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

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Introduction

This document provides a summary of information gathered for an Endangered Species Act (ESA) status assessment for Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). In 1977, the Research Management Division of the National Marine Fisheries Service (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 data base and information library (Murawski and Pacheco 1977). Three years later, in 1980, another document was prepared at the request of the NMFS 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 (Hoff 1980). In 1988, the NMFS announced the creation of a list of candidate species and requested information on Atlantic sturgeon. Candidate species include any species being considered by the Secretary for listing as an endangered or a threatened species, but not yet the subject of a proposed rule. The NMFS added Atlantic sturgeon to its list of candidate species (56 FR 26797) in 1991 and it remained on the revised list published in 1997 (62 FR 37560). 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 in the candidate species list is intended to stimulate voluntary conservation efforts that, if effective, may prevent an ESA listing.

On June 2, 1997, a petition dated May 29, 1997, was received by the NMFS and the U.S. Fish and Wildlife Service (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 petitioner's request for listing the species was based on three criteria: (1) present or threatened destruction, modification, or curtailment of habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; and (3) inadequacy of existing regulatory mechanisms. On October 17, 1997, the Services published their determination that the petition presented substantial information indicating that listing 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.

Section 4(a)(1) of the ESA states that a species is "threatened" or "endangered" if any one or more of the 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. The ESA directs the Services to make determinations under section 4(a)(1) as follows: (1) conduct a review of the species status utilizing the best scientific and commercial data available, and (2) take into account those efforts, if any, being made by any State or foreign nation, or any political subdivision of a State or foreign nation, to protect such species, whether by predator control, protection of habitat and food supply, or other conservation practices, within any area under its jurisdiction, or on the high seas (Section 4(b)(1)(A)).

A status review team was created to investigate the status of the species with regard to listing criteria provided by the ESA. This status review was undertaken concurrently with the Atlantic State Marine Fisheries Commission's (ASMFC) stock assessment of Atlantic sturgeon. Although the two documents duplicate some information, those seeking the details of catch data, abundance surveys, and population modeling should refer to the ASMFC stock assessment document (Kahnle et al. 1998). This document addresses listing determination criteria identified in the ESA: status of the species, the effect of the five factors, and the effect of efforts underway to protect the species.

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Life History

The life history of Atlantic sturgeon has been reviewed by many authors, including Murawski and Pacheco (1977), Van den Avyle (1983), Smith and Dingley (1984); and, more recently, Smith and Clugston (1997), Bain (1997), and Bemis and Kynard (1997). While details vary latitudinally, the general life history pattern of Atlantic sturgeon is that of a long lived, late maturing, estuarine dependent, anadromous species. The species' historic range included major estuarine systems ranging from Hamilton Inlet on the coast of Labrador to the St. Johns River in Florida (reviewed in Murawski and Pacheco 1977, Smith and Clugston 1997).

Atlantic sturgeon spawn in fresh water, but spend most of their adult life in the marine environment. Spawning adults migrate upriver in the spring, beginning in February-March in southern systems, April-May in mid-Atlantic rivers, and May-July in Canadian waters (Murawski and Pacheco 1977, Smith 1985, Smith and Clugston 1997). In some areas, a small spawning migration also occurs in the fall. Spawning occurs in flowing water between the salt front and fall line of large rivers. Sturgeon eggs, which are highly adhesive, are deposited on the bottom, usually on hard surfaces (i.e. cobble) (Smith and Clugston 1997). Hatching occurs approximately 94-140 hours after egg deposition at temperatures of 20° and 18° C, respectively (Smith et al. 1980). The yolksac larval stage is completed in about 10 days, after which the young assume a demersal existence. Juvenile sturgeon are thought to gradually move downstream into brackish waters, and remain resident 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), where they may undertake long range migrations. Despite extensive mixing in coastal waters, statistically significant genetic differences between stocks have been identified (Bowen and Avise 1990, Waldman et al. 1996b). Not all portions of the species' range have been represented in the genetic testing.

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, female Atlantic sturgeon mature in South Carolina at 7-19 years, (Smith et al. 1982), in the Hudson River at 15-30 years (Dovel 1979, Dovel and Berggren 1983; VanEenennaam et al. 1996), and in the St. Lawrence River at 27-28 years (Scott and Crossman 1973). Males mature at younger ages and smaller sizes than females (e.g. 5-13 years in South Carolina, 11-20 years in the Hudson River, 22-34 years in the St. Lawrence River). These ages should be taken as approximations since there has not been an age validation study conducted to date. Atlantic sturgeon probably do not spawn every year, though data on spawning intervals do not exist for most populations. In South Carolina, females spawn at 3-5 year intervals, while males spawn at 1-5 year intervals (Smith 1985). A weight-fecundity relationship for Atlantic sturgeon from South Carolina has been estimated as follows: fecundity = 233064 + 13307 x fish weight (kg) (Smith et al. 1982). The ripe ovaries may make up as much as 25% of the total fish weight (Smith

1985). VanEenennaam et al. (1996) measured fecundity of Atlantic sturgeon in the Hudson River at between 400,000 and 2.6 million eggs. Insufficient information exists for estimation of age specific emigration rates; however, juveniles are thought to remain in riverine or estuarine habitats for 1-6 years (Smith 1985). Atlantic sturgeon have been aged to 60 years, but without validation (Mangin 1964).

