The Accord is directed toward Atlantic salmon, herring, and American eel restoration and the overall benefits to sturgeon species are unknown. However, it is anticipated that dam removal will provide benefits to Atlantic sturgeon.

The SRT identified several other threats to Atlantic sturgeon in the Penobscot River that are not addressed by the Penobscot Accord. As a result, the SRT decided that the Accord is beneficial for reopening spawning habitat to Atlantic sturgeon, but other threats to the subpopulation (e.g., dredging, water quality, bycatch, etc.) are not being addressed by other management plans; thus, this conservation effort does not change the risk of extinction for this subpopulation.

5.7. Summary

Overall, none of the current conservation efforts underway was considered to improve the status of the species to such an extent that a listing determination should be re-evaluated. The majority of the conservation efforts did not describe the threats to Atlantic sturgeon subpopulations in question and how these threats would be reduced or eliminated. Conservation efforts lacked recovery objectives or the appropriate steps to reduce threats, and they did not quantify performance measures for both compliance and effectiveness.

Though these plans were not applicable under the PECE analysis, these conservation efforts will and/or already are increasing our knowledge and understanding of Atlantic sturgeon life history strategies, their status, and identify methods or work toward restoring important habitat that is used as nursery and spawning grounds.

6. Needed Research

Though Atlantic sturgeon historically supported an important commercial fishery since the 1800s and many aspects of this species' life history have been investigated, current knowledge regarding threats to and the current status of this species in many areas of its range are lacking. To fill in some of these data gaps, the following research is needed:

- <u>Long-term population monitoring programs</u>: Currently, there are only three subpopulations (Hudson, Albemarle, and Edisto) with long-term monitoring programs in place to help determine the status of the species (e.g., whether it is decreasing, increasing, or remaining stable). It is critical that all other extant subpopulations be surveyed to better understand their status. Recently, Sweka et al. (2006) noted that the relative abundance (CPUE) of juvenile Atlantic sturgeon in the Hudson River could be determined with 95% 'power' if biologists sampled as little as 24 net sets per year over a

10-year period of sampling or 36 net sets every other year (biennial sampling). Though this model was developed for the Hudson River subpopulation and is based on the coefficient of variation on mean CPUE (1.019), variations to this methodology and data analysis may serve as a model when developing monitoring programs (J. Sweka, USFWS-NFC, Pers. Comm. 2006).

- Spawning population abundance estimates: As noted earlier in this report, there are only two extant subpopulations with estimates of yearly spawning adults, the Hudson (~860/year) and Altamaha (~350/year). These Atlantic sturgeon subpopulations are suspected to be the largest within the U.S. portion of the species' range. Therefore, all of the other U.S. subpopulations are expected to have less than 300 spawners per year. Using the F_{50} value of 0.03 as a guide, the loss of only nine spawners a year could impede the recovery of a subpopulation. As a result, it is very important to determine the average number of spawners per year for each subpopulation, as the risk of extinction increases greatly for smaller subpopulations.

- Population Genetics: Several subpopulation genetic studies have been performed on Atlantic sturgeon since the 1990s using both mtDNA and nDNA. However, many of the rivers that have been examined thus far have used results from juvenile tissue samples, which increase the chances that the sample was a migrant from another system. Researchers are now reanalyzing subpopulations only using YOY and spawning adult samples to reduce sampling error to provide increased certainty that Atlantic sturgeon subpopulations are likely adapted to unique habitats. This research will be very useful in the event that hatchery programs are needed to help recover this species.

- Estimate Bycatch and Bycatch Mortality: Though the ASMFC 1998A FMP stated that bycatch should be monitored to determine its impacts on Atlantic sturgeon recovery, the impacts of bycatch are still unclear. Currently, most states rely on fishers voluntarily reporting bycatch of Atlantic sturgeon. Very few to no Atlantic sturgeon have been documented each year by commercial fishers using this voluntary reporting scheme. In states and programs where observer coverage is present, however, Atlantic sturgeon are landed with some frequency and bycatch mortality ranges from 0 – 51% mortality. This dichotomy in reported bycatch has resulted in significant uncertainties regarding the extent of bycatch. The need for bycatch monitoring is especially great in the southern range of the species where observer coverage is lacking and only a few American shad fisheries have been monitored to determine bycatch.

- Identification of Spawning and Nursery Grounds: Overall, the location of spawning and nursery grounds for Atlantic sturgeon is not known. For instance, only nine of the 36 subpopulations that once supported a spawning subpopulation have had spawning grounds identified. Though generally found in the vicinity of the fall line, some spawning locations are known to occur above or below this area of elevation change. Identifying these critical habitats is an important step in determining potential stressors to the subpopulation and identifying areas that should be protected from degradation.

- Toxic Contaminant Impacts and Thresholds: Since Atlantic sturgeon are a long-lived species, they have the potential to bioaccumulate toxins. Though contaminants have been greatly reduced over the last two decades, the presence of dioxins, PCBs, and mercury is still apparent. In other fish species, the bioaccumulation of these contaminants has been shown to reduce reproductive capabilities, growth, and cause death. However, surveys for the Atlantic sturgeon concentrations are lacking where only a few systems have examined the contaminant levels of Atlantic sturgeon.

- Develop Fish Passage Devices for Sturgeon: Currently there is little information that Atlantic sturgeon utilize fish passage devices. However, the smaller shortnose sturgeon are frequently observed (4.7/year) passing the Holyoke Dam, Connecticut (Kynard 1996, Gephard and McMeney 2004). Though, shortnose sturgeon are capable of passing the Holyoke dam, managers now prevent sturgeon from passing the dam to prevent subsequent mortalities when they migrate back downstream and through the hydropower turbines. Thus, both up- and down-stream fish passage devices need to be engineered to help sturgeon species pass dams so that historic and possibly more suitable spawning habitat can be reached.

7. Extinction Risk Analysis (ERA)

Risks of extinction assessments are performed to help summarize the status of the species, and do not represent a decision by the SRT on whether the species should be proposed for listing as endangered or threatened under the ESA.[37] There are no standard methods or protocols employed to estimate the risk of extinction. Instead, the method used is dependent on the availability of data for the species in question. Information such as geographic range, population numbers, population trends, and expert opinion can be utilized in a purely qualitative methodology (reviewed in Regan et al. 2005), or through the use of ranking or scoring systems, in semi-quantitative analysis. Models relying on stochasticity and variances in genetics, birth-death demography, ecology and interactions among mechanisms can be employed in a highly quantitative methodology, such as Population Viability Analysis (PVA) (Boyce 1992, Ludwig 1999).

7.1. Determining the Best "Risk of Extinction" Method for Atlantic Sturgeon

The deciding factor in choosing a method to assess the biological status of a species is data availability. To utilize the most simple quantitative model – that which is often used by American Fisheries Society (AFS), the Convention on International Trade in Endangered Species

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[37] Neither does the results of an extinction risk analysis represent a decision by the NMFS on whether this taxon (Atlantic sturgeon) should be proposed for listing as threatened or endangered under the ESA. That decision will be made by NMFS after reviewing this report, other relevant biological and threat data not included herein, and all relevant laws, regulations, and policies. The result of the decision will be posted on the NMFS website (http://www.nero.noaa.gov/prot_res/) and announced in the *Federal Register*.

(CITES), and the International Union for the Conservation of Nature and Natural Resources (IUCN) – at least ten years or three generations of time-series data are required, and 15 years of data are preferable (Dulvy et al. 2004). Because ten years of time-series data exist for only five of the 23 extant Atlantic sturgeon subpopulations undergoing review, even the most simplistic quantitative method cannot be used in the risk analysis of Atlantic sturgeon.

The SRT decided to use a semi-quantitative approach employing a scoring system that has been used previously in extinction risk analyses (Myers et al. 1998, Wainwright and Kope 1999, *Acropora* Biological Review Team 2005, Gustafson et al. 2006). Traditionally, the scoring system has been applied in three stressor categories: abundance, trend/productivity/variability, and genetic integrity (Myers et al. 1998, Wainwright and Kope 1999, Gustafson et al. 2006). Others have identified additional stressor categories (*Acropora* Biological Review Team 2005). In previous status review documents, a standardized 1 to 5 scoring scheme was used. Status Review Team members assigned individual scores ranging from 1 to 5 for each threat or stressor, where for any given stressor, a score of 1 indicated that it was not likely to cause a population to become extinct (low risk) and a score of 5 indicated a high risk for causing extinction of the population. The respondents' scores were then averaged for each category.

The Atlantic sturgeon SRT determined that it was important for this review to clearly address how these scores related to the five factors being evaluated, where the three most commonly used stressor categories in the qualitative ranking method are related to abundance, productivity trends and genetic integrity. A recent status review of coral (*Acropora palmata* and *A. cervicornis*) used the same extinction risk scoring methods (1-5 scale) but expanded the stressors to 15 separate categories, effectively breaking down the five broad factors outlined in Section 4(a)(1) of the ESA. These 15 stressor categories were described in detail within the status review (*Acropora* Biological Review Team 2005). The SRT preferred the use of a broader ranking system that was directly related to the five factor analysis.

The SRT also felt it was important to address the "significant portion of its range" (SPOIR) and timeframes inferred in the ESA definition of an endangered and threatened species. The ESA defines an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range," while a "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The phrase "throughout all or a significant portion of its range" is neither defined nor explained in the ESA and a final policy on how to interpret this language has not been developed by USFWS or NMFS. Recent internal guidance from NMFS developed the following definition for a SPOIR; extinction in a SPOIR is a spatial, functional, or character loss that poses a serious risk of eventual extinction to the species as a whole by substantially reducing the ability of a species to respond to demographic risks and future environmental challenges.

Similarly, the ESA refers to timeframes for which endangered and threatened status are determined. An endangered species is in danger of extinction while a threatened species is likely to become endangered in the foreseeable future. However, these timeframes are not explicitly defined within the ESA. Endangered status reflects imminent risks to a species' continued existence due to its present abundance, productivity, and/or spatial structure. Due to the uncertainties in species' dynamics at very low abundance, the exact timeframe in which the species is expected to become extinct cannot be reliably predicted. Thus, there is no explicit time horizon of risk that corresponds to endangered status, although timeframes have been suggested, e.g., 10 years (Gerber and DeMaster 1999), 20% probability of extinction of 20 years (Shelden et al. 2001). Concerning the foreseeable future, the appropriate period of time corresponding to the foreseeable future depends on the particular kinds of threats, the life-history characteristics, specific habitat requirements for the species under consideration and should be adequate for the conservation and recovery of the threatened species and the ecosystems upon which they depend. Timeframes that have been used in the past for defining the foreseeable future include 25 years for North Pacific Humpback Whale (Gerber et a. 1999) and 10% probability of extinction in 100 years for Bowhead Whales (Shelden et al. 2001). Determining these timeframes and associated probabilities is an important first step in assessing the extinction risk of Atlantic sturgeon, as it is important that the timeframes associated with assessing risk are clearly understood.

To address each of these issues, the Atlantic sturgeon SRT decided to modify previous approaches by using the five factor analysis as a guide for determining stressors to a species, including a SPOIR analysis to determine the status of the species and define timeframes and probabilities for "imminent extinction" and "foreseeable future" as they pertain to Atlantic sturgeon biology and recovery.

7.2. The Structure of the Semi-Quantitative Analysis

7.2.1. Stressor Evaluation and Scoring

Each of the five factors listed in Section 4(a)(1) is comprised of numerous stressors that could contribute to a species being listed as threatened or endangered. For instance, "Dredging on spawning grounds" is one of the stressors in the Factor A (related to habitat) and "Competition" is one of the stressors in Factor C (Disease or Predation). These individual stressors were evaluated by SRT members for each extant subpopulation unit within a DPS. Scores could range from 1 to 5 for each of these stressors:

1 – Low Risk
2 – Moderately Low Risk
3 – Moderate Risk
4 – Moderately High Risk
5 – High Risk

The SRT concluded a score of 4 (Moderately High Risk) should represent a stressor that had a >50% chance of causing the subpopulation unit to become endangered over the next 20 years, while a score of 5 (High Risk) had a >50% chance of causing the subpopulation unit to become extinct over the next 20 years. The rationale for a >50% probability was based on the SRT interpretation of "likely," which meant having a better chance of occurring than not; thus, a >50% chance. The SRT also concluded that 20 years is an appropriate timeframe for determining the status of a species, as it was not too far into future that qualitative analysis would prove to be ineffective or unreliable, allowed sufficient time (10+ years) to determine the productivity of Atlantic sturgeon subpopulations using standardized protocols (Sweka et al. 2006), and is the approximate age of maturity for Atlantic sturgeon or is approximately equal to one generation (Scott and Crossman 1973, Smith et al. 1982, Young et al. 1998).

Once the SRT had scored stressors for each extant subpopulation, the team revisited all of the subpopulations in which a score of 4 or 5 was given by at least one SRT member. The rationale for the scores was discussed, and the SRT had the opportunity to change their individual scores. The median values for each of these stressor categories were used to summarize the overall risk for each subpopulation. The greatest median stressor score (e.g., dams) within a factor score (e.g., Factor 1) was used as the overall factor score. The SRT also evaluated whether a factor score should be elevated after considering the cumulative impacts of each of the individual stressors.[38] Similarly, to determine the overall subpopulation score, the greatest of the five factor scores was used.

7.2.2. Significant Portion of its Range Criteria

After factor and subpopulation risk scores were determined, the SRT determined which subpopulations should be considered significant under the SPOIR language of the ESA. The SRT decided that a subpopulation should be considered significant to a DPS' viability if one or more of the following proposed SPOIR criteria were met:

1) the subpopulation historically supported a large population,
2) relative to the DPS, the current abundance is greater than other subpopulations,
3) if lost, would result in the loss of spatial structure within the DPS.

The historical abundance of a subpopulation was determined to be a good indicator of the DPS' potential to recover, because the subpopulation could contribute substantially to the ecological function of the DPS and therefore, reduce the susceptibility of becoming extinct. This criterion assumes the genetic diversity of the subpopulation and the habitat on which it depends are not beyond a restorable threshold.

The current abundance of a subpopulation was determined to be a good indicator of the DPS's viability because, all else being equal, a large subpopulation is more likely to subsist as compared to a small subpopulation. The protection of the most abundant subpopulations, in relation to the DPS, is essential for the recovery of a DPS.[39]

A DPS' spatial structure depends on habitat quality, spatial configuration, dynamics, and dispersal characteristics of subpopulations within the DPS. The loss of spatial structure has the potential to affect evolutionary processes and therefore, alter the ability of subpopulations within the DPS to respond to environmental change or catastrophic events, resulting in a DPS that may be more vulnerable to extinction.[40]

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[38] No factor scores were elevated in risk due to cumulative impacts.
[39] The current abundance significance and rationale were taken from Viable Salmonid Population language.
[40] The spatial structure definition was taken from Viable Salmonid Population language.

After group discussion and evaluation of the three criteria outlined to evaluate SPOIR, the SRT determined that 10 of the 18 subpopulations, from various DPSs, should be considered to constitute a significant portion of the range of the DPS (Table 12). This information was combined with ERA scores to determine if a DPS should be considered threatened or endangered.

7.3. Extinction Risk Analysis Results and Status of each DPS

The SRT evaluated the status of each DPS by comparing the risk of each subpopulation and whether or not it was considered a SPOIR. The SRT also evaluated whether there were sufficient data available to make a recommendation to list Atlantic sturgeon as threatened or endangered. There were three possible outcomes for making a recommendation: 1) there were sufficient data to recommend listing as threatened or endangered; (2) there were sufficient data to recommend that listing is not warranted; (3) there were insufficient data to allow a full assessment of these subpopulations within the DPS, and thus, a recommendation could not be provided. Of the five DPSs evaluated, the SRT concluded that three DPSs (Carolina, Chesapeake, and New York Bight) had a moderately high risk (>50% chance) of becoming endangered in the next 20 years, and the SRT recommended that these DPSs be listed as threatened (Table 13). The other two DPSs, South Atlantic and Gulf of Maine, were determined to have a moderate risk (<50% chance) of endangerment in the next 20 years; however, there were insufficient data to allow a full assessment of these subpopulations.