Tagging data indicate that immature Atlantic sturgeon travel widely once they emigrate from northern natal rivers. Until they mature, juveniles and subadults wander among coastal and estuarine habitats, undergoing rapid growth (Dovel and Berggren 1983, Stevenson 1997). Seasonal movement is north in the late winter and south in the fall and early winter. Subadult Atlantic sturgeon tagged in the Hudson River estuary were recaptured in estuaries and the nearshore ocean from Marblehead, MA to Ocracoke, NC. Thirty-three percent of the recaptures outside of the Hudson River came from the Delaware River and Bay. Approximately 1,700 subadult Atlantic sturgeon from the lower Delaware River were tagged by the Delaware DFW from 1991-1997. The sample included individuals that were previously tagged in the Hudson River (n=4), coastal New Jersey (n=2), and coastal North Carolina (n=1). Sturgeon tagged in the Delaware River were subsequently recaptured from the nearshore ocean from Maine through North Carolina. Juvenile Atlantic sturgeon from southeastern rivers do not move as extensively as those from the north. The majority of Atlantic sturgeon tagged in South Carolina rivers, estuaries, and coastal waters were recaptured three months to two years later within 32 km of their tagging location while the remainder of recaptures occurred in North Carolina, Georgia, and Florida (Kahnle et al. 1998). This data shows that Atlantic sturgeon juveniles undergo long migrations as they mature and can be found many kilometers away from their rivers of origin.

Completion of the sturgeon's life cycle is dependent on a wide range of estuarine and freshwater habitats for spawning, early life stage survival, and survival and growth of juveniles (Beamesderfer and Farr 1997). Thus, many aspects of habitat degradation may impact Atlantic sturgeon populations, including industrial and municipal pollution, blockage of access to habitats by dams, channelization or elimination of backwater habitats, dewatering of streams, and physical destruction of spawning grounds (reviewed in: Boreman 1997). Anadromous spawning behavior also concentrates large numbers of individuals in areas easily accessible to fishermen, thus exposing populations to potentially high fishing mortality rates.

Boreman (1997) used models integrating the effects of variation in natural mortality, fecundity, maturation rates, and spawning frequency on lifetime egg production to evaluate sensitivity of Atlantic sturgeon and several other fish species to overfishing. The reproductive output of Atlantic sturgeon is more sensitive to fishing pressure than the reproductive output of striped bass, winter flounder, or bluefish. For Atlantic sturgeon, the average age at which 50% of maximum lifetime egg production is achieved was estimated to be 29 years, approximately 3-10 times longer than for the bony fish species examined.

Recovery of depleted populations is inherently a slow process, particularly with a late maturing species such as Atlantic sturgeon. The late age of maturity of Atlantic sturgeon provides more opportunities for individuals to be removed from the population due to harvest, bycatch, and/or habitat degradation before their first chance to spawn. However, because Atlantic sturgeon are long lived and have few potential predators (other than humans), high natural survival rates are expected. Their long life span affords individual with multiple opportunities to contribute to future generations.

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. Systems for which 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 the professional opinion of fishery management personnel. Systems in which gravid female Atlantic sturgeon or juveniles ≤ age 1 have been documented within the past five years were considered to contain extant spawning populations. Presence of juveniles > age 1, does not provide evidence of spawning within a river because they undertake extensive migrations as subadults.

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 abundance of Atlantic sturgeon in east coast estuarine systems of the United States is summarized in Appendix A. Size and age data indicate how a particular habitat (i.e. spawning, nursery, or migrating habitat) is used. 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 documents changes in abundance of sturgeon populations are included in the text.

The most recent quantitative trend information is available for the Delaware and Hudson Rivers where commercial fisheries existed through 1996. These data reveal a decrease in abundance in recent years correlated with high rates of commercial harvest. In some southern areas where the directed fishery has been closed for some time, limited data from bycatch and fishery independent surveys suggest that those stocks are rebuilding. For example, limited sampling in the Cape Fear River, NC, during 1997 suggested a substantial increase in abundance of juvenile Atlantic sturgeon in comparison to sampling during 1990-1992 (the fishery was closed in 1991). During 1995-1997, approximately 500 age ≤ 1 Atlantic sturgeon were tagged in a single 0.5 mile section of the Edisto River, SC. This suggests successful recruitment, which is indicative of a healthy population, despite heavy fishing pressure prior to the closure of the fishery in 1985. Unfortunately, similar data from previous years are not available for comparison.

Overfishing in the late 1800's led to significant declines in abundance of Atlantic sturgeon throughout their range. Sturgeon stocks were also impacted by environmental degradation, especially in the early to mid-1900's. Harvest in more recent years reduced abundance in most systems and caused extirpation of some historic spawning stocks (Connecticut River, St. Marys River, GA/FL, and possibly the St. Johns River, FL). Despite these extirpations, the geographic range of the species in the United States has not significantly changed. Historically, Atlantic sturgeon were present in approximately 34 rivers in the United States from the Penobscot River, ME to the St. Johns River, FL. It is not known how many of these rivers supported spawning. The current range has contracted slightly, from the Kennebec River, ME (absence from the Penobscot River has not been conclusively determined) to the Satilla River, GA. Atlantic sturgeon are currently present in 32 rivers and spawning occurs in at least 14 of these rivers (see Appendix A).

The following section presents information on rivers that support Atlantic sturgeon spawning or nursery habitat. Detailed information that supports this summary is available in the ASMFC Stock Assessment (Kahnle et al. 1998).

River Specific Distribution and Abundance Information

CANADIAN RIVERS

Atlantic sturgeon have been reported to occur as far north as the lower George River in Ungava Bay and Hamilton Inlet in Labrador, but it is not known if spawning ever occurred in any Labrador River (Leim and Scott 1966, Vladykov and Greeley 1963). In Quebec, Atlantic sturgeon are found in the Gulf of St. Lawrence from the Blanc Sablon on the Quebec side of the Strait of Belle Isle, and in the St. Lawrence River up to Three Rivers and occasionally further upriver at Sorel (Vladykov and Greeley 1963). Atlantic sturgeon have been captured on the Gulf of St. Lawrence shore of Newfoundland; in the Mirimichi River, New Brunswick; and at Cheticamp, Aspy Bay, Canso Straits, and Halifax in Nova Scotia (Leim and Scott 1966, Vladykov and Greeley 1963). In the Bay of Fundy, Atlantic sturgeon were found in abundance in the Saint John River, New Brunswick and have also been reported from Minas Basin and the Avon River (Leim and Scott 1966, Vladykov and Greeley 1963).

Very little systematic sampling had been done to document the presence or absence of Atlantic sturgeon in many Canadian Rivers; however, it is likely that Atlantic sturgeon spawned in the Mirimichi, Shubenacadie, La Have Rivers, and in other systems of similar size (M. Dadswell, Acadia University, personal communication). Historically, Atlantic sturgeon probably spawned in the Annapolis River, Nova Scotia (M. Dadswell, Acadia University, personal communication), but it is unknown whether the population was extirpated following construction of a tidal power project. It is unlikely that sturgeon spawn in the Petitcodiac River, New Brunswick because there is very little freshwater habitat below the lowermost dam/causeway (M. Dadswell, Acadia University, personal communication).

St. Lawrence River, Quebec

Historical records indicate that Atlantic sturgeon were found in Maryland to Sorel (approximately river kilometer (rkm) 760 in the 1200 km long St. Lawrence River). Vladykov and Greeley (1963) reported that young Atlantic sturgeon (15-38 cm) were abundant at St. Vallier (about 30 km downstream of Quebec City). Although the exact location of spawning areas in the St. Lawrence River are not well documented, Vladykov and Greeley (1963) suggested that Atlantic sturgeon spawned in pools below waterfalls on tributaries to the St. Lawrence River (the Bastican River on the south shore and Riviere-aux-Outardes on the north shore). Caron (1998) reported that in 1997, 13 running ripe males were captured, tagged, and released in a deep section of river located about 100 km upriver from the saltwater front. Attempts to collect eggs, larvae, or juveniles were not successful; however, strong currents and high tidal amplitudes (4m) hamper sampling in this stretch of the river (Caron 1998). The limited information indicates that Atlantic sturgeon probably spawn in the St. Lawrence River; yet this hypothesis must be confirmed through the capture of ripe females and/or juveniles $\leq$ age 1.

Saint John River, New Brunswick

Data on the size, age, and sex composition of the spawning stock, spawning area, and timing of spawning are unavailable for this system (B. Jessop, DFO, personal communication). Dr. Dadswell (Acadia University, personal communication) believes that Atlantic sturgeon spawn in the mainstem of the Saint John River and tributaries such as the Kennebecasis River. Dr. Dadswell believes Atlantic sturgeon occasionally migrated above the head-of-tide, but construction of the Mactaquac Dam did not greatly diminish the amount of spawning habitat. In the mid- 1970's, sampling with small mesh gill nets resulted in the capture of a large number of juvenile Atlantic sturgeon ranging in size from 30-90 cm in the Long Reach section of the Saint John River (M. Dadswell, Acadia University, personal communication). Based on the presence of a sustained commercial fishery and juvenile fish, reproducing populations of Atlantic sturgeon are believed to occur in the Saint John River.

U.S. RIVERS

Estuarial Complex of the Kennebec, Androscoggin, and Sheepscot Rivers, ME

Atlantic sturgeon were historically abundant in the Kennebec River and its tributary the Androscoggin River (Bigelow and Schroeder 1953, Vladykov and Greeley 1963). One hundred and fifty-seven Atlantic sturgeon have been captured in the Kennebec River in scientific sampling programs since 1977. Nine adult and 52 subadult Atlantic sturgeon were captured in the Kennebec River in bottom set multifilament gillnets from 1977-1981. The average total length (TL) of the fifty-two subadults was 86.7 cm with a range from 48-114.5 cm (a subadult was classified as being less than 130 cm in the Kennebec River). The majority of the adult captures occurred in July in the stretch of the river from Merrymeeting Bay to Gardiner, suggesting that this is likely a spawning area. 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 Maine Department of Marine Resources (MDMR) in South Gardiner were recaptured in this fishery.

On July 13, 1994, while conducting a sampling effort for sturgeon, the MDMR captured seven adult Atlantic sturgeon just below the spillway of the Edwards Dam in Augusta. Five of the seven Atlantic sturgeon, which ranged from 156-195 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 MDMR in September of 1997 in the Eastern River (n=18) and the Cathance River (n=5), freshwater tributaries to the Kennebec, in overnight sets of gill nets (T. Squiers, MDMR, personal communication).