7.3.1. Gulf of Maine DPS

The Gulf of Maine (GOM) DPS historically supported at least four spawning subpopulations; however, today it is suspected that only two extant subpopulations exist (Penobscot and Kennebec rivers). Of these two extant subpopulations, the Kennebec was considered a subpopulation of significant value to the Gulf of Maine DPS, as this subpopulation was historically large, relative to the DPS its current population size is large, and if extirpated would likely result in the loss of spatial structure. The SRT found these two extant subpopulations to have a moderate risk (< 50% chance) of becoming endangered in the next 20 years. The extant subpopulations received median scores of 3 (moderate risk) on a number of stressors, including dredging, water quality, and commercial bycatch. It was speculated that the Penobscot subpopulation was extirpated until a fisherman captured an adult Atlantic sturgeon in 2005, and a gill net survey directed toward Atlantic sturgeon captured seven in 2006. Based on the time of year (spring) and length (1400 mm TL), one of the captures in 2006 may have been an adult. The SRT concluded that the Penobscot subpopulation had a moderate risk of becoming endangered due to its potentially small size (likely less than 300 spawning adults), recent approvals to dredge in the Penobscot Harbor along with eight other dredging projects, and poor water quality. Within the Penobscot, substrate has been severely degraded by upstream mills, and water quality has been negatively affected by the presence of coal deposits and mercury hot spots. The potential for commercial bycatch was also viewed as a moderate threat to this subpopulation due to its small size.

Historically, the Kennebec supported ~15,000 spawning adults. According to limited CPUE data, the CPUE increased by a factor of 10-25 over a 20 year period from 1977 to 2000.

However, these data were limited to eight years of sampling, where catch from 1977-1981 was compared to catch from 1998-2000, and sampling 1977-1981 is noted as conservative due to high flow years. Additional sampling from 2000-2003 in the MEDMR inshore groundfish trawl survey collected 13 subadults at the mouth of the Kennebec River, which had the largest occurrences of Atlantic sturgeon among five regions sampled along the New Hampshire and Maine coasts (Squiers 2003). The SRT concluded that there are several stressors within the Kennebec that result in a moderate risk of this subpopulation becoming endangered in the next 20 years. These stressors include poor water quality, dredging, and commercial bycatch.

Although the Gulf of Maine subpopulations were found to have a moderate risk of becoming endangered in the next 20 years, the SRT determined that there were insufficient data to allow a full assessment of these subpopulations within the DPS, and thus, a recommendation could not be provided.

7.3.2. New York Bight DPS

The New York Bight, ranging from the Delmarva Peninsula to Cape Cod, historically supported four or more spawning subpopulations. Currently, this DPS only supports two spawning subpopulations, the Delaware and Hudson River. The Delaware River supported the largest spawning subpopulation of Atlantic sturgeon in the U.S., with 3,200 mt of landings in 1888. Today, the capture of YOY and spawning adults within the Delaware River is sporadic, and the majority of sub-adults captured in the Delaware Bay are thought to be of Hudson River origin, based on genetic analysis. Population estimates based on mark and recapture of juvenile Atlantic sturgeon (declined from 5,600 juveniles in 1991 to less than 1,000 in 1995) and voluntary logbook reporting (declined from 32 fish/effort hr in 1991 to only 2 fish/effort hr in 2004) indicate that the Delaware subpopulation has been declining rather rapidly over the last 20 years (Figure 8). In the U.S., the Hudson River currently supports the largest subpopulation of spawning adults (~850 males and females) and ~8,000 subadults, although historically, it supported 6,000 to 7,000 spawning females. Long-term surveys indicate that the Hudson River subpopulation has been stable since 1995 and/or slightly increasing in abundance.

The SRT concluded that the Hudson River subpopulation had a moderate risk (< 50% chance) of becoming endangered in the next 20 years due to the threat of commercial bycatch. A study conducted by the ASMFC technical committee in February of 2006 determined that bycatch mortality from just the New York Bight sink net fishery had the potential to impede the recovery of Hudson River Atlantic sturgeon. Other stressors, such as water quality, have improved since the 1980s and no longer seem to present a significant threat to Hudson River Atlantic sturgeon.

However, the SRT found that the Delaware River subpopulation had a moderately high risk (>50% chance) of becoming endangered in the next 20 years, due to the loss of adults from ship strikes. Several other stressors received scores of moderate risk (i.e., dredging, water quality, and commercial bycatch). Dredging was considered a moderate risk, as the river is continually dredged from the Delaware Bay to Trenton, NJ (~150 kms). Dredging in the upper portions of the river near Philadelphia were considered detrimental to successful Atlantic sturgeon spawning as this is suspected to be the historical spawning grounds of Atlantic sturgeon. Though dredging restrictions are in place during the spawning season, the continued degradation of suspected spawning habitat likely increases the instability of the subpopulation and could lead to its endangerment in the foreseeable future. Commercial bycatch was considered to be a moderate risk to this subpopulation's viability, as the subpopulation is suspected to be relatively small with less than 300 spawning adults. As is the case in other DPSs, only a few adult mortalities (~10, F_{50} = 0.03) are needed to impeded the recovery of this subpopulation. The SRT also recognized that this region, especially the offshore portion of the New York Bight, is heavily fished by sink nets that commonly have a large number of associated bycatch mortalities.

Both the Hudson and Delaware rivers were considered to constitute a SPOIR within the New York Bight DPS, based on historical abundances (both), current abundance (Hudson), and if extirpated would likely result in the loss of spatial structure (both). The SRT concluded that the moderately high risk of the Delaware River, combined with the moderate risk of the Hudson River subpopulation, was sufficient to recommend the DPS be listed as threatened under the ESA.

7.3.3. Chesapeake Bay DPS

The Chesapeake Bay once supported at least six historical spawning subpopulations; however, today the Bay is believed to support at the most, only two spawning subpopulations (James and York). Of these two extant subpopulations, the James was considered a subpopulation of significant value to the Chesapeake Bay DPS, as this subpopulation was historically large, relative to the DPS its current population size is large, and if extirpated would likely result in the loss of spatial structure.

Though the York River has not been confirmed to support a spawning subpopulation, the capture of 38 age-1 juveniles suggest that a subpopulation may exist in this river. Genetic analyses of these York River captures indicated these fish were genetically unique and statistically different ($P < 0.05$) from neighboring subpopulations; however, geneticists were unable to differentiate James and York River fish from one another using classification techniques. Scientists do know that the majority of recaptures, reported in the Maryland tagging program, are from the York River, suggesting the river is a favorable nursery ground within the Bay. The highest ranked stressor for the York River was commercial bycatch, which received a median score of 3 (moderate risk).

The SRT concluded that the James River had a moderately high risk (>50% chance) of becoming endangered in the next 20 years, as it received median scores of 4 for impacts from commercial bycatch. Commercial bycatch was considered a moderately high risk to this subpopulation, because it is expected to be relatively small (<300 spawning adults) and only a few adult mortalities are needed to impede the recovery of this species (~10, F_{50} = 0.03).

Dredging was a concern to SRT members, receiving a score of three (moderate risk), as it has been extensively dredged since the 1800s, removing large portions of rock outcroppings called "the Rocket's" speculated to be the historic spawning grounds of Atlantic sturgeon in this river. Since the mass removal of these rock outcroppings (multiple locations), the quality of spawning habitat is suspected to have been significantly reduced. The continued maintenance dredging of the navigation channel and the recent approval to expand the terminal in Richmond requiring additional dredging is thought to further impact the remaining habitat.

Ship strikes were also found to be a moderate stressor for this subpopulation, as five Atlantic sturgeon are reported on average each year to have been struck by boats (likely ocean-going vessels). Though the reports are relatively low (~5/year), there are no surveys in place to estimate how many sturgeon are actually struck by ships in this system. In some places, the river narrows and the navigation channel is approximately the width of the river. Coupled with the relatively large number of ship strike sightings and the expected low abundance, this subpopulation is likely impacted by ship strikes.

The SRT concluded that there was sufficient evidence to suggest that the Chesapeake Bay DPS is at risk of becoming endangered in the foreseeable future and recommends it be listed as threatened under the ESA.

7.3.4. Carolina DPS

The Carolina DPS ranges from the Santee-Cooper River to the Albemarle Sound and consists of seven extant subpopulations, one subpopulation (Sampit) is believed to be extirpated. The current abundance of these subpopulations is likely less than 3% of their historical abundance based on 1890s commercial landings. The subpopulations within this DPS seem to be at moderate to moderately high risk of becoming endangered. Five to six of the extant subpopulations received multiple scores of moderate risks for impacts related to water quality, and/or commercial bycatch. Major causes of concern were related to the water quality conditions within the Pamlico Sound and Cape Fear River. The Pamlico Sound suffers from eutrophication and experiences periodically low DO events, mainly in the Neuse Estuary of the Sound. The Cape Fear River is a blackwater river; however, the low DO concentrations in this river can also be attributed to eutrophication. It was the opinion of the SRT that inhabitability of these waters posed moderate risk to the stability of these subpopulations. Water quality is also a problem in Winyah Bay, where portions of the Bay have high concentrations of dioxins that can adversely affect sturgeon development. Commercial bycatch was a concern for all of the subpopulations examined. Like the Chesapeake Bay DPS, the mortality of just a few sturgeon (~10, based on $F_{50} = 0.03$) could adversely affect these small subpopulations.

The Cape Fear and Santee-Cooper rivers, were found to have a moderately high risk (>50%) of becoming endangered in the next 20 years as a result of impeded habitat from dams. The Cape Fear and Santee-Cooper are the most impeded rivers along the range of the species, where dams are located in the lower coastal plain and impede between 62-66% of the habitat available between the fall line and mouth of the river. The SRT concluded that the limited habitat in which sturgeon could spawn and utilize for nursery habitat in these rivers likely leads to the instability of these subpopulations and to the entire DPS being at risk of endangerment. The SRT also concluded that the loss of both the Santee-Cooper and Cape Fear River subpopulations would likely result in the loss of spatial structure within the DPS and thus, constitutes a SPOIR. As a result of these findings, the SRT recommends that Carolina DPS be listed as threatened under the ESA.

7.3.5. South Atlantic DPS

The SA DPS historically supported eight spawning subpopulations ranging from the St. Johns River, FL to the ACE Basin in SC. Currently, this DPS supports five extant spawning subpopulations. Of these subpopulations, the Altamaha and ACE Basin support the largest number of spawning adults, and based on the available data, are considered to be the second and third largest subpopulations within the U.S., respectively. The current abundance of these subpopulations are suspected to be less than 6% of their historical abundance, extrapolated from the 1890s commercial landings. Few captures have been documented in other subpopulations within this DPS and are suspected to be less than 1% of their historic abundance.

A review of the literature and potential threats to this DPS revealed that dredging, water quality, and commercial bycatch were ranked as the greatest threats to this DPS - receiving ERA scores of 3 or moderate risk (<50% chance of becoming endangered over the next 20 years). Overall, the SRT found that the SA DPS had a moderate risk (<50% chance) of becoming endangered over the next 20 years. While the median value associated with the risk for the DPS was moderate and did not meet the threshold of >50% chance of becoming endangered, the team recognized that three of the eight historic subpopulations are likely extirpated and data is lacking for many of the other subpopulations. As a result, the SRT determined that available science was insufficient to allow a full assessment of these subpopulations within the SA DPS.

8. Conclusions of the Status Review

Previously in 1998, the status review team (different members) determined that the Atlantic sturgeon did not warrant listing at that time as the species had persisted through the late 1800s and earlier 1900s when fishing pressure was high and water quality was at its lowest. In 1998, direct fishing pressure was essentially removed by the ASMFC who imposed a 40-year moratorium on the fishery and water quality had improved substantially since the early 1900s. The 1998 status review team, also determined that bycatch of Atlantic sturgeon in other fisheries was unsubstantial and did not pose a threat to the viability of species.

However, since the 1998 status review only a few subpopulations seem to be increasing or stablizing. The majority of the subpopulations show no signs of recovery, and new information suggests that stressors such as bycatch, ship strikes, and low DO can and do have substantial impacts on subpopulations. Furthermore, population estimates of the relatively healthiest subpopulations of Atlantic sturgeon are low ranging from 300 – 800 spawning adults; thereby, suggesting that smaller subpopulations likely have less than 300 spawning adults and could be considered unstable. The lack of recovery in these subpopulations may be attributed to many years of habitat degradation and the continued take of Atlantic sturgeon as bycatch. Overall, the SRT concluded that at least three (New York Bight, Chesapeake Bay, and Carolina) of the five DPSs should be considered threatened under the ESA as it was determined that they had a moderately high risk of becoming threatened in the foreseeable future (next 20 years). The SRT determined that the remaining two DPSs had a moderate risk of becoming extinct, though there were insufficient data to allow for a full assessment of these subpopulations; thus, a listing recommendation was not provided.

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Table 1. Historic and current spawning status of Atlantic sturgeon throughout its natural range, and current uses of the riverine habitat.

State	River	Historical Spawning Status	Current Spawning Status	Use of River by Atlantic Sturgeon
QE	Saint Lawrence	Yes	Yes	Spawning, Nursery
NB	Miramichi	Unknown	Unknown	Nursery
NS	Avon	Yes	No	Unknown
NS	Annapolis	Yes	Yes	Spawning, Nursery
NB	Saint John	Yes	Yes	Spawning, Nursery
NB/ME	Saint Croix	Yes	Possibly	Nursery
ME	Penobscot	Yes	Possibly	Nursery
ME	Kennebec	Yes	Yes	Spawning, Nursery
ME	Androscoggin	Yes	Possibly	Nursery
ME	Sheepscot	Yes	Possibly	Nursery
NH	Piscataqua	Unknown	No	Unknown
NH/MA	Merrimack River	Yes	No	Nursery
MA/RI	Taunton	Yes	No	Nursery
RI/CT	Pawcatuck	Unknown	No	Unknown
MA/RI/CT	Thames	No	No	Unknown
CT	Connecticut	Yes	No	Nursery
CT	Housatonic	Unknown	No	Unknown
NY	Hudson	Yes	Yes	Spawning, Nursery
DE/NJ/PA	Delaware	Yes	Yes	Spawning, Nursery
MD/PA	Susquehanna	Yes	No	Nursery
MD/VA	Potomac	Yes	No	Nursery
VA	James	Yes	Yes	Spawning, Nursery
VA	York	Yes	Possibly	Spawning, Nursery
VA	Rappahannock	Yes	No	Nursery
VA	Nottoway	Yes	Unknown	Unknown
NC	Roanoke	Yes	Yes	Spawning, Nursery
NC	Tar-Pamlico	Yes	Yes	Spawning, Nursery
NC	Neuse	Yes	Possibly	Spawning, Nursery
NC	Cape Fear-New Brunswick	Yes	Yes	Spawning, Nursery
SC	Waccamaw	Yes	Yes	Spawning, Nursery
SC/NC	Great Pee Dee	Yes	Yes	Spawning, Nursery
SC	Black	Unknown	Unknown	Unknown
SC	Santee	Yes	Yes	Spawning, Nursery
SC	Cooper	Yes	Yes	Spawning, Nursery
SC	Ashley	Yes	Unknown	Nursery
SC	Ashepoo	Unknown	Unknown	Nursery
SC	Combahee	Yes	Yes	Spawning, Nursery
SC	Edisto	Yes	Yes	Spawning, Nursery
SC	Sampit	Yes	No	Nursery
SC	Broad-Coosawatchie	Yes	Unknown	Unknown
SC/GA	Savannah	Yes	Yes	Spawning, Nursery
GA	Ogeechee	Yes	Yes	Spawning, Nursery
GA	Altamaha	Yes	Yes	Spawning, Nursery
GA	Satilla	Yes	Yes	Spawning, Nursery
GA/FL	St. Mary's	Yes	No	Nursery
FL	St. John's	Unknown	No	Nursery

Table 2. Atlantic sturgeon pair-wise comparisons among sampled populations, indicating significant or visually interpreted differences between populations.