The presence of adult male Atlantic sturgeon in ripe condition near the head-of-tide during June and July presents strong evidence that a spawning population still exists in the Kennebec River. No eggs, larvae, young-of-the-year, or age 1 Atlantic sturgeon have been captured; however, the presence of subadults, ranging from 37 cm to over 100 cm TL in tidal freshwater tributaries and the mid-estuary 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 in recent years was an adult captured and released approximately one kilometer 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 likely functions as a nursery area for Kennebec River Atlantic sturgeon. Currently, the estuarial complex of the Kennebec, Androscoggin, and Sheepscot Rivers in Maine is the only system in New England with evidence of Atlantic sturgeon spawning.

Penobscot River, ME

The MDMR conducted a limited sampling effort in 1994 and 1995 to assess whether there was a population of shortnose sturgeon present in the Penobscot River. The MDMR made 55 sets of 90 meter experimental gill nets for a total fishing effort of 409 net hours (1 net hour = 100 yds fished for 1 hour). The majority of the fishing effort in the Penobscot River was in the upper estuary near head-of-tide. No shortnose sturgeon or Atlantic sturgeon were captured. The sampling was inadequate to assess the presence of 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 addition, based on the fact that very few Atlantic sturgeon (36 individuals) were captured in the Merrimack River with a tremendous amount of effort over a four year period (over 5000 net hours) (Kieffer and Kynard 1993), it is possible that a small population of sturgeon could have escaped capture in the Penobscot River with a significantly smaller sampling effort. There is no evidence that a population of Atlantic sturgeon exists in the Penobscot River; but, given the availability of suitable habitat and the limited extent of sampling efforts to date, it is possible that a small population exists.

Other Maine Rivers

The geomorphology of most small coastal rivers in Maine is not sufficient to support Atlantic sturgeon spawning populations. During the summer months, the salt wedge intrudes almost to the site of impassable falls in these systems (e.g. the St. Croix River (rkm 16), the Machias River (rkm 10), and also on the Saco River (rkm 10)). Although surveys have not been conducted to document Atlantic sturgeon presence, subadult Atlantic sturgeon may use the estuaries of these smaller coastal drainages during the summer months.

Piscataqua River/Great Bay Estuary System (Salmon Falls, Lamprey, Oyster), NH

Few Atlantic sturgeon have been captured in the Piscataqua River (Hoff 1980). A subadult Atlantic sturgeon (57 cm) was captured by New Hampshire Fish and Game 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, the New Hampshire Fish and Game surveyed the deeper tributaries of the Great Bay Estuary including the Piscataqua, Oyster, and Lamprey Rivers as well as Little and Great Bays. Eleven different locations were sampled with 30.5 m nets (3 m deep with 14 and 19 cm stretch mesh) which 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 and temperatures ranging from 14-16^{o}C) (T. Squiers, MDMR, personal communication). No Atlantic sturgeon were captured. A large female Atlantic sturgeon, 228 cm TL and weighing 98 kg (of which 15.9 kg were eggs), was captured in a small mesh gill net at the head-of-tide in the Salmon Falls River in South Berwick, ME on June 18, 1990. There is currently no evidence that Atlantic sturgeon spawn in the Piscataqua River/Great Bay Estuary system, but subadults appear to use the Bay as a nursery habitat.

Merrimack River, NH/MA

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, ranging in size from 70.0-156.0 cm TL, most being under 100 cm TL. One dead Atlantic sturgeon (approximately 262 cm TL) was found on June 30, 1990 at the shortnose spawning area in Haverhill, MA (between rkm 31-32). Of nineteen subadult Atlantic sturgeon sonically tracked in the river, eleven left the river within seven days and the rest left by September or October of each year. Fish captured in one year were not observed in the river during subsequent years. This information provides no evidence of a spawning population of Atlantic sturgeon in the Merrimack River though it appears that the estuary is used as a nursery area (B. Kynard, Conte Anadromous Fish Research Center, personal communication).

Taunton River, MA/RI

Historical records indicate that Atlantic sturgeon spawned in the Taunton River at least until the turn of the century (Tracy 1905 in: Kynard 1994). 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). Since spawning adults were not found during the expected spawning period of May and June, it is likely determined 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).

Connecticut River, MA/CT

Judd (1905) states that sturgeon were speared at the South Hadley Falls in the mid-1700's. 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 the presence of significant rapids (Judd 1905). A dam constructed at Enfield in 1827 effectively blocked any migration beyond that point, until 1977 when the dam was breached. There is no evidence that Atlantic sturgeon use the Massachusetts portion of the Connecticut River.

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 1980's, Connecticut Department of Environmental Protection (DEP) fisheries staff reported occasional visual observations of Atlantic sturgeon below the Enfield dam during May and June. From 1988-1997, the Connecticut DEP studied the abundance, locations, and seasonal movement patterns of shortnose sturgeon in the lower Connecticut River. Sampling was conducted using gill nets ranging from 10-18 cm stretched mesh (this mesh size is appropriate for the capture of subadult Atlantic sturgeon). A total of 99 Atlantic sturgeon (67-99 cm FL) were collected during these studies (Savoy 1996). The majority of these subadult Atlantic sturgeon were captured in the lower river (between rkm 10-26) within their summer range of the saltwedge (Savoy and Shake 1993).

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 (1.5-3 m) are made, but most Atlantic sturgeon captured within tidal or fresh water 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 of spawning adults, stocks of Atlantic sturgeon native to Connecticut waters are believed to be extirpated (Savoy 1996).

Thames River, CT

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 1830's (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. Subadult Atlantic sturgeon have been captured in the estuary (Whitworth 1996), but it is unlikely that a spawning population is present.

Housatonic River, CT

Coffin (1947) reports that Atlantic sturgeon were abundant in the Housatonic River and were used 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. A spawning population is not believed to be present in the Housatonic River.

Hudson River, NY

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 1970's; however, both fishery dependent and independent data are available since the early 1970's to characterize the population of Atlantic sturgeon in the Hudson River.

Two estimates of immature Atlantic sturgeon have been made 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 zero Atlantic sturgeon provided at a USFWS hatchery into the Hudson Estuary at Newburgh Bay. These fish were reared from Hudson River broodstock. In 1995, Cornell University sampling crews collected 15 stocked and 14 wild age 1 Atlantic sturgeon (Peterson et al. *in press*). A simple Peterson population estimate from these data suggest that there were 9,529 age 0 Atlantic sturgeon in the estuary in 1994. Since 4,929 were stocked, 4,600 fish were of wild origin. This was a substantial decline from the abundance of the 1976 year class. In addition, from July to November during 1982-1990 and 1993, the NYSDEC sampled abundance of juvenile fish in Haverstraw Bay and the Tappan Zee Bay. Catch per unit effort (CPUE) of immature Atlantic sturgeon was 0.269 in 1982 and declined to zero by 1990.

The commercial gill net fishery in the Hudson River estuary which is conducted from early April to late May exploits the spawning migration of American shad. Young (< one meter) Atlantic sturgeon are caught as bycatch. The commercial fishery has been monitored annually since 1980 by onboard observers. Data are recorded on gear type and size, fishing time (effort), location, numbers and species caught. CPUE is calculated as the number of fish collected per yd^2 x hrs x 10^{-3} of net fished. Annual CPUE data were summarized as total observed catch/total observed effort. CPUE of Atlantic sturgeon as bycatch was highest in the early 1980's and steadily decreased through the present.

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 fisheries surveys to obtain data for estimating impacts of power plant operation. Detailed survey descriptions are provided in the Utilities' annual reports (CONED 1997). Two surveys regularly catch 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. For the period 1974-1984, the shoals in the entire river (rkm 19-246) were sampled by epibenthic sled, but the gear was switched in 1985 to a three meter beam trawl. Length data are available from the beam trawl survey from 1989 to the present; sturgeon ranged from 0.1-1.0 m TL, but most were less than 700 mm TL. Based on these length data, it appears that ages zero, one, and two sturgeon were present in the samples. Indices from Utility surveys conducted from 1974 to the present (LSS and FSS) indicated a trend consistent with NYSDEC data; abundance of young juvenile Atlantic sturgeon declined through the late 1970's, increased slightly through the middle to late 1980's, and then declined through the present.

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- 1970's. The greatest decline appeared to occur in the middle to late 1970's followed by a secondary drop in the late 1980's. Sturgeon are still present and juveniles (age zero, one, and two years) were captured in recent years. The capture of age zero fish indicates that the Hudson River supported spawning as recently as 1997. Adult Atlantic sturgeon were successfully collected in 1991 and 1993-1996. However, efforts to secure mature adult Atlantic sturgeon in 1997 resulted in the capture of only males, unlike previous years when both adult males and females were captured (M. Hendrix, USFWS, personal communication).

Delaware River and Bay, NJ/DE/PA

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). Juveniles were abundant enough to be considered a nuisance bycatch of the American shad fishery. Very little is known about current spawning locations of Atlantic sturgeon in the Delaware estuary; however, based on reported catches in gill nets and harpoons during the 1830's, they may have spawned as far north as Bordentown, just below Trenton, NJ (PA State Commissioners of Fisheries 1897). Borodin (1925) reported that running-ripe sturgeon were captured near Delaware City, DE adjacent to Pea Patch Island. Good spawning grounds occurred near Chester, PA over hard stony and gravelly bottom. 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.

During the last 40 years, immature Atlantic sturgeon have been collected throughout the Delaware estuary and tidal reaches of the Delaware River up to Trenton, NJ (Brundage and Meadows 1982, Lazzari et al. 1986). Annual length frequency distributions of subadult fish from 1991-1997 also suggest the presence of several age classes in the lower Delaware River. The presence or absence of ages in these data can indicate changes in abundance and describe relative trends. Strong cohorts appeared to enter the sample as two or three year old fish (650-750 mm) in 1991 and in 1995. Each cohort could be followed through the length frequencies for at least two succeeding years.

The current abundance of all Atlantic sturgeon life stages in the Delaware River has been greatly reduced from historical levels. Bottom trawl collections by the Delaware DFW in Delaware Bay began in 1966 and rarely encountered Atlantic sturgeon. However, there are a few isolated areas within the estuary where juvenile sturgeon regularly occur. Lazzari et al. (1986) frequently captured juvenile Atlantic sturgeon from May-December in the upper river below Trenton, NJ. In addition, directed gill net sampling from 1991-1997 consistently took subadult Atlantic sturgeon in the mid-estuary throughout the summer months (C. Shirey, Delaware DFW, personal communication). However, the number of fish taken in the lower river each year declined dramatically through this time period from over 500 to less than 60. Population estimates based on mark and recapture of immature Atlantic sturgeon declined from a high of 5,600 in 1991 to less than 1,000 in 1995. No estimates could be made during 1996 and 1997 due to the lack of any recaptures. Based on the number of fish taken and catch per unit of effort, Atlantic sturgeon abundance continued to sharply decline.