	Altamaha	Cape Fear	Chesapeake	Combahee	Combahee/Edisto	Delaware	Edisto	Hudson
Alatamaha								
Cape Fear	ns-B, VIS-D, ***E							
Chesapeake	**C							
Combahee	VIS-D, *E	VIS-D, **E						
Combahee/Edisto	*D	*D		ns-D				
Delaware	ns-A, **C		**C					
Edisto	ns-A, ****B, VIS-D, ****E	****B, VIS-D, ****E		ns-D, ns-E	ns-D	ns-A		
Hudson	****A, ****B, **C, VIS-D	****B, VIS-D	**C	VIS-D	*D	*A, **C	****A, ****B, VIS-D	
James	VIS-D	VIS-D		VIS-D	*D		VIS-D	****D, VIS-D
Kennebec	****B, VIS-D	****B, VIS-D		VIS-D	*D		*B, VIS-D	****B, VIS-D
Neuse		ns-E		ns-E			ns-E	
Ogeechee	ns-A, *B, VIS-D, ***E	ns-B, VIS-D, ****E		ns-VIS-D, ns-E	ns-D	ns-A	ns-A, ns-b, ns-VIS-D, ns-E	****A, ****B, VIS-D
Pee Dee	**E	ns-E					**E	
Roanoke	****B, **C, VIS-D	****B, VIS-D, ****E	**C	VIS-D, **E	*D	**C	****B, VIS-D, ****E	****B, **C, VIS-D
Savannah	ns-A, *B, VIS-D	****B, VIS-D, ***E		VIS-D, ns-E	*D	ns-A	ns-A, ****B, VIS-D, ****E	****A, ****B, VIS-D
St. John	****A, **B, **C, VIS-D	****B, VIS-D	**C	VIS-D	*D	****A, **C	****A, *B, VIS-D	****A, ****B, **C, VIS-D
St. Lawrence	****A, ****B, **C, VIS-D	****B, VIS-D	**C	VIS-D	*D	*A, C**	****A, *B, VIS-D	****A, ****B, **C, VIS-D

	James	Kennebec	Neuse	Ogeechee	Pee Dee	Roanoke	Savannah	St. John
Alatamaha								
Cape Fear								
Chesapeake								
Combahee								
Combahee/Edisto								
Delaware								
Edisto								
Hudson								
James								
Kennebec	VIS-D							
Neuse								
Ogeechee	VIS-D	****B, VIS-D	*E					
Pee Dee	****E		ns-E	***E				
Roanoke	****D	***B, VIS-D	****E	*B, VIS-D, ****E	****E			
Savannah	VIS-D	****B, VIS-D	ns-E	ns-A, ns-B, VIS-D, **E	ns-E	*B, ns-VIS-D, ****E		
St. John	VIS-D	ns-B, ns-VIS-D		****A, ****B, VIS-D		**B, **C, VIS-D	****A, **B, VIS-D	
St. Lawrence	VIS-D	ns-B, ns-VIS-D		****A, ****B, VIS-D		****B, **C, VIS-D	****A, ****B, VIS-D	ns-A, ns-B, **C, ns-VIS-D

A - Waldman et al. 1996 - RFLP (*Bgl* I, *Msp* I, *Eco* R V, *Hinf* I, and *Hinc* II)
B - Wirgin et al. 2000 - mtDNA Sequencing (203 bp TAS1 - Control Region)
C - King et al. 2001 - nDNA Microsatellites (Aox9, Aox10, Aox12, Aox23, Aox27, Aox45)
D - Waldman et al. 2002 - mtDNA Sequencing (203 bp TAS1 - Control Region)
E - Wirgin Personal Communication and Supplemental Data 2005

* - P < 0.05
** - P < 0.01
*** - P < 0.001
**** - P < 0.0001
VIS - Visually Different As Interpreted From UPGMA Tree

Table 3. (A) Statistical significance of FST (lower diagonal) and Monte-Carlo-based X^2 (upper diagonal) comparisons of mtDNA control region haplotype frequencies among Atlantic sturgeon collections. All p-values, corrected using sequential Bonferroni methods, were significantly different except those noted in bold font (Wirgin, supplemental data 2006). (B) Statistical significance of FST (lower diagonal) and allele frequency heterogeneity pair-wise comparisons of 12 locus nDNA markers among Atlantic sturgeon collections. All p-values, corrected using sequential Bonferroni methods, were significantly different (King, supplemental data 2006).

(A)

Subpopulation	St. Lawrence	St. John	Kennebec	Hudson	Delaware	James	Albermarle	Edisto	Combahee	Savannah	Ogeechee	Altamaha
St. Lawrence	***	<0.0063	**0.1271**	<0.0063	<0.0063	<0.0063	**0.0230**	**0.0195**	<0.0063	<0.0063	<0.0063	<0.0063
St. John	**0.9990**	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
Kennebec	**0.2188**	**0.0332**	***	<0.0063	<0.0063	<0.0063	**0.0379**	**0.0108**	**0.1073**	<0.0063	<0.0063	<0.0063
Hudson	<0.0050	<0.0050	<0.0050	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
Delaware	<0.0050	<0.0050	<0.0050	**0.0596**	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
James	<0.0050	<0.0050	<0.0050	<0.0050	0.0000	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
Albermarle	<0.0050	<0.0050	**0.0117**	<0.0050	<0.0050	<0.0050	***	<0.0063	<0.0063	<0.0063	<0.0063	<0.0063
Edisto	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	***	**0.3947**	<0.0063	<0.0063	<0.0063
Combahee	<0.0050	<0.0050	**0.0293**	<0.0050	**0.0195**	<0.0050	**0.0938**	**0.2725**	***	**0.0558**	<0.0063	<0.0063
Savannah	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	***	<0.0063	<0.0063
Ogeechee	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	***	<0.0063
Altamaha	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	**0.0078**	<0.0050	<0.0050	***

(B)

Subpopulation	Kennebec	Hudson	James	Albermarle	Ogeechee	Altamaha
Kennebec	***	<0.001	<0.001	<0.001	<0.001	<0.001
Hudson	<0.0001	***	<0.001	<0.001	<0.001	<0.001
James	<0.0001	<0.0001	***	<0.001	<0.001	<0.001
Albermarle	<0.0001	<0.0001	<0.0001	***	<0.001	<0.001
Ogeechee	<0.0001	<0.0001	<0.0001	<0.0001	***	<0.001
Altamaha	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	***

Table 4. Analysis of Molecular Variance (AMOVA) results employing 12 locus nDNA markers and nine Atlantic sturgeon populations (King, supplemental data 2006).

DPSs	Population Groupings	Among Regions %	Among Populations within a Region %
2	1. Saint John, Kennebec, Hudson 2. York, James, Roanoke, Savannah, Ogeechee, Altamaha	7	10
3	1. Saint John, Kennebec, Hudson 2. York and James 3. Roanoke, Savannah, Ogeechee, Altamaha	8	7
4	1. Saint John, Kennebec, Hudson 2. York and James 3. Roanoke, Savannah, Altamaha 4. Ogeechee	10	6
5	1. Saint John and Kennebec 2. Hudson 3. York and James 4. Roanoke, Savannah, Altamaha 5. Ogeechee	11	5
6	1. Saint John and Kennebec 2. Hudson 3. York and James 4. Roanoke 5. Savannah and Altamaha 6. Ogeechee	12	3
7	1. Saint John 2. Kennebec 3. Hudson 4. York and James 5. Roanoke 6. Savannah and Altamaha 7. Ogeechee	13	2
8	1. Saint John 2. Kennebec 3. Hudson 4. York and James 5. Roanoke 6. Savannah 7. Ogeechee 8. Altamaha	13	1

Table 5. Analysis of Molecular Variance (AMOVA) results from 12 Atlantic sturgeon populations using mtDNA sequence data (Wirgin, supplemental data 2006).

DPSs	Population Groupings	Among Regions %	Among Populations within a Region %
3	1. Saint Lawrence, Saint John, Kennebec 2. Hudson, Delaware, James, Roanoke 3. Edisto, Combahee, Savannah, Ogeechee, Altamaha	15	15
4	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James and Savannah 4. Roanoke, Edisto, Combahee, Savannah, Ogeechee, Altamaha	20	10
5	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James and Savannah 4. Roanoke, Edisto, Combahee, Altamaha 5. Ogeechee	23	7
6	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James and Savannah 4. Roanoke 5. Edisto, Combahee, Altamaha 6. Ogeechee	23	5
7	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James and Savannah 4. Roanoke 5. Edisto and Combahee 6. Ogeechee 7. Altamaha	24	4
8	1. Saint Lawrence, Saint John, Kennebec 2. Hudson and Delaware 3. James 4. Roanoke 5. Edisto and Combahee 6. Savannah 7. Ogeechee 8. Altamaha	27	0
9	1. Saint Lawrence and Saint John 2. Kennebec 3. Hudson and Delaware 4. James 5. Roanoke 6. Edisto and Combahee 7. Savannah 8. Ogeechee 9. Altamaha	26	1

Table 6. Classification success rate for Atlantic sturgeon to their natal river and distinct population segment (DPS) using both 7 and 12 locus nDNA microsatellites. Top: a classification matrix, in which YOY or adults were exclusively used in the analysis employing a 12 locus nDNA marker. Bottom: a classification matrix, in which YOY or adults were exclusively used in the analysis employing a 7 locus nDNA marker.

12 – Locus nDNA microsatellites

Collection	Kennebec River	Hudson River	James River	Albemarle Sound	Savannah River	Ogeechee River	Altamaha River	**Correct Assign.**
Kennebec River	**37**	**3**	**2**					**88.1**
Hudson River	**3**	**49**	**1**					**92.5**
James River		**5**	**109**				**1**	**94.8**
Albemarle Sound	**1**	**1**		**33**	**1**			**91.7**
Savannah River			**2**	**2**	**21**		**10**	**60.0**
Ogeechee River			**1**		**2**	**34**		**91.9**
Altamaha River					**7**	**1**	**41**	**83.7**
DPS	**88.1**	**92.5**	**94.8**	**91.7**		**95.9**		**88.3** **93.7**

7 – Locus nDNA microsatellites

Collection	Kennebec River	Hudson River	James River	Albemarle Sound	Savannah River	Ogeechee River	Altamaha River	**Correct Assign.**
Kennebec River	**34**	**6**	**2**					**81.0**
Hudson River	**2**	**47**	**3**	**1**				**88.7**
James River	**2**	**9**	**97**		**3**		**4**	**84.4**
Albemarle Sound		**3**		**29**	**4**			**80.6**
Savannah River		**1**	**3**	**1**	**13**	**1**	**16**	**37.1**
Ogeechee River			**1**	**1**	**1**	**33**	**1**	**89.2**
Altamaha River			**1**	**1**	**6**	**3**	**38**	**77.6**
DPS	**81.0**	**88.7**	**84.4**	**80.6**		**91.7**		**79.0** **86.9**

Table 7. The percentage of riverine habitat (rkm) available to Atlantic sturgeon in each river system, ranging from the mouth of the river to the fall line or historic spawning grounds. Estimates of river kilometers were based on GIS mapping and reference points provided by Oakley 2005 and other sources. However, river kilometers is only an estimate of habitat availability and should not be confused as a reference to habitat suitability as many factors can reduce the quality of this available habitat (e.g., impeded by water flow, dredging, water quality and other similar factors).

State	River	Fall Line or Historic Spawning Location (rkm)	Current Upstream Migration (rkm)	% of Habitat Currently Available	% of Historic Habitat Impeded	Blockage	Fall Line or Historic Spawning RKM Source	Current RKM Source
QB	Saint Lawrence	760	760	100%	0%		GIS Mapping	GIS Mapping
NB	Saint John	110	110	100%	0%	Mactaquac Dam	GIS Mapping	GIS Mapping
ME	Penobscot	71	56	79%	21%	Veazie Dam	T. Squiers, PC, 2006	T. Squiers, PC, 2006
ME	Kennebec	98	98	100%	0%	Lockwood Dam	T. Squiers, PC, 2006	T. Squiers, PC, 2006
ME	Androscroggin	14	14	100%	0%	Brunswick Dam	GIS Mapping	Oakley 2005
ME	Sheepscot	32	32	100%	0%		T. Squiers, PC, 2006	T. Squiers, PC, 2006
NH/MA	Merrimack	116	49	42%	58%	Essex Dam	GIS Mapping	Oakley 2005
MA	Taunton	79	70	89%	11%	Town River Pond Dam	GIS Mapping	GIS Mapping
MA/CT	Connecticut	167	143	86%	14%	Holyoke Dam	GIS Mapping	Oakley 2005
NY	Hudson	204	280	100%	0%		GIS Mapping	Oakley 2005
NJ/DE/PA	Delaware	140	579	100%	0%		GIS Mapping	Oakley 2005
PA/MD	Susquehanna	-6	10	100%	0%	Conowingo Dam	GIS Mapping	GIS Mapping
MD/VA	Potomac	248	248	100%	0%		GIS Mapping	Oakley 2005
VA	Rappahanock	172	172	100%	0%		Bushnoe et al. 2005	GIS Mapping
VA	York	374	374	100%	0%		GIS Mapping	GIS Mapping
VA	James	203	203	100%	0%		Bushnoe et al. 2005	GIS Mapping
NC/VA	Chowan/Nottoway	227	227	100%	0%		GIS Mapping	GIS Mapping
NC	Roanoke	252	207	82%	18%	Roanoke Rapids Dam	GIS Mapping	GIS Mapping
NC	Tar-Pamlico	199	199	100%	0%	Rocky Mount Mill Pond Dam	GIS Mapping	GIS Mapping
NC	Neuse	253	253	100%	0%		GIS Mapping	GIS Mapping
NC	Cape Fear	267	95	36%	64%	Lock and Dam #1	GIS Mapping	Oakley 2005
SC	Waccammaw	214	214	100%	0%		GIS Mapping	Oakley 2005
SC	Great Pee Dee	266	276	100%	0%	Blewett Falls	GIS Mapping	Oakley 2005
SC	Sampit	40	40	100%	0%		GIS Mapping	GIS Mapping
SC	Ashley	95	95	100%	0%		GIS Mapping	GIS Mapping
SC	Santee/Cooper	311	119	38%	62%	Pinnpolis and Santee Dams	GIS Mapping	Oakley 2005
SC	Ashepoo	78	78	100%	0%		GIS Mapping	Oakley 2005
SC	Combahee	163	163	100%	0%		GIS Mapping	Oakley 2005
SC	Edisto	280	280	100%	0%		GIS Mapping	Oakley 2005
SC	Broad/Coosawatchi	90	90	100%	0%		GIS Mapping	GIS Mapping
SC/GA	Savannah	343	317	92%	8%	New Savannah Bluff L&D	GIS Mapping	Oakley 2005
GA	Ogeechee	375	375	100%	0%	Jordan Mill Pond Dam	GIS Mapping	Oakley 2005
GA	Altamaha	400	400	100%	0%		GIS Mapping	Oakley 2005
GA	Satilla	376	376	100%	0%		GIS Mapping	GIS Mapping
GA/FL	St. Mary's	274	274	100%	0%		GIS Mapping	GIS Mapping
FL	St. Johns	416	153	37%	63%	Kirkpatrick Dam	GIS Mapping	GIS Mapping
		AVERAGE		91%	9%			

Table 8. Atlantic sturgeon captured by dredge type as reported by the U.S. Army Corps of Engineers for the U.S. east coast from 1990 – 2005. Reports include only those trips when an observer was on board to document capture, and numbers do not reflect all sturgeon captures.

	Dredge Type		
Year	**Hopper**	**Clam**	**Pipeline**
1990	1		
1991			
1992			
1993			
1994	3		
1995			
1996			
1997			
1998	2	1	1
1999			
2000	2	1	
2001		1	
2002			
2003			
2004	1		
2005	1		
Totals	**10**	**3**	**1**

Table 9. Summary of the National Coastal Condition Report (NCCR II) for the U.S. east coast published by the U.S. Environmental Protection Agency (2004) that grades coastal environments. Northeast Region is Maine south through Virginia; southeast region is North Carolina south through Florida. Chesapeake Bay was also graded separately from the Northeast Region.

	Region		
Status Index	**Northeast**	**Chesapeake Bay**	**Southeast**
Water Quality	D	F	B
Sediment	F	F	B
Coastal Habitat	B	-	C
Benthos	F	F	C
Fish Tissue	F	F	A
Overall	**F**	**F**	**B-**

Table 10. Bycatch and bycatch rate of Atlantic sturgeon and landings for monitored trips by targeted species from 1989 – 2000. Estimates provided by Stein et al. 2004(b).

Rank	Target Species	Sturgeon catch (lbs)	Landings for monitored trips (lbs)	Bycatch rate (lbs/trip)
1	Weakfish - Striped bass	35	210	0.1667
2	Northern kingfish	85	3,511	0.0242
3	American shad	540	22,582	0.0239
4	Southern flounder	107	5,361	0.0200
5	Red hake	50	2,912	0.0172
6	Witch flounder	341	20,628	0.0165
7	Winter skate	105	7,008	0.0150
8	Scup	570	48,525	0.0117
9	Weakfish	116	11,163	0.0104
10	Striped bass	456	58,874	0.0077
11	Goosefish	7,975	1,599,948	0.0050
12	Atlantic cod	1,542	323,795	0.0048
13	Smooth dogfish	760	246,244	0.0031
14	Winter flounder	277	108,613	0.0026
15	Summer flounder	1,196	720,499	0.0017
16	Unidentified dogfish	2,107	1,320,843	0.0016
17	Tautog	10	8,906	0.0011
18	Spiny dogfish	3,910	4,126,878	0.0009
19	Butterfish	265	331,064	0.0008
20	Bluefish	169	257,215	0.0007
21	Yellowtail flounder	230	434,270	0.0005
22	Atlantic croaker	373	749,476	0.0005
23	Horseshoe crab	97	205,728	0.0005
24	Haddock	45	97,974	0.0005
25	Atlantic menhaden	8	25,792	0.0003
26	Weakfish - Atlantic croaker	10	45,290	0.0002
27	Longfin inshore squid	355	1,826,769	0.0002
28	Pollock	75	717,607	0.0001
29	Unidentified squid	50	519,933	0.0001
30	Unidentified tuna	8	843,336	0.0000

Table 11. Summary of Atlantic sturgeon bycatch mortality for different gear and target fisheries.