An estimate of the abundance of mature adult Atlantic sturgeon occurring in the Delaware estuary cannot be made, although it is likely to be low. Despite the high value of caviar, there was no viable commercial fishery in recent years for adult sturgeon within the estuary, which suggests a very low abundance of spawning stock. The recent gill net sampling by Delaware DFW did not target adult fish and the selectivity of the gear could have prevented efficient capture. Some of the larger specimens taken in the program may have been mature males based on the reported size at maturity of Atlantic sturgeon, but no mature females were taken.

Three carcasses of mature fish have been documented from the lower river and upper Bay during the spawning season, including two gravid mature females and one male in recent years (J. Skjeveland, USFWS, personal communication). A 2.4 m (8 ft) female Atlantic sturgeon was found dead on June 14, 1994, adjacent to Port Penn. A pectoral spine was used to age it at approximately 25 years old (D. Secor, University of Maryland, personal communication). 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 C&D Canal. The third sturgeon, a male, was located on May 19, 1997, just north of the mouth of the Cohansey River, on Beechwood Beach. This fish appeared to have been cut in half by the propeller of a large vessel. Gonadal tissue and a pectoral spine were collected and sent to USFWS-NEFC, Fish Technology Section, Lamar, PA for analysis, which confirmed that it was a male (W. Andrews, New Jersey Division of Fish, Game, and Wildlife, personal communication).

Currently, although numbers have declined during the last decade, the Delaware River still hosts both juveniles $\leq$ age 1 and mature adults. The collection of juveniles $\leq$ age 1 and gravid females suggest that some spawning has continued to occur (Kahnle et al. 1998).

<u>Chesapeake Bay and Tributaries (Potomac, Rappahannock, York, James, Susquehanna, Nanticoke), PA/MD/VA</u>

Historically, Atlantic sturgeon were common throughout the Chesapeake Bay and its tributaries (Kahnle et al. 1998, Wharton 1957). 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. Historically important sturgeon fisheries in Maryland occurred in the Potomac and incidental harvest of sturgeon was common in other Maryland tributaries. Several sightings were made by commercial fishermen and research biologists during 1978-1987 near the Susquehanna River mouth. Also, a deep hole (18 m) on the Susquehanna River near Perryville, MD, once supported a limited sturgeon fishery (R. St. Pierre, USFWS, personal communication). Maryland DNR personnel reported large mature female Atlantic sturgeon in the Potomac River in 1970, and in the Nanticoke River in 1972 (H. Speir, Maryland DNR, personal communication).

For the past several decades, state fishery agencies and research facilities operating in the Chesapeake Bay have conducted extensive finish sampling surveys in the mainstem Bay and all major tributaries. These surveys occurred in all seasons and are conducted using many gear types including trawls, seines, and gill nets. Though none of the survey work is directed at sturgeon, incidental captures are routinely recorded. This information is supplemented by reports of sturgeon captures from commercial fishermen using gill nets, pound nets, and fake nets with occasional visual observations of large sturgeon, including dead animals, washed onto beaches. A tagging study conducted in the 1970's indicated that most subadults collected in the Chesapeake Bay were from the

Hudson River stock (Dovel and Berggren 1983). Recent genetic analysis suggests that southern stocks may also contribute subadults found in the Chesapeake Bay (T. King, USES Leeton Science Center, personal communication).

An interagency reward program conducted during late 1996 through early 1998 documented 878 first time captures of Atlantic sturgeon of which 455 were hatchery fish. In Maryland waters, most sturgeon were of hatchery origin from the 1996 release in the Nanticoke River. The great majority of fish taken in Virginia were wild including numerous fish from the lower James and York rivers in the 200-400 mm size range which are believed to be young-of-year or age 1+ (A. Spells, USFWS, personal communication). Presumed age zero and 1+ fish were captured, tagged, and released in 1997 (A. Spells, USFWS, personal communication). These captures indicate that spawning may have occurred as recently as 1996 or 1997 in the lower Chesapeake Bay, and most of the Bay and several major tributaries are used as nursery habitat. Further evidence that spawning may have occurred recently is provided by three carcasses of large adult females found in the James River in 1996-1998 and the capture, tagging, and release of a 2.4 m Atlantic sturgeon near the mouth of the Potomac River in April, 1998 (J. Skjeveland, USFWS, personal communication). A monitoring program directed at Atlantic sturgeon began in 1998 to further investigate the location and extent of spawning in the lower James River.

North Carolina Rivers (Roanoke, Tar-Pamilco, Neuse, Cape Fear, Brunswick)

Atlantic sturgeon historically were abundant in most coastal rivers and estuaries in North Carolina with the largest fisheries occurring in the Roanoke River/Albemarle Sound system and in the Cape Fear River (Kahnle et al. 1998). Historic and current survey data indicate that spawning occurs in the Roanoke River/Albemarle Sound system and the Cape Fear River, where both adults and small juveniles have been captured. Spawning is also thought to have occurred in the Neuse and Tar-Pamlico Rivers, based on captures of very young juveniles (Hoff 1980). Two juveniles (approximately 45 and 60 cm TL) were observed dead on the bank of Banjo Creek, a tributary to the Pungo River, in the spring of 1996, suggesting that small sturgeon are present in the Pamlico system (B. Brun, USFWS and U.S. Army Corps of Engineers (retired), personal communication).

A gill net survey for adult shortnose and juvenile Atlantic sturgeon was conducted in the Cape Fear River drainage from 1990-1992, and replicated again in 1997. Each sampling period included two overnight sets, i.e. the nets were set on the first day, checked on the second day, and retrieved on the third day of sampling. The 1990-1992 survey captured 100 Atlantic sturgeon below Lock and Dam #1 for a CPUE of 0.11 fish/net-day. No sturgeon were collected during intensive sampling above the first low elevation lock and dam (rkm 90). In 1997, 16 Atlantic sturgeon were caught below Lock and Dam #1, 60 Atlantic sturgeon were caught in the Brunswick, and 12 Atlantic sturgeon were caught in the Northeast Cape River stations (Moser et. al. 1998). Abundance of Atlantic sturgeon below Lock and Dam #1 has apparently increased dramatically since the survey was conducted in this area from 1990-1992 (Moser and Ross 1995). CPUE of

Atlantic sturgeon was 2-8 times higher during 1997 than in the earlier survey. This increase may reflect the effects of North Carolina's ban on sturgeon fishing that began in 1991.

Some adult Atlantic sturgeon apparently migrate upstream in the fall, even though they may not spawn until the following spring. One large Atlantic sturgeon was tracked moving upstream in the Black River in early October. Moreover, all of the largest sturgeon that were collected were later captured only during September and October in both the Cape Fear and Northeast Cape Fear Rivers. Finally, one dead adult female Atlantic sturgeon was found with fully developed ovaries 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, Kynard 1997, Moser et al. 1998).

Additional information was obtained on Atlantic sturgeon in North Carolina by examining all databases within the state for entries for Atlantic sturgeon. Databases covered various years within the time span 1957-1997. A total of 1,210 Atlantic sturgeon were recorded in those databases (Moser et al. 1998) providing evidence that Atlantic sturgeon are present in all major rivers of North Carolina.

South Carolina Rivers

Historically, Atlantic sturgeon were likely present in many South Carolina river/estuary systems, but it is not known where spawning occurred. Based on sampling conducted during the last two decades, Atlantic sturgeon were present in the Great PeeDee, Waccamaw, and Sampit Rivers (all tributaries to Winyah Bay); Santee River; Lake Moultrie; Cooper River; Ashley River; South Edisto River, Ashepoo River, Combahee River (all tributaries to St. Helena Sound); Broad/Coosawhatchie River; and the Savannah River (Collins and Smith 1997). In 1997, documented reports of Atlantic sturgeon adults exist in the Combahee (2 adults), Edisto (14 adults), and Savannah (1 adult) Rivers in South Carolina. All of these systems, except Lake Moultrie probably provide nursery habitat. Based on the collection of juveniles $\leq$ age 1, spawning appears to occur in the following rivers: the Santee, one or more of the ACE Basin tributaries (Ashepoo, Combahee, or Edisto), the Savannah, and possibly the Cooper, Great PeeDee, and Waccamaw Rivers.

Winyah Bay Rivers (Waccamaw, Great PeeDee, Black, Sampit), SC

Captures of age 1 juveniles from the Waccamaw River during the early 1980's suggests that a reproducing population of Atlantic sturgeon may persist in that river, although the fish could have been from the nearby Great PeeDee River (Collins and Smith 1997). It is possible that the Great PeeDee and Black Rivers support spawning populations, but the Sampit probably does not due to its small size.

Santee River, SC

Capture of 151 subadults, including age 1 juveniles, in the Santee River suggests that an Atlantic sturgeon population still persists there (Collins and Smith 1997). It is doubtful that there is a reproducing population of Atlantic sturgeon in the Santee-Cooper lake system.

Cooper River, SC

A reproducing population of Atlantic sturgeon is suspected in the Cooper River, but this has not been verified (Collins and Smith 1997).

ACE Basin Rivers (Ashepoo, Combahee, Edisto), SC

From 1995 to the present, thousands of juveniles including 500 age 1 sturgeon, have been captured in the lower Edisto River near the confluence of the three rivers (Collins and Smith 1997). The ACE Basin rivers and the Cooper River are currently being sampled for adult Atlantic sturgeon. In March, 1997, four adult sturgeon were captured in the Edisto (one was a gravid female, 234 cm TL), and two in the Combahee (one a running ripe male, 193 cm TL). The ripe male was recaptured in the Edisto River one week later, suggesting that this three river system may support a single population that spawns in at least two of the rivers.

Port Royal Sound Rivers (Broad, Coosawatchie), SC

There has been little or no scientific sampling for Atlantic sturgeon in Port Royal Sound Rivers; however, one fish of unknown size was reported from a small directed fishery during 1981-1982 (Smith et al. 1984).