Region/State/River	Gear	Target Fishery	Mortality (%)	Source
Delaware	Anchor Gill Net	DFW Survey	10	C. Shirey, DFW
NC to MA	Drift Net	General	10	Stein et al. 2004
Chesapeake Bay	Gill Net	Striped Bass	0-8	C. Hager, VIMS
Winyah Bay, SC	Gill Net	American shad	16	M. Collins, SCDMF
Albemarle Sound, NC	Gill Net	Flounder	0	White and Armstrong 2000
NC to MA	Pound Net	General	0.2	NEFO 2000-2004
NC to MA	Sink Gill Net	Monkfish	51	NEFO 2000-2004
NC to MA	Sink Gill Net	Striped Bass	10	NEFO 2000-2004
NC to MA	Sink Gill Net	Smooth Dogfish	6	NEFO 2000-2004
NC to MA	Sink Gill Net	Spiny Dogfish	10	NEFO 2000-2004
NC to MA	Sink Gill Net	Atlantic Cod	30	NEFO 2000-2004
Cape Fear, NC	Sink Gill Net	UNCW Survey	25-37	F. Rohde, NCDMF
Chesapeake Bay	Staked Gill Net	American shad	4	C. Hager, VIMS
NC to MA	Trawl	General	0	Stein et al. 2004

Table 12. Significant portion of its range criteria collectively scored by the status review team.

Population Unit	DPS	Historic Pop	Current Pop	Spatial Structure	Number of Criteria Met
Penobscot	Gulf of Maine				
Kennebec		√	√	√	3
Androscoggin		-	-	-	
Sheepscot		-	-	-	
Piscatiquis		-	-	-	
Merrimack		-	-	-	
Taunton	NY Bight	-	-	-	
Connecticut		-	-	-	
Hudson		√	√	√	3
Delaware		√		√	2
James	Chesapeake Bay	√	√	√	3
York					
Rappahannock		-	-	-	
Potomac		-	-	-	
Susquehanna		-	-	-	
Nanticoke		-	-	-	
Roanoke	Carolina	√	√		2
Tar/Pamlico					
Neuse					
Cape Fear				√[1]	1
Waccamaw					
Pee Dee		√	√		2
Sampit		-	-	-	
Santee-Cooper				√[1]	1
ACE Basin	South Atlantic		√		1
Broad/Coosawatchie		-	-	-	
Savanah					
Ogeechee					
Altamaha		√	√	√	3
Satilla					
St. Mary's		-	-	-	
St. John's		-	-	-	

1 - In combination, the Cape Fear and Santee-Cooper River populations would represent a loss of spatial structure.

Table 13. Results of the extinction risk analysis by population unit and stressor categories. Scores reflect the status review team's median scores, and scores were defined as: 1 – low risk, 2 – moderately low risk, 3 – moderate risk, 4 – moderately high risk, and 5 – high risk of extinction. Cells with hyphens denote subpopulations that were considered extirpated and thus not examined.

Population Unit	DPS	Dams	Dredging	Water Quality	Factor 1 Score	Commercial Bycatch	Scientific Colletion	Factor 2 Score	Competition	Predation	Disease	Factor 3 Score	International Authorites	US Interstate-Federal Authorities	State Authorities	Factor 4 Score	Impingement and Entrainment	Ship Strikes	Artificial Propagation	Factor 5 Score	Overall Score	Subpopulation Risk Level	Considered Significant under SPOIR Criteria	DPS Recommendation
Penobscot	Gulf of Maine	2	2	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		Insufficient Data
Kennebec		1	3	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate	Yes	
Androscoggin		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Sheepscot		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Piscatiquis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Merrimack		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Taunton	NY Bight	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Threatened
Connecticut		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Hudson		1	1	2	2	3	1	3	1	1	1	1	1	2	2	2	2	1	2	2	3	Moderate	Yes	
Delaware		1	3	3	3	3	1	3	1	1	1	1	1	2	2	2	1	4	1	4	4	Moderately High	Yes	
York	Chesapeake Bay	1	1	2	2	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		Threatened
James		1	3	3	3	4	1	4	1	1	1	1	1	2	2	2	1	3	1	3	4	Moderately High	Yes	
Rappahannock		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Potomac		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Susquehanna		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Nanticoke		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Roanoke	Carolina	2	1	2	2	3	2	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate	Yes	Threatened
Tar/Pamlico		1	1	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		
Neuse		3	1	3	3	3	1	3	1	1	1	1	1	3	3	3	1	1	1	1	3	Moderate		
Cape Fear		4	3	3	4	3	3	3	1	1	1	1	1	2	2	2	1	2	1	2	4	Moderately High	Yes	
Waccamaw		1	1	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		
Pee Dee		1	1	3	3	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate	Yes	
Sampit		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Santee-Cooper		4	2	2	4	2	1	2	1	1	1	1	1	2	3	3	1	1	1	1	4	Moderately High	Yes	
ACE Basin	South Atlantic	1	1	2	2	2	1	2	1	1	1	1	1	2	2	2	1	1	1	1	2	Moderately Low	Yes	Insufficient Data
Broad/Coosawatchie		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Savanah		2	3	2	3	2	1	2	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		
Ogeechee		1	1	3	3	2	1	2	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate		
Altamaha		1	1	2	2	3	1	3	1	1	1	1	1	2	2	2	1	1	1	1	3	Moderate	Yes	
Satilla		1	1	2	2	2	1	2	1	1	1	1	1	2	2	2	1	1	1	1	2	Moderately Low		
St. Mary's		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
St. John's		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
ESA Factors		(1) The Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range				(2) Overutilization for Commercial, Recreational, or Scientific Purposes			(3) Competition, Predation, and Disease				(4) Existing Regulatory Authorities, Laws and Policies				(5) Other Natural or Manmade Factors				Overall Score	Subpopulation Risk Level	Considered Significant under SPOIR Criteria	DPS Recommendation

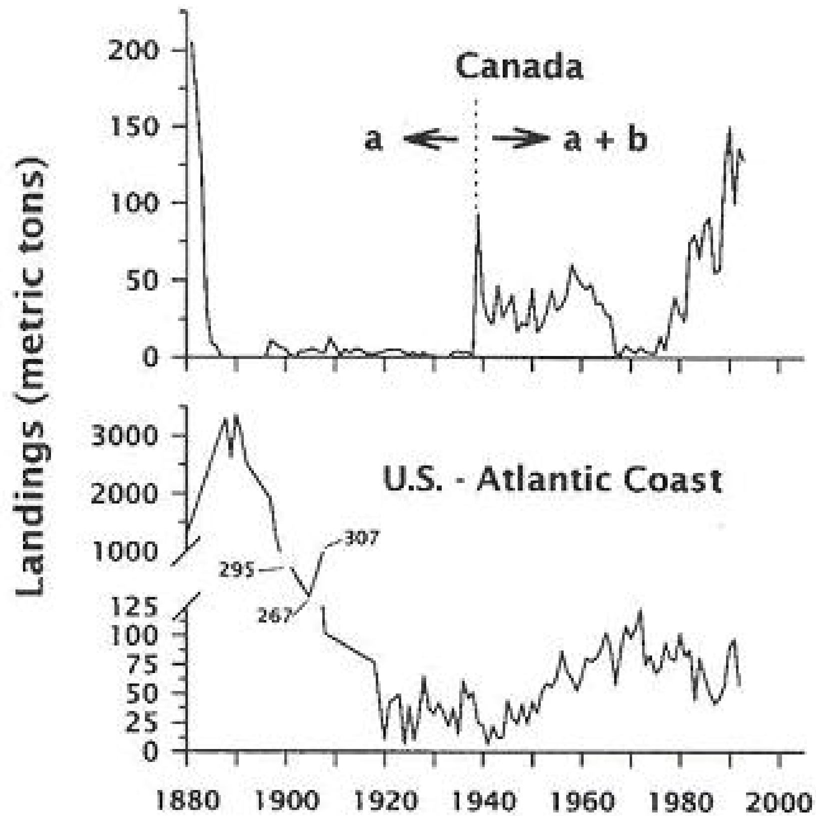

Figure 1. Reported landings of Atlantic sturgeon (1880 – 2000). Canadian estimates prior to 1940 only existed for the Saint John fishery. After 1940, landings data include both Saint John (a) and Saint Lawrence (b) fisheries. U.S. landings are based on NMFS data and may include shortnose sturgeon prior to 1972, as these species are difficult to differentiate. Courtesy of Smith and Clugston (1997).

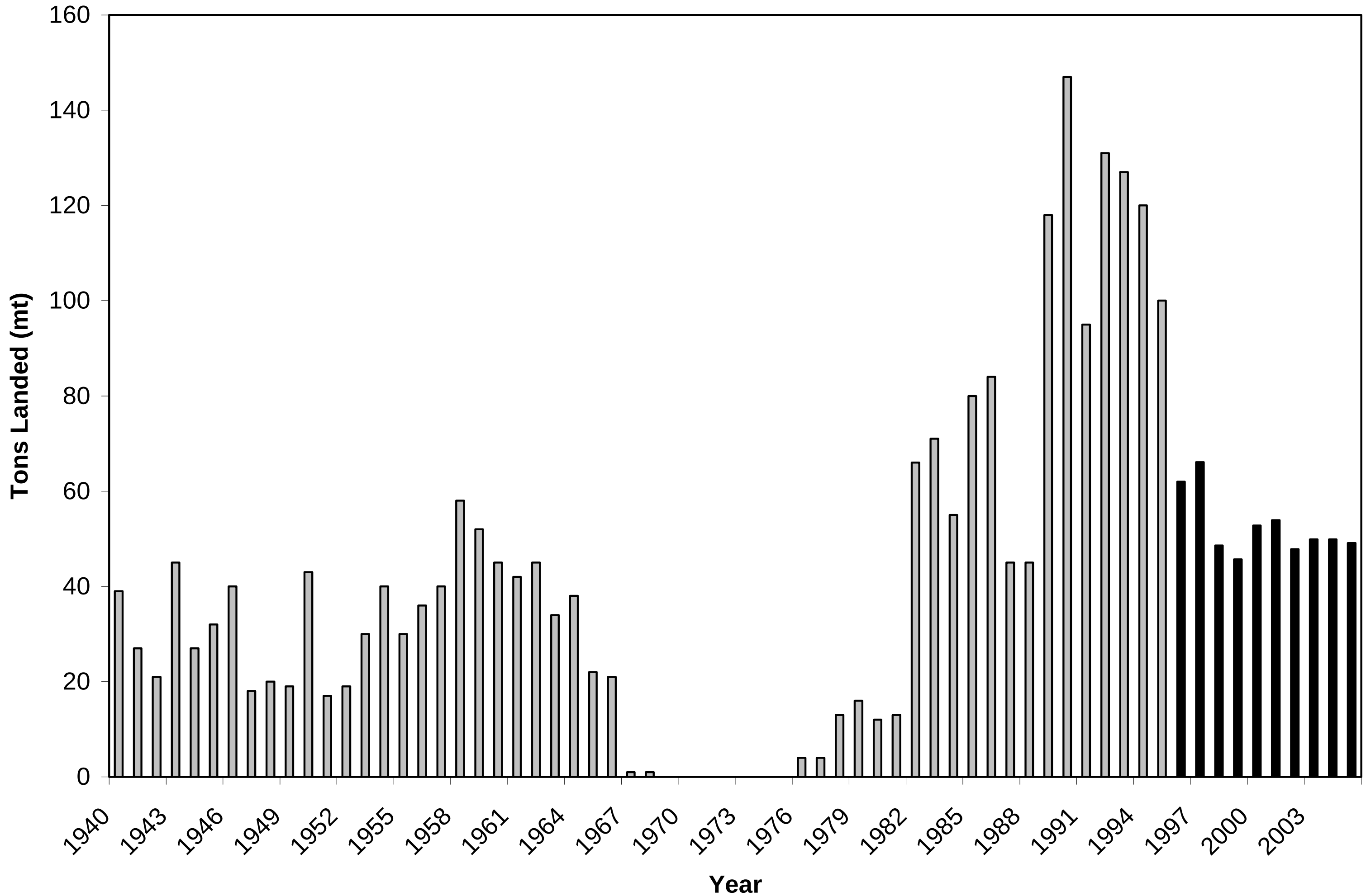

Figure 2. Atlantic sturgeon landings from the Saint Lawrence River 1940 – 2005. Black bars indicate years when a 60 mt quota was in place. Landings data from 1940 – 2000 were estimated from data presented in Trencia et al. (2002). There were no landings during 1970-1976.

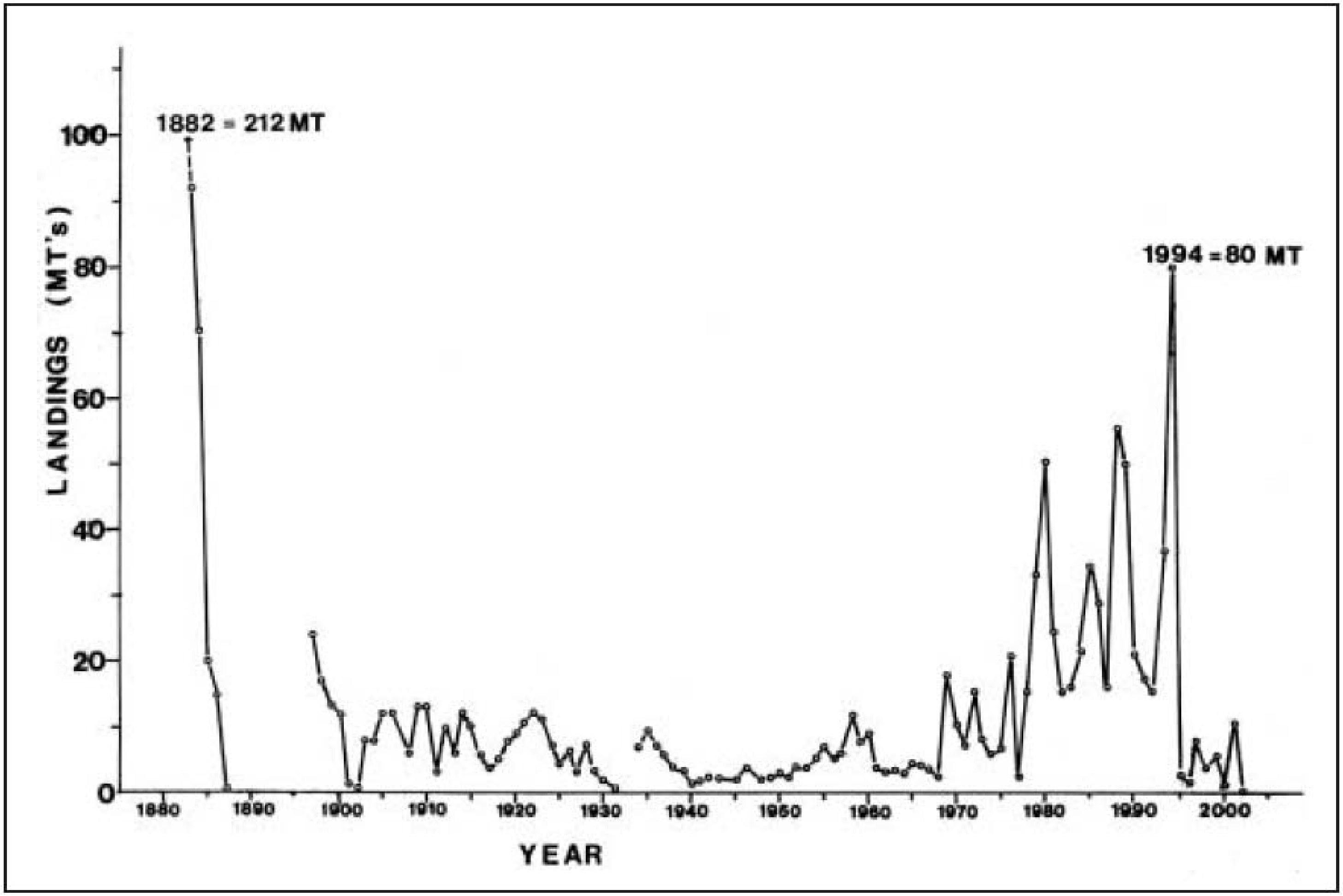

Figure 3. Atlantic sturgeon landings from the Saint John River 1882 – 2002. Courtesy of Dadswell (2006), based on data provided by Rogers (1936) and Canadian Fisheries Statistics.

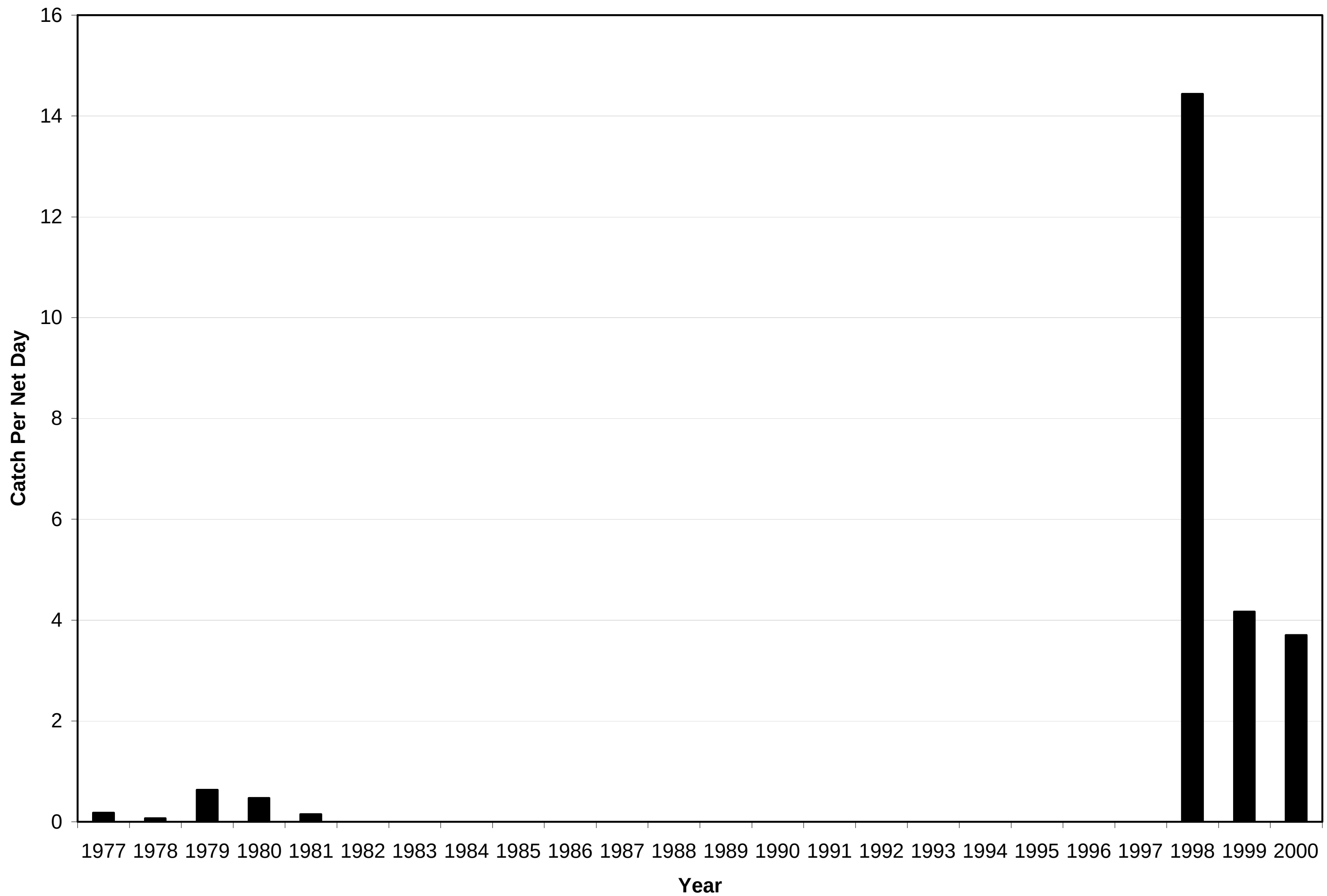

Figure 4. Atlantic sturgeon bycatch from a standardized shortnose sturgeon survey conducted between the periods of 1977-1981 and 1998-2000 in the Kennebec River, Maine.

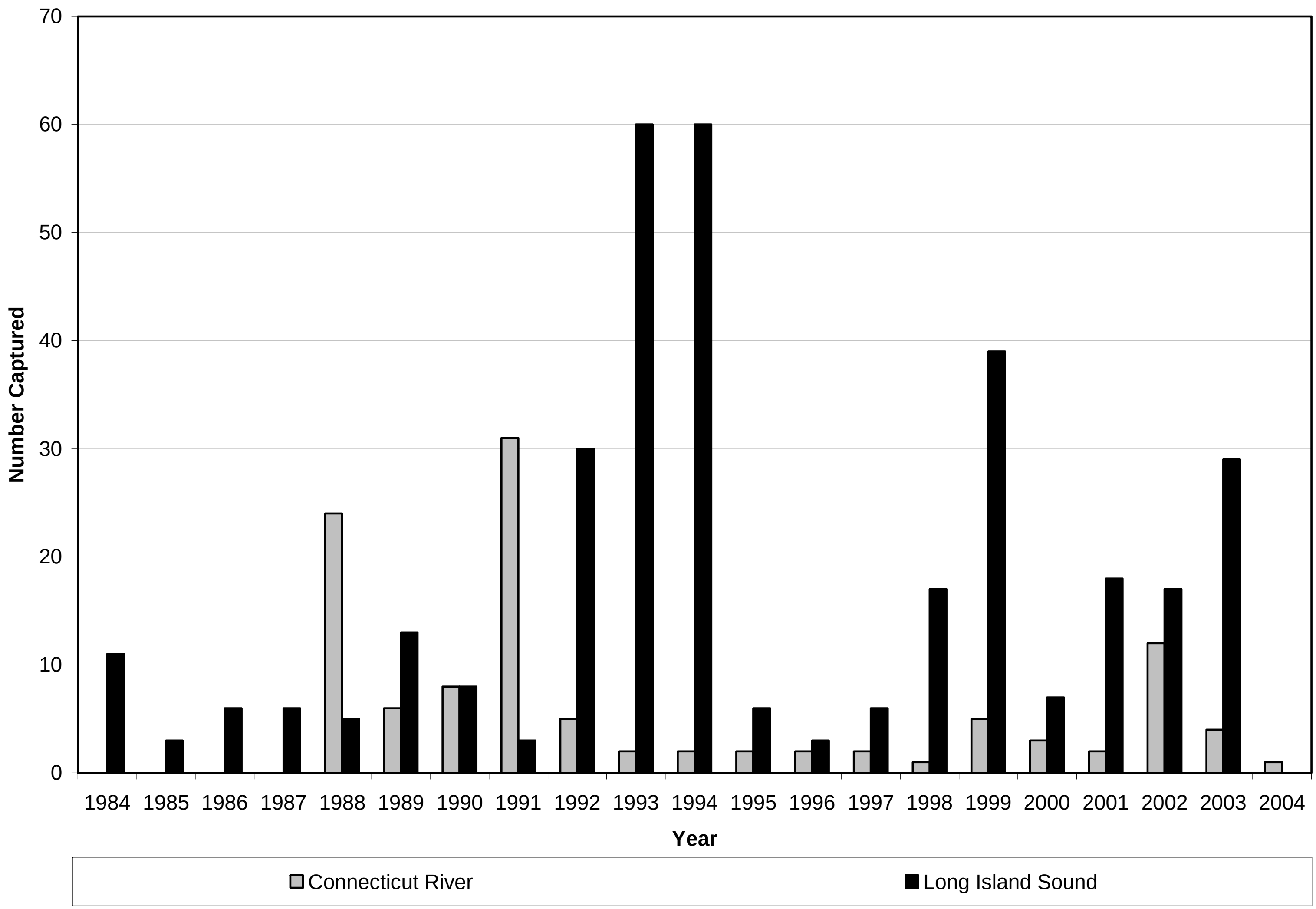

Figure 5. Atlantic sturgeon captures from the Long Island Sound Trawl and Connecticut DEP surveys. These sturgeon are believed to be of Hudson River origin.

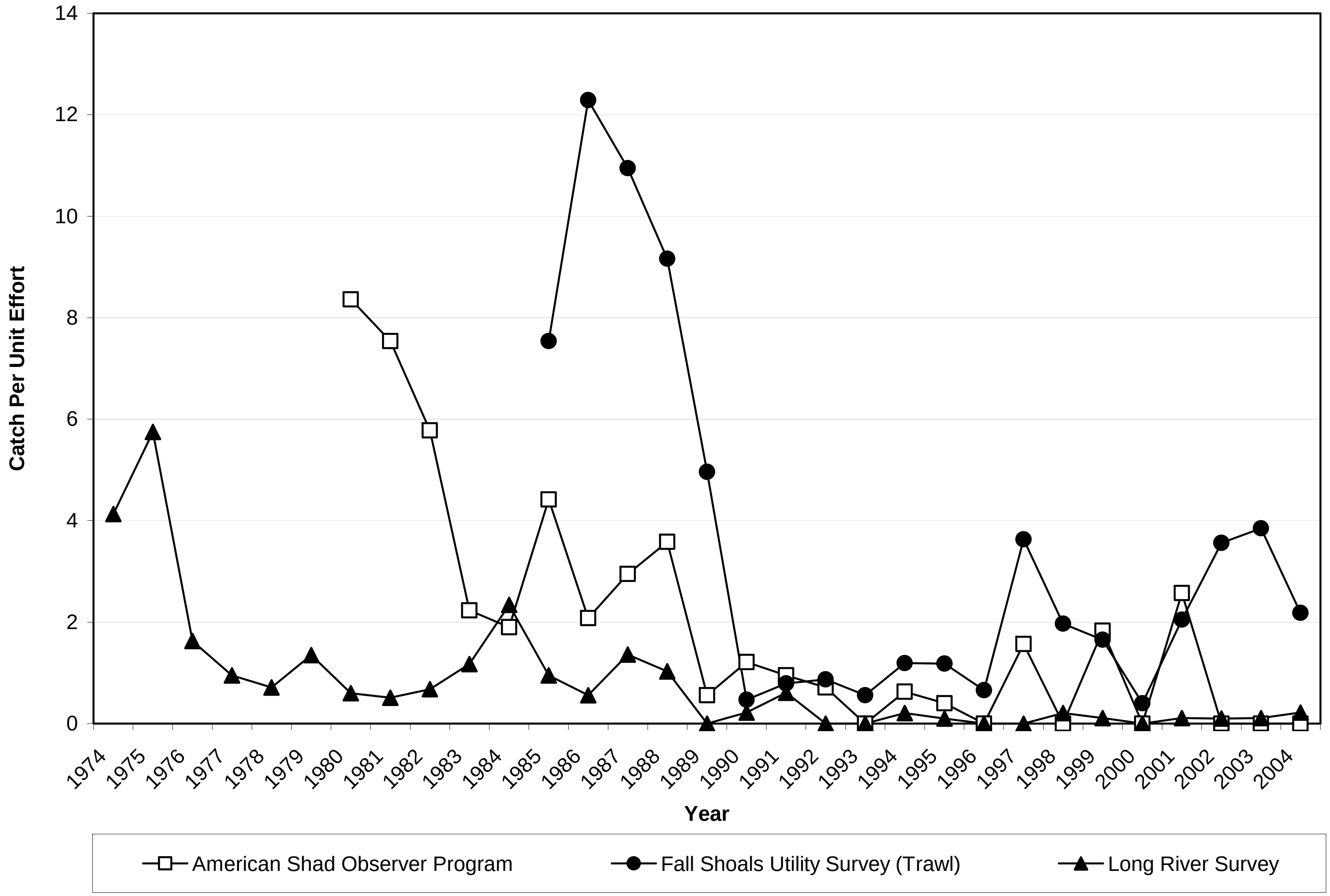

Figure 6. CPUE of Hudson River surveys that captured Atlantic sturgeon by year (1974-2004) and survey.

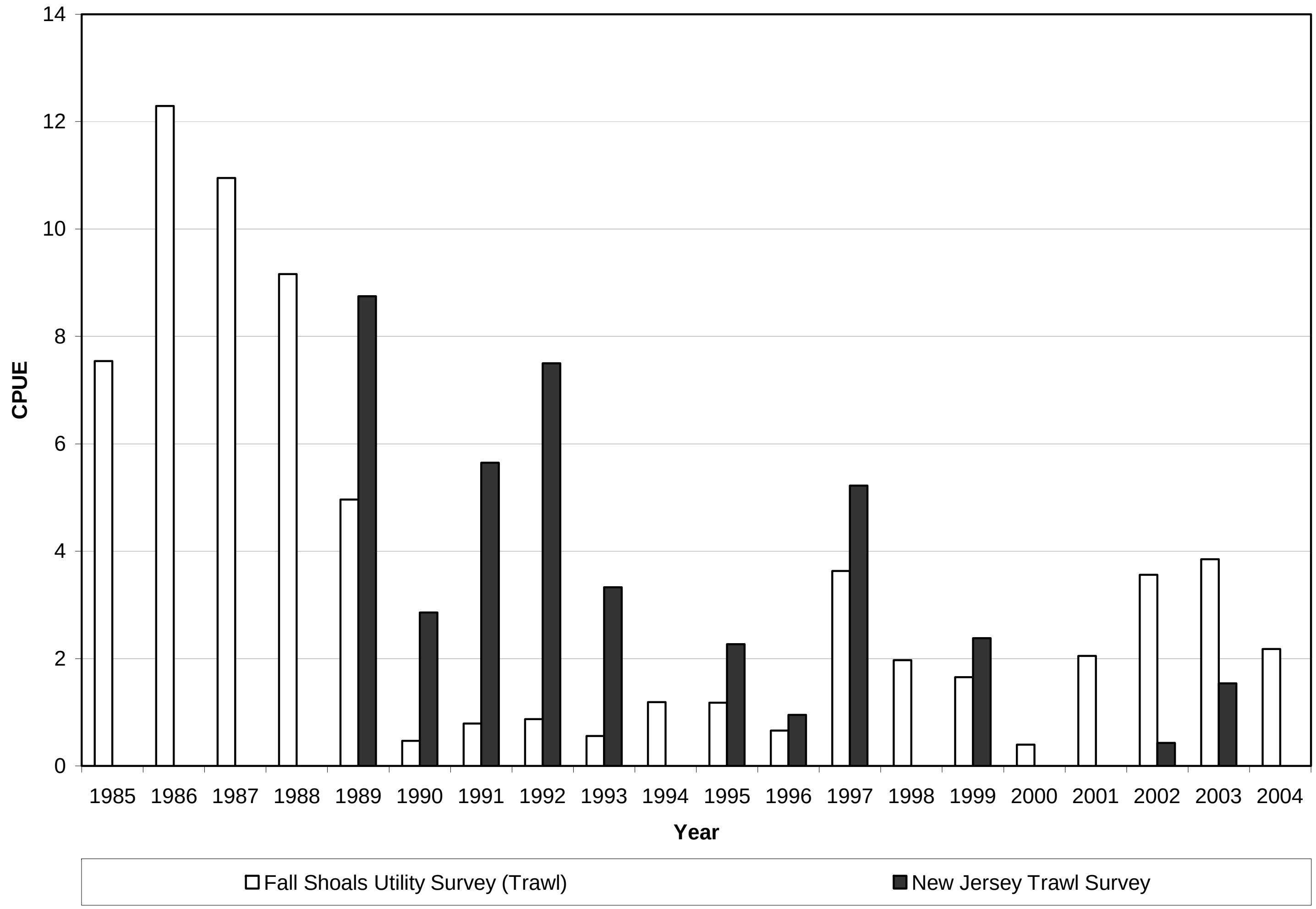

Figure 7. A comparison between Hudson River CPUE within the mainstem of the river (Fall Shoals Utility) and New York Bight (New Jersey Trawl Survey) captures. The Fall Shoals Utility CPUE is multiplied by 10 to adjust the y-axis.

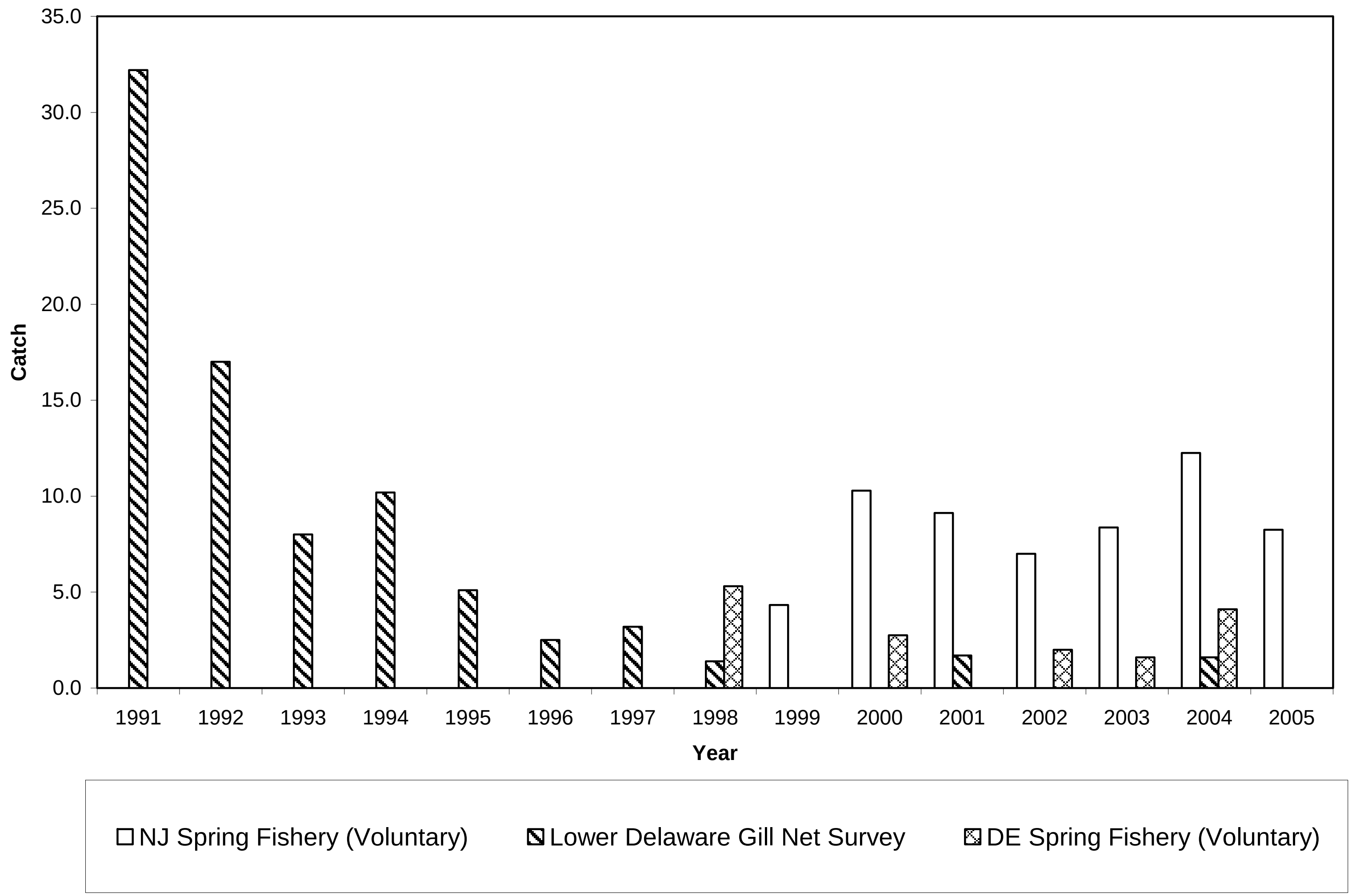

Figure 8. CPUE of Atlantic sturgeon from the Delaware River 1991 – 2005 from three surveys. The Delaware and New Jersey Spring Gill Net Fishery reports mean #/fisher and the Lower Delaware River Gill Net Survey reports number captured/hr.

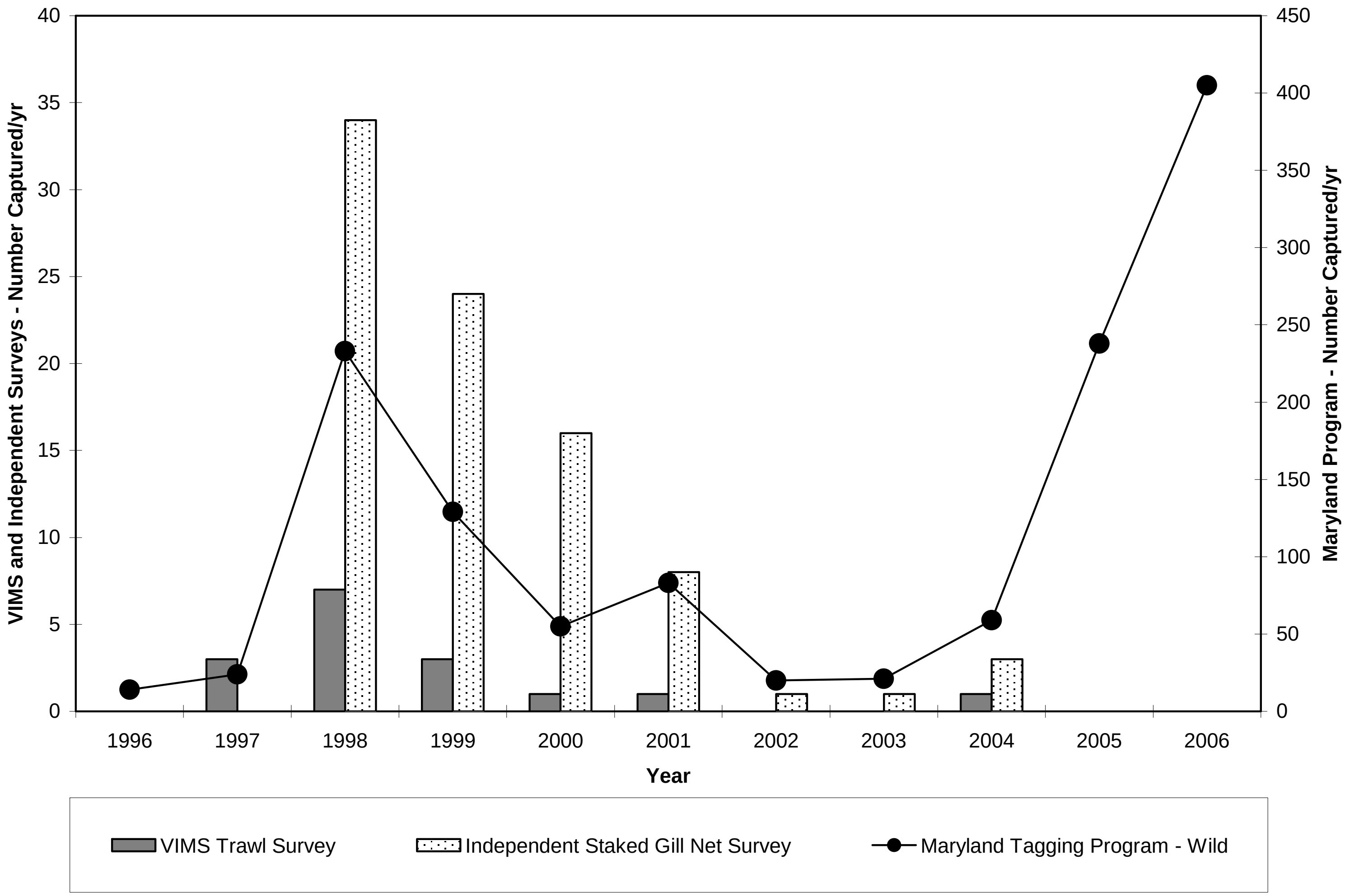

Figure 9. Reported catch rates of Atlantic sturgeon from the Chesapeake Bay (1996 – 2005) by survey. VIMS Trawl data are available from 1955 to 2004; however, zero sturgeon were captured between 1990 and 1996. Independent Staked Gill Net Survey data are available from 1997 to 2004.

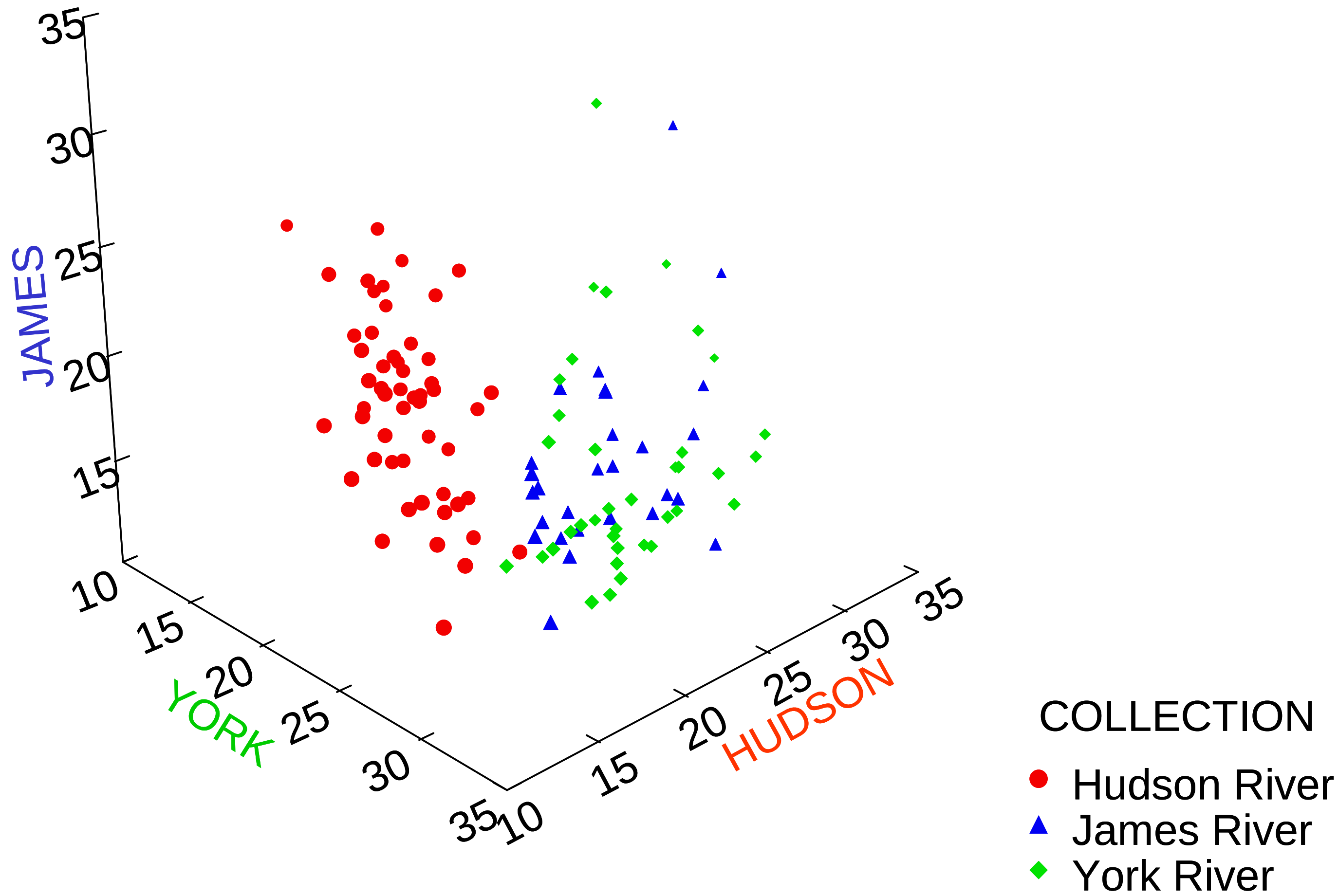

Figure 10. A 3-D scatter plot demonstrating how well York, James, and Hudson River Atlantic sturgeon can be differentiated from one another, using 12 locus nDNA markers.

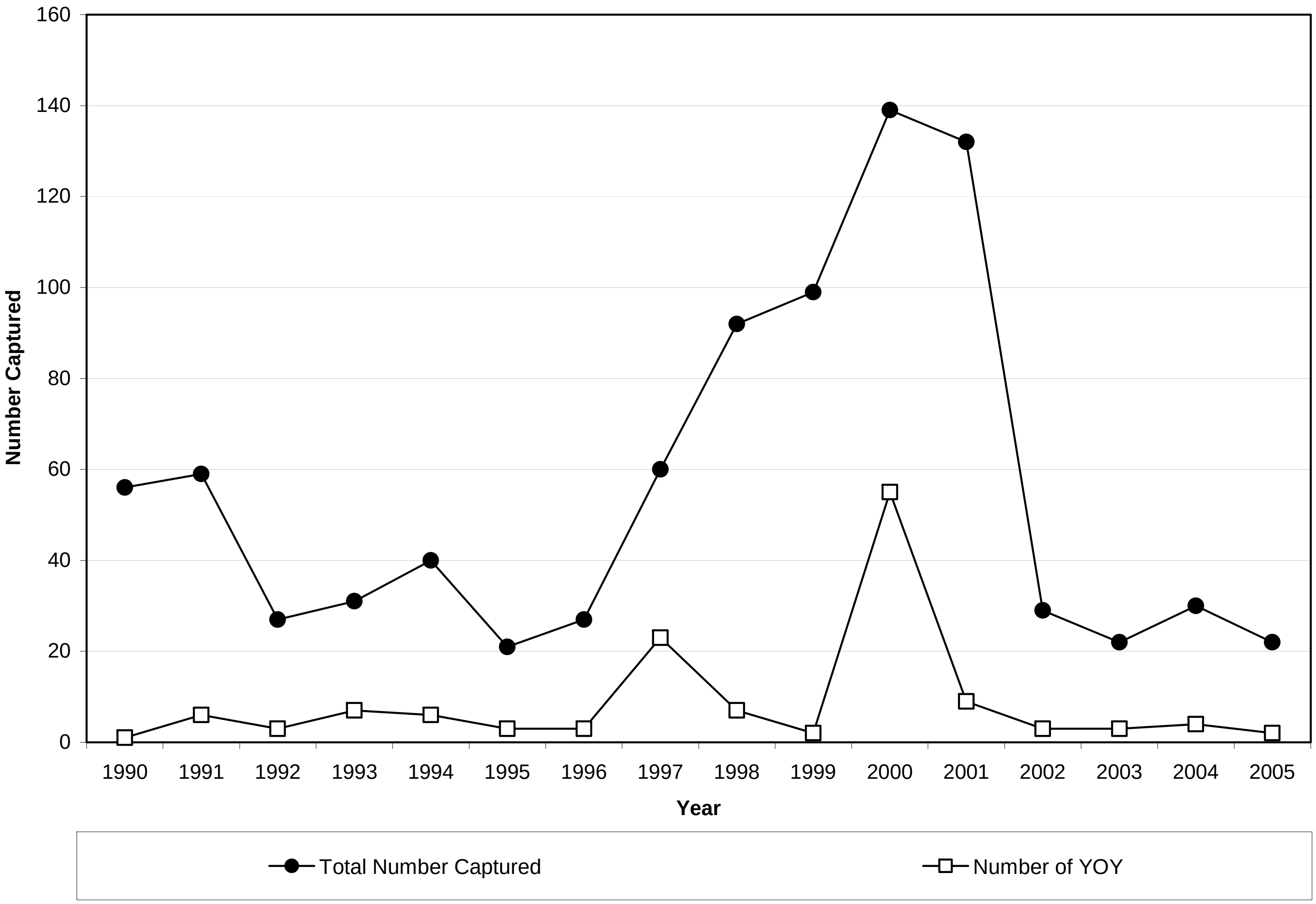

Figure 11. Comparison of total Atlantic sturgeon versus young-of-year captured during the NC Division of Marine Fisheries, Albemarle Sound Independent Gill Net Survey 1990 – 2006.

Figure 12. Left: A 39 cm TL young-of-year Atlantic sturgeon captured by recreational fishers on the Roanoke River near Jamesville, NC. Right: A 46 cm TL juvenile Atlantic sturgeon captured in the Neuse River, above New Bern, North Carolina (Photos courtesy of NCWRC).

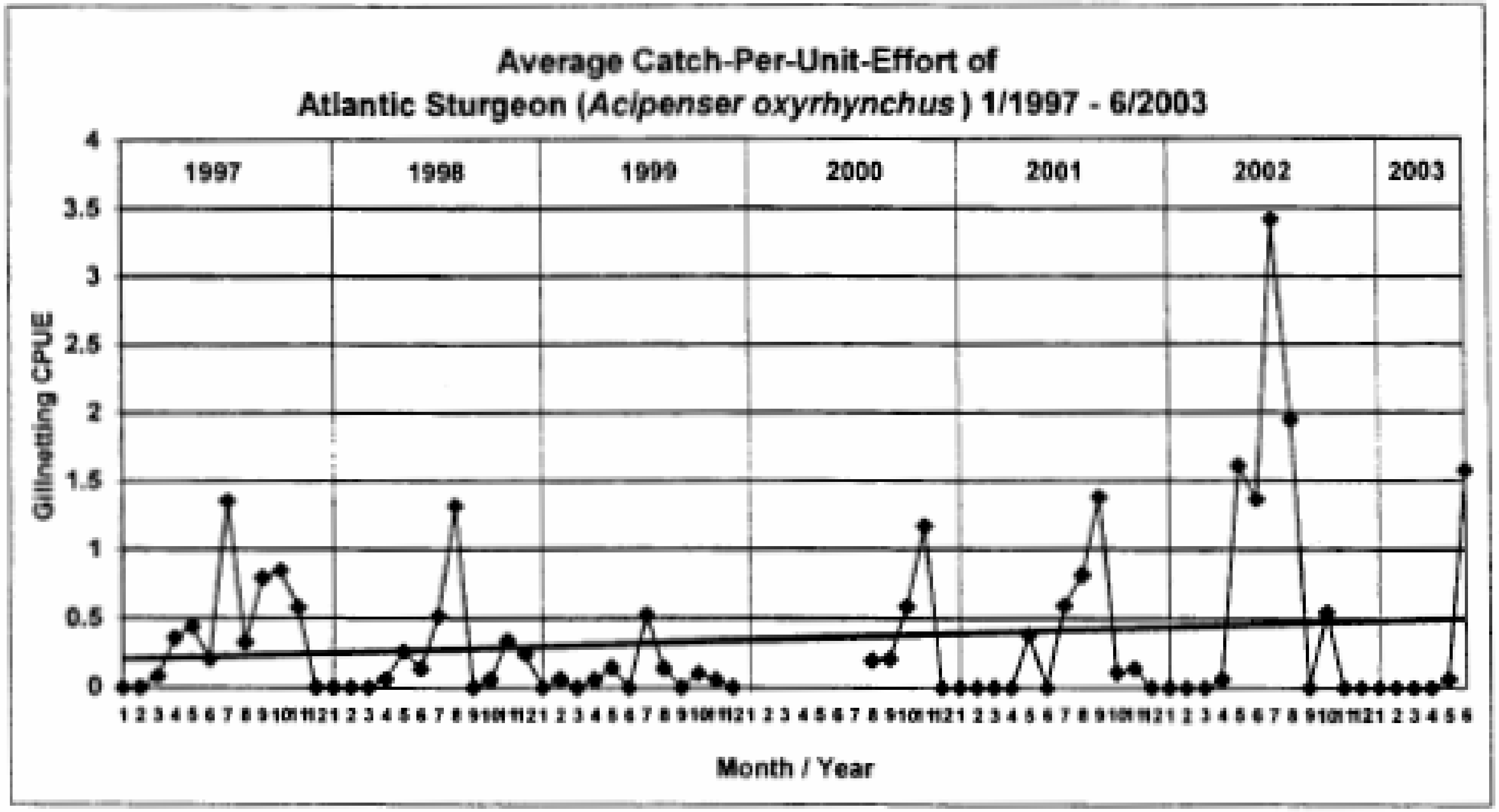

Figure 13. The average CPUE of Atlantic sturgeon captured on the Cape Fear River during the periods of 1997-2003. Courtesy of Williams and Lankford (2003).

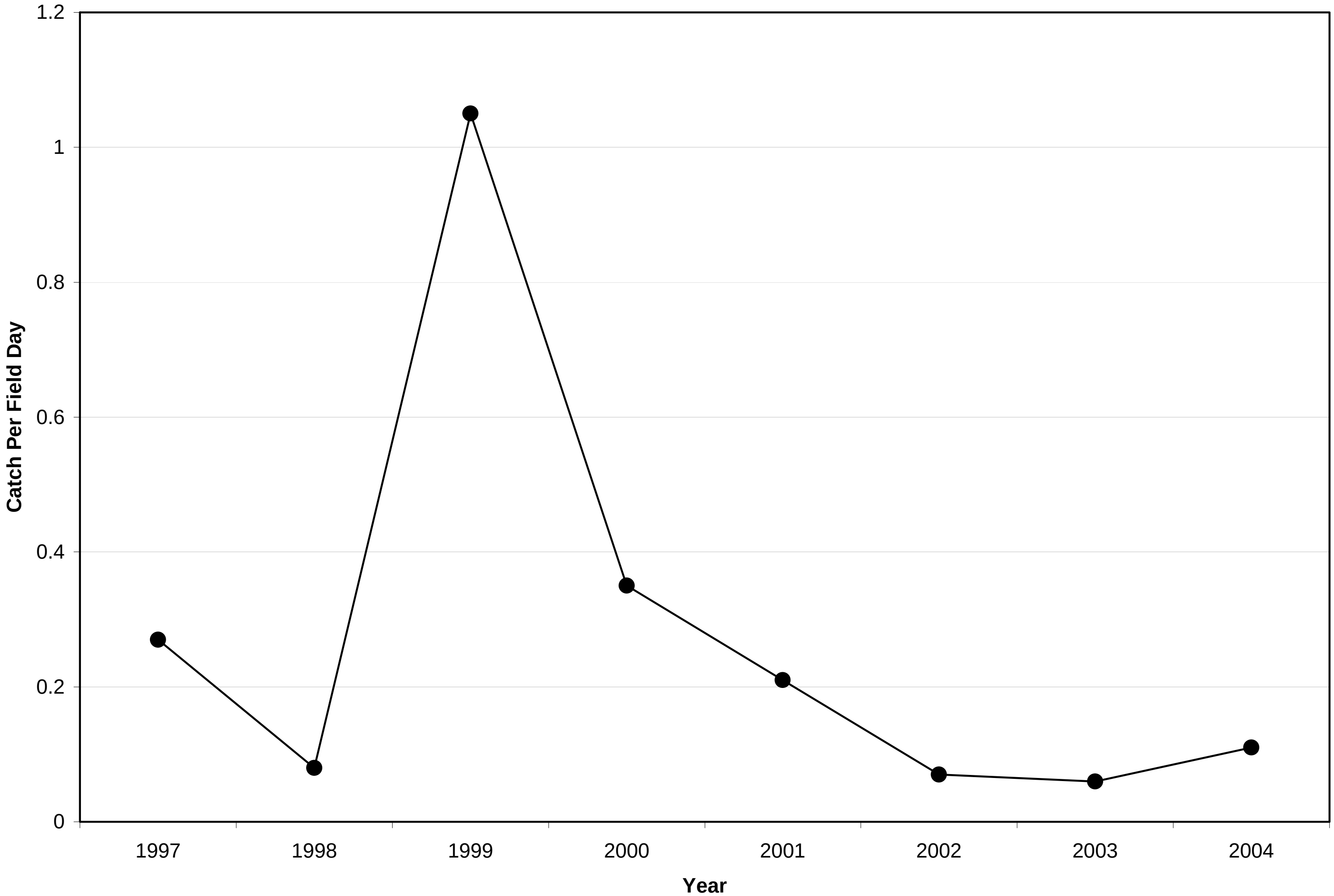

Figure 14. CPUE data of Atlantic sturgeon captures as bycatch in the Georgia Wildlife Resources Division Shad Monitoring Program 1997-2004, in the Georgia Altamaha River.

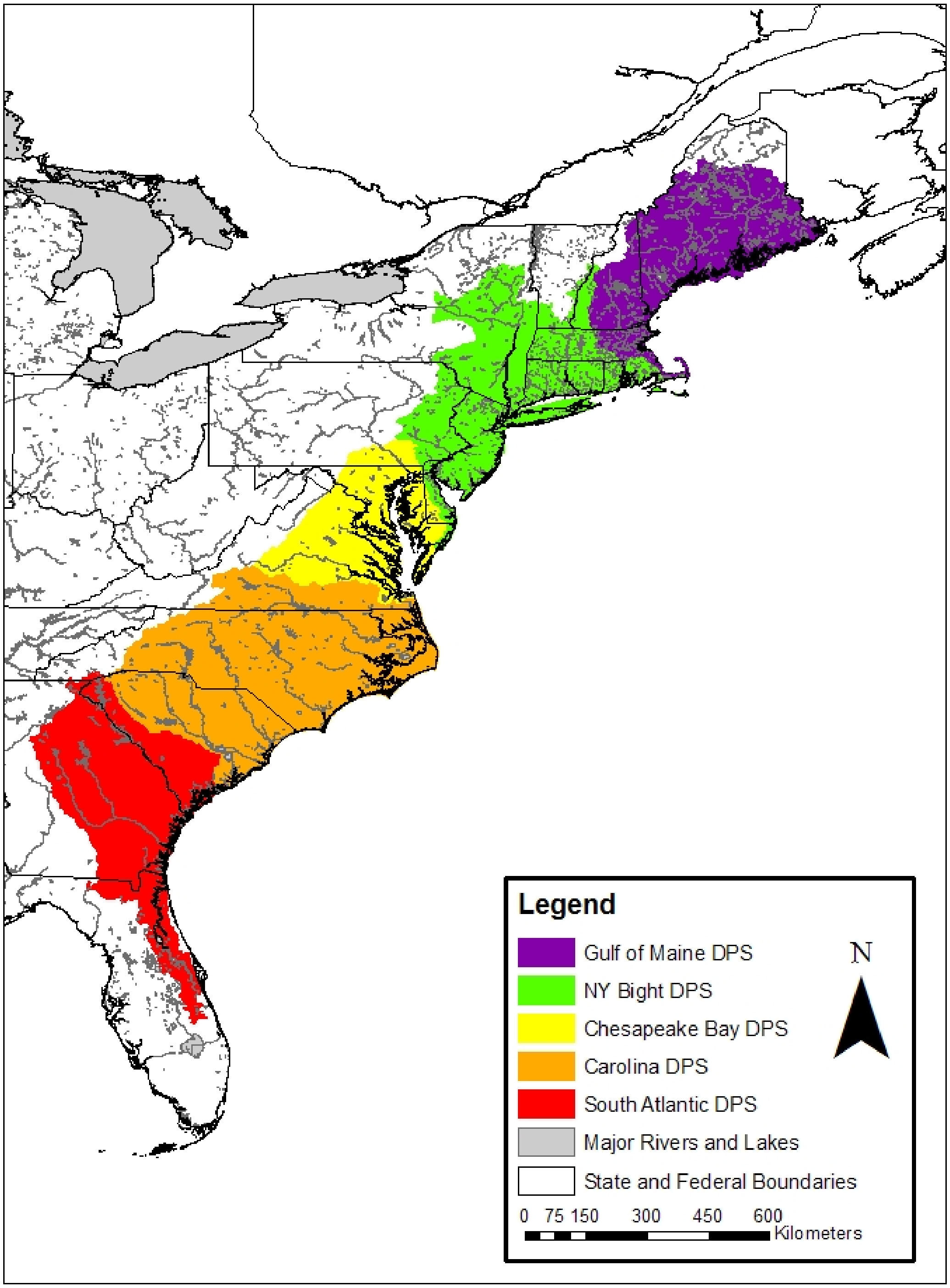
Legend
Gulf of Maine DPS
NY Bight DPS
Chesapeake Bay DPS
Carolina DPS
South Atlantic DPS
Major Rivers and Lakes
State and Federal Boundaries
0 75 150 300 450 600
Kilometers
N

Figure 15. Map depicting the five Distinct Population Segments (DPSs) of Atlantic sturgeon: Gulf of Maine, New York Bight, Chesapeake Bay, Carolina, and South Atlantic.

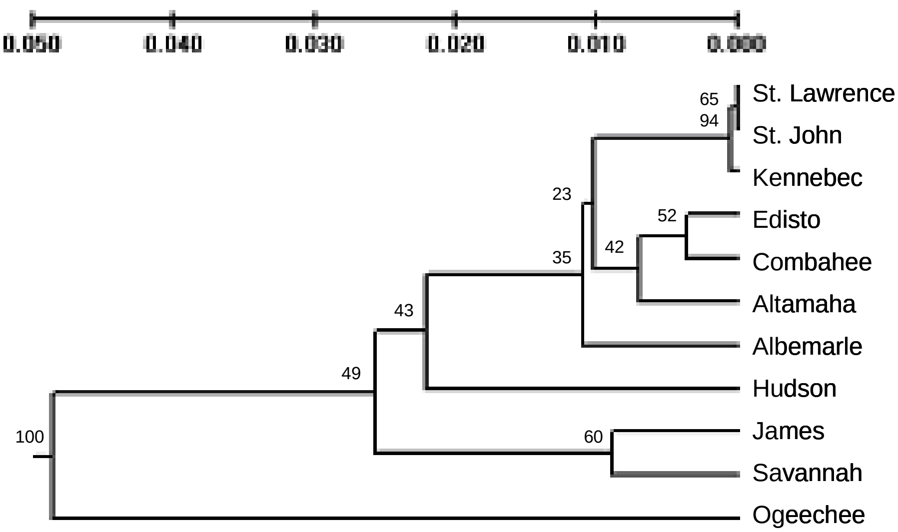

Figure 16. A UPGMA genetic tree and bootstrap values produced from mtDNA collected from Atlantic sturgeon young-of-year and spawning adults (Wirgin, supplemental data 2006).

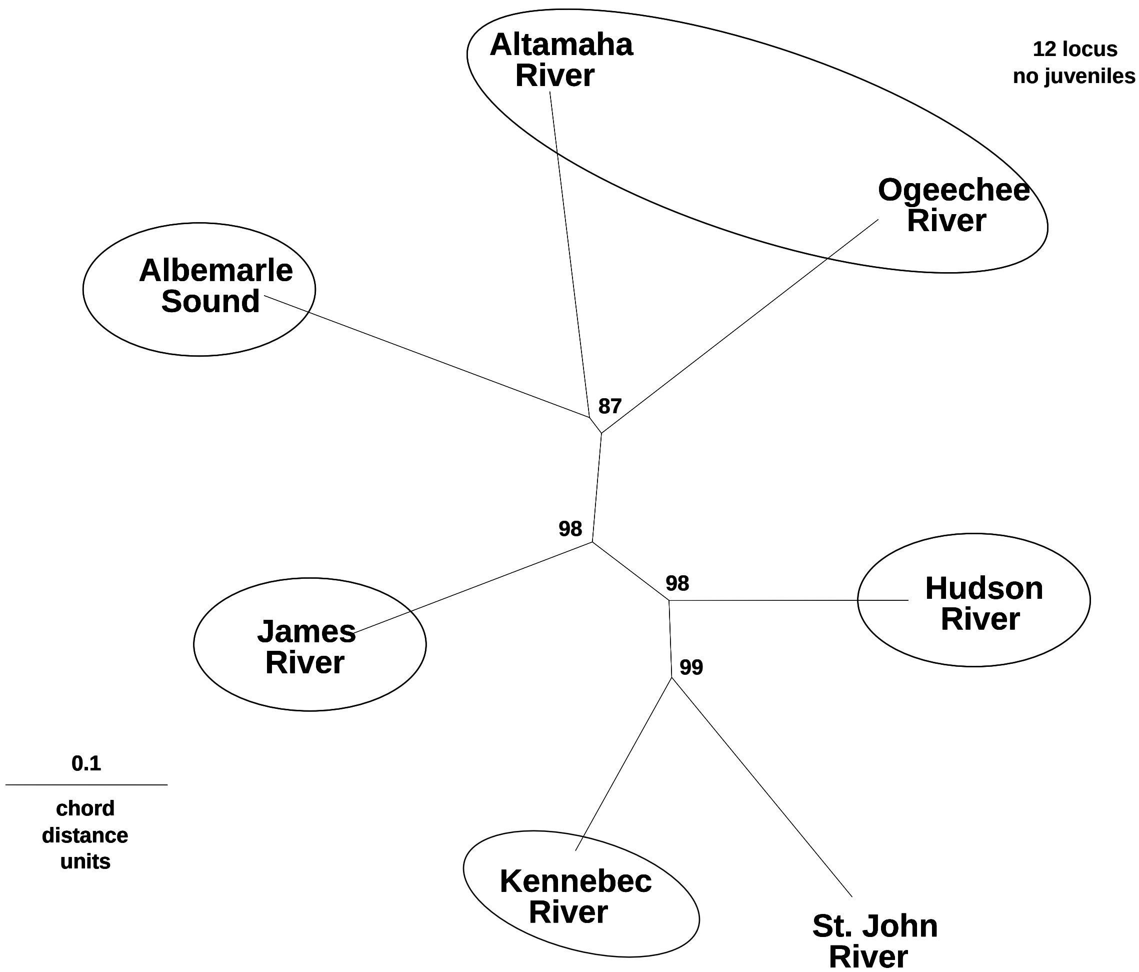

Figure 17. A neighbor-joining genetic tree and bootstrap values produced from nDNA (12 microsatellite markers) collected from Atlantic sturgeon young-of-year and spawning adults (King, supplemental data 2006).

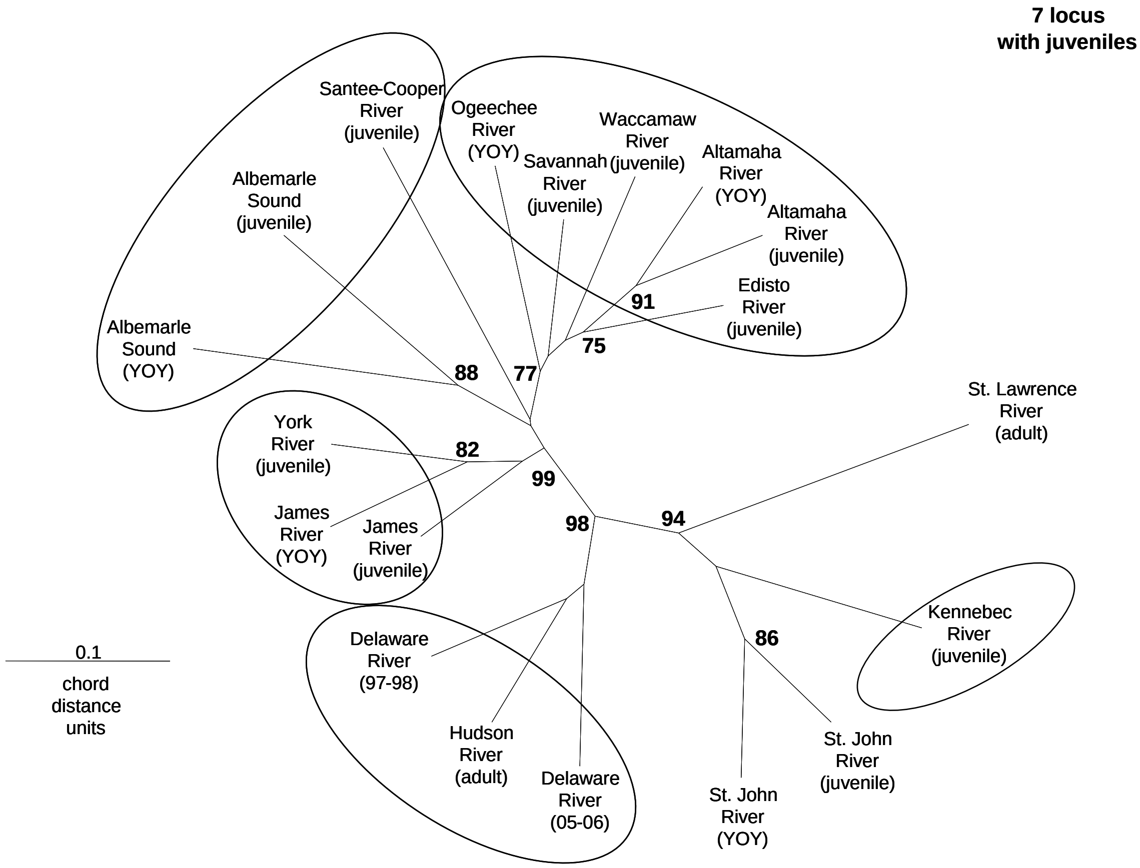

Figure 18. A neighbor-joining genetic tree and bootstrap values produced from nDNA (7 microsatellite markers) collected from Atlantic sturgeon YOY, subadults, and spawning adults (King, supplemental data 2006). Note that the Waccamaw River population is grouped with south Atlantic DPS populations, the SRT attribute this misclassification to the small sample size (N = 21), and the use of only juveniles that could be migrants from more southern populations.

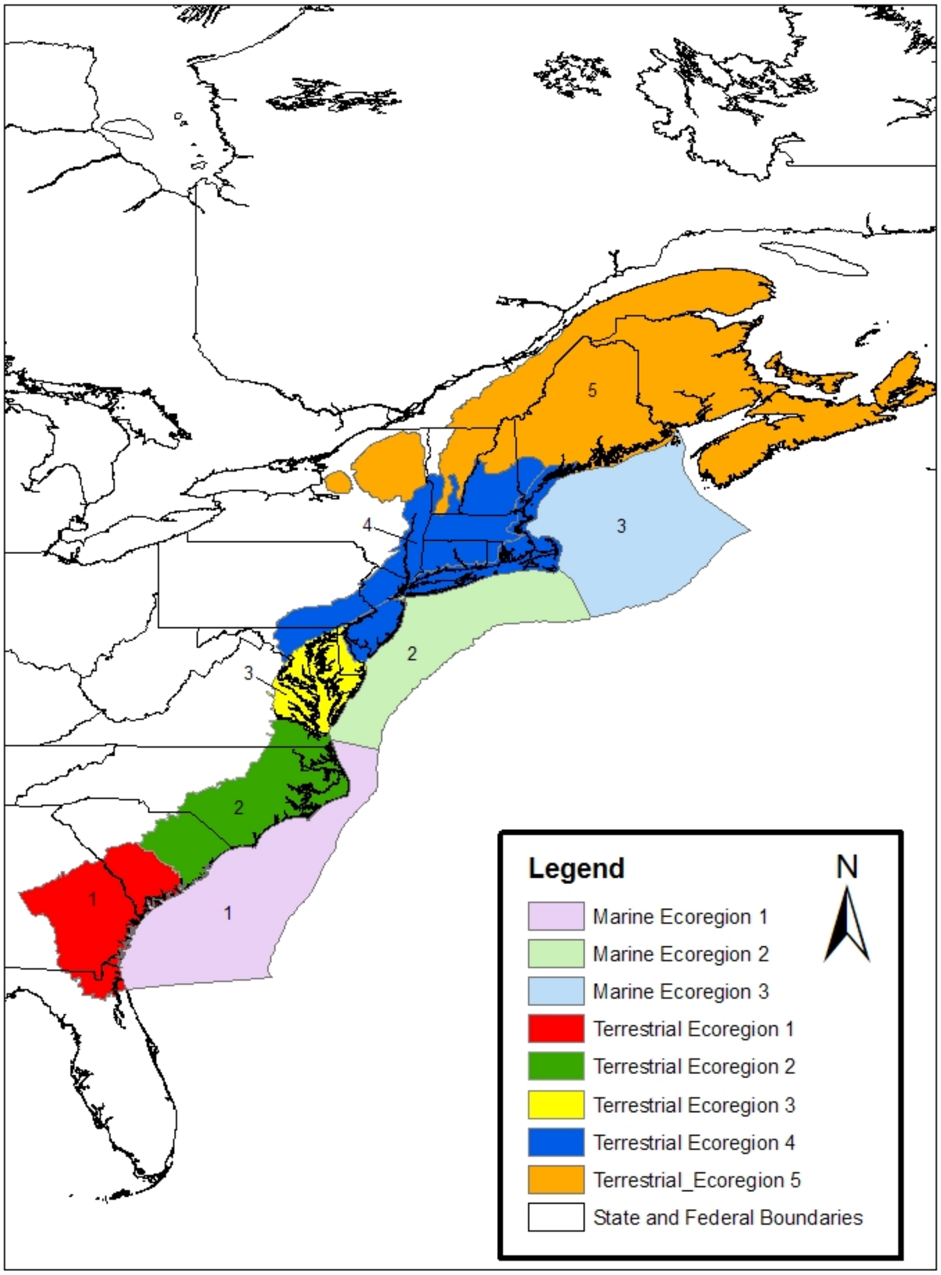

Figure 19. Terrestrial and marine ecoregions of eastern United States as determined by The Nature Conservancy (TNC). Each ecoregion has unique habitat characteristics. Terrestrial ecoregion #4 is comprised of two separate ecoregions: the Lower New England and North Atlantic regions that were combined for the Atlantic sturgeon status review because the Hudson and Delaware rivers cross both regions.

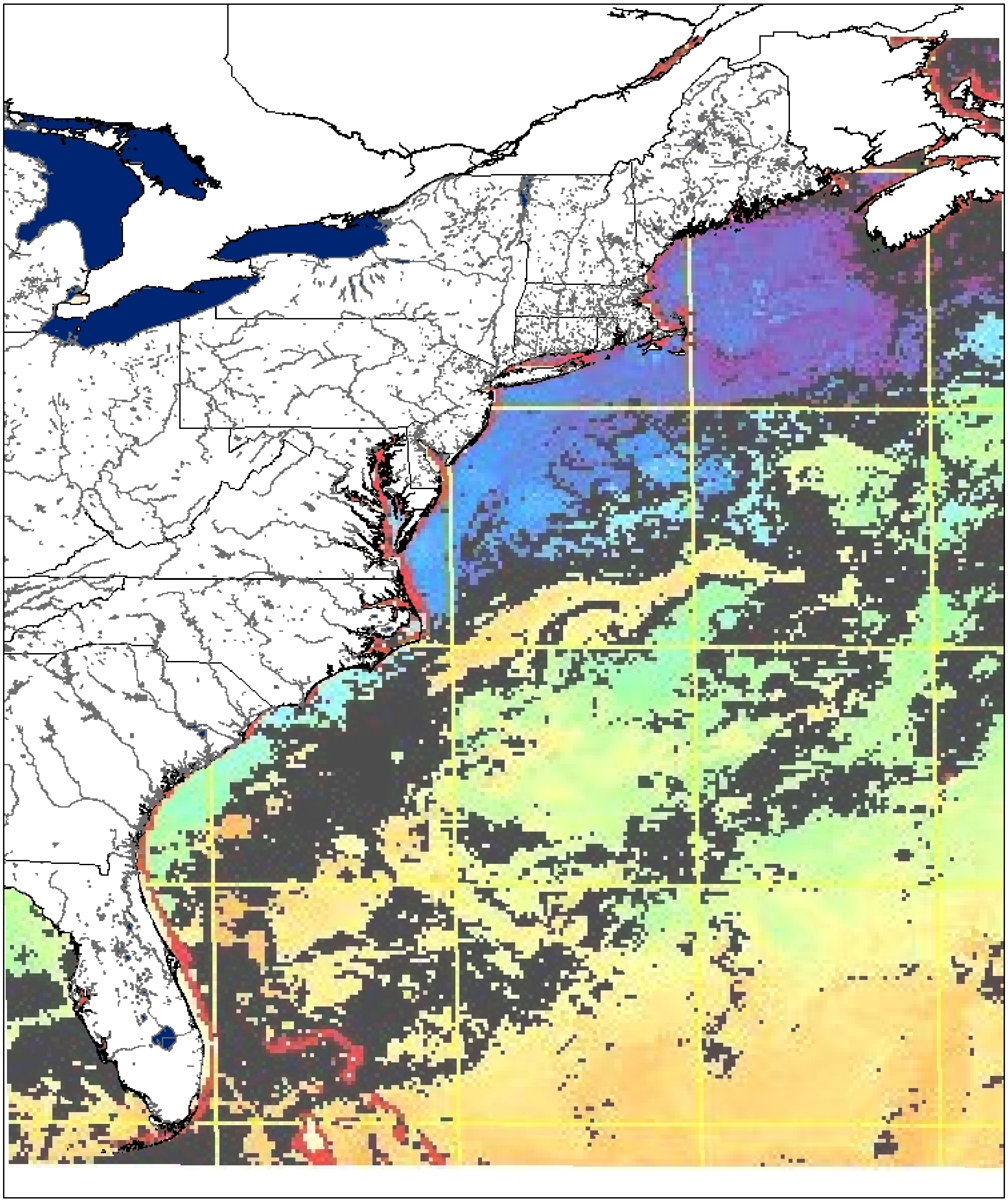

Figure 20. A map of sea surface temperatures along the Atlantic coast during the month of May (unknown year).

Figure 21. A gravid female Atlantic sturgeon found below the Annapolis River tidal power plant; decapitation of the fish was attributed to contact with the dam's turbine blade (Courtesy of M. Dadswell, 2006).

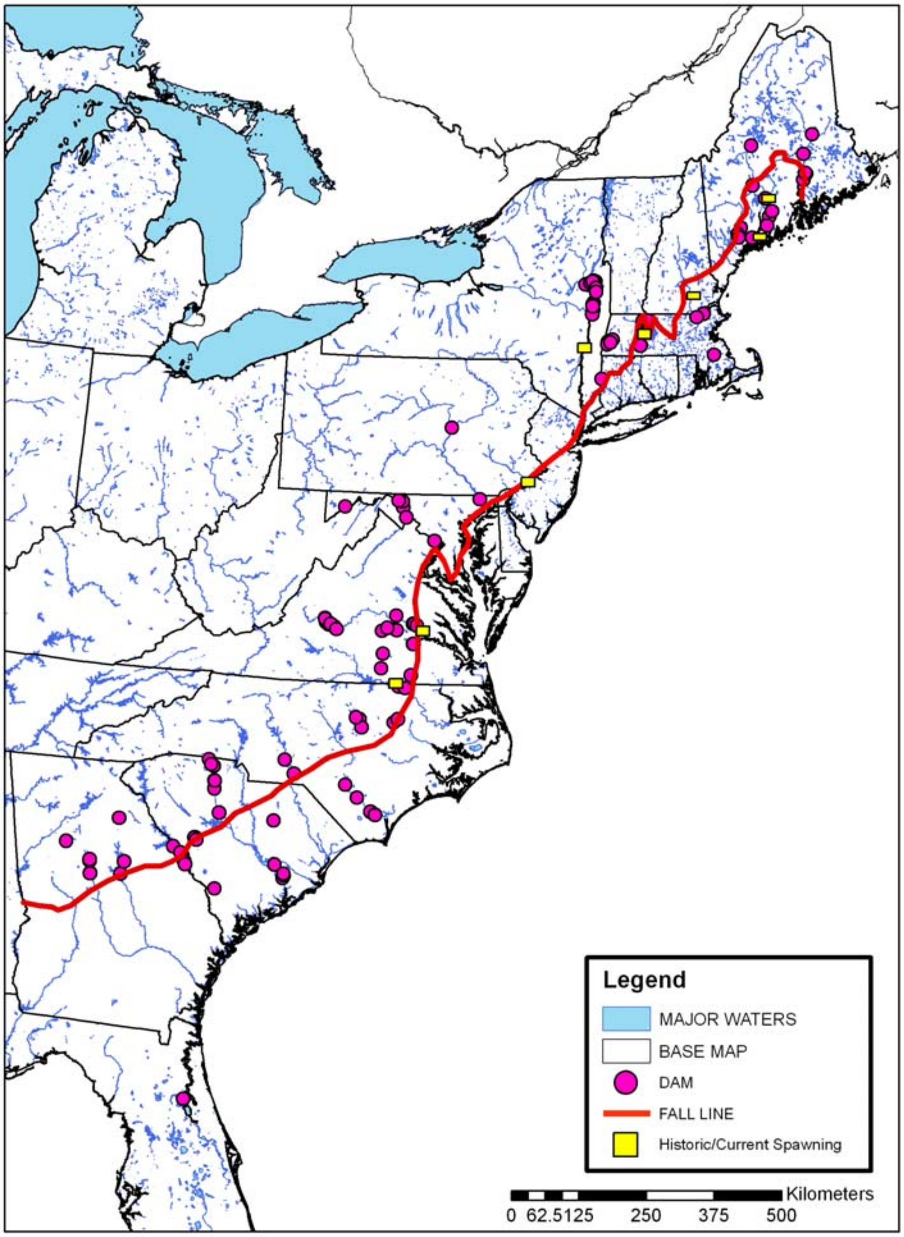

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Figure 22. Historic and current spawning locations of Atlantic sturgeon, locations of dams in rivers that have historically supported a spawning population, and their relationship to the fall line. Dam locations were provided by the U.S. Army Corp of Engineers National Inventory of Dams data layer and may be incomplete.

Figure 23. Photos of Atlantic sturgeon apparently struck by ships in the Delaware River. Photos courtesy of DFW.