Savannah River, SC/GA

The Savannah River supports a reproducing population of Atlantic sturgeon (Collins and Smith 1997). The NMFS (Saltonstall-Kennedy Program) has funded a stock identification (molecular genetics) study of Atlantic sturgeon, and the Savannah River is presently being sampled for age 0-1 juveniles as a part of that study. Twenty age 1 fish have been captured to date. Life history information is also being collected on all sturgeons captured. A running ripe male was captured at the base of the dam at Augusta during the late summer of 1997, supporting the hypothesis that spawning occurs there in the fall.

Georgia Rivers

The Altamaha River appears to support one of the healthiest Atlantic sturgeon populations in the southeast, based on the presence and relative abundance of juveniles in the system. Atlantic sturgeon are also present in the Ogeechee River; however, the absence of age 1 fish in some annual sampling efforts and the unbalanced age structure suggest that the population is highly stressed (Rogers and Weber 1995). Young Atlantic sturgeon also occur in the Satilla River. Recent sampling of the St. Marys River failed to locate any sturgeon, suggesting that the population may be extirpated (Rogers et al. 1994). Atlantic sturgeon appear to spawn in the Savannah, Ogeechee, Altamaha, and possibly the Satilla Rivers in Georgia.

Altamaha River, GA

The Altamaha River appears to support one of the healthiest Atlantic sturgeon populations in the Southeast with over 2,000 juveniles, 800 which were nominally age 1, sampled there using trammel nets. The ecology of juveniles was studied rather extensively during 1991-1994, and a large reference collection of tissue samples was archived for use in future molecular genetics studies (Rogers et al. 1994).

Ogeechee River, GA

Although a population of Atlantic sturgeon apparently persists in this river, results of recent sampling efforts (including 1991-1994, 1997 efforts to collect age 1 juveniles as part of the genetics study described for the Savannah River, and in 1998) suggest that juveniles are scarce and apparently absent in some years, indicating spawning or recruitment failure.

Satilla River, GA

Recent sampling indicates that the Atlantic sturgeon population in the Satilla River is highly stressed (Rogers and Weber 1995). [See the Satilla River in Habitat section.]

St. Marys River, GA/FL

Recent standardized sampling within the appropriate salinity regime resulted in zero catch of Atlantic sturgeon, suggesting that the Atlantic sturgeon population has been extirpated from this river (Rogers and Weber 1995).

Florida Rivers

Historical populations were reportedly present in the St. Marys, St. Johns, and possibly, the St. Augustine and St. Lucie Rivers; but, it is unknown whether these were limited to migrating fish or if reproduction also occurred in these rivers. No evidence exists for the current presence of any Atlantic sturgeon in these systems.

St. Johns River, FL

The lack of Atlantic sturgeon captures (scientific sampling and as bycatch in other fisheries) in the St. Johns River indicate that they no longer exist in the St. Johns River. Additionally, there is no documentation that spawning ever took place in this river.

Rivers Farther South

Although there are anecdotal reports of Atlantic sturgeon from locations south of the St. Johns River, including the St. Augustine and the St. Lucie Rivers (ASMFC 1990), there is no documented evidence for the previous or current existence of sturgeon populations in any river south of the St. Johns River.

Distinct Vertebrate Population Segment

The Endangered Species Act (ESA) considers "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" to be a species. One of the purposes of establishing distinct population segments is to conserve genetic diversity. In February of 1996, the Services published a policy to clarify their interpretation of the phrase “distinct population segment (DPS)” for the purposes of listing, delisting, and reclassifying species under the ESA (51 FR 4722). The policy identified the following three elements to be considered in deciding whether to list a possible 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) and the conservation status of the population segment in relation to the ESA’s standards for listing. This section of the status review focuses on two elements - discreteness and, to a lesser extent, significance. The conservation status of Atlantic sturgeon is reviewed in subsequent sections that analyze listing factors and efforts underway to protect the species.

DISCRETENESS OF THE POPULATION SEGMENT

According to the Services’ DPS policy, a population segment may be considered discrete if it satisfies either of the following two conditions: (1) it is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological or behavioral factors; or (2) it is delimited by international governmental boundaries across which there is a significant difference in control of exploitation, management of habitat, or conservation status. The Policy advises that quantitative measures of genetic or morphological discontinuity may provide evidence of separation.

To allow evolutionarily important differences to accrue in different population units, reproductive isolation does not have to be absolute, only strong enough for these differences to develop and be maintained (Waples 1991). Reproductive isolation can be maintained by geographical distance, behavioral differences, and/or temporal segregation.

Gulf coast (*A. o. desotoi*) and Atlantic coast (*A. o. oxyrinchus*) forms of Atlantic sturgeon have been demonstrated to be separate subspecies because of their allopatric distributions, differences in single morphometric feature (relative spleen length) and in life history characteristics (Wooley 1985), and by fixed differences in the control region of the mitochondrial deoxyribonucleic acid (mt DNA) (Ong et al. 1996, Stabile et al. 1996). Differences in life history include estuarine residence patterns. Subadult and adult *A. o. oxyrinchus* inhabit coastal marine waters for most of their annual life cycles and return to their natal rivers to spawn (Dovel and Berggren 1983). Gulf sturgeon dwell in their natal rivers for much of the year and only make a brief wintertime excursion into Gulf of Mexico waters (Wooley and Crateau 1985). Some suggest that only one consistent morphological distinction (relative spleen length) constitutes weak support for the subspecies distinction within *A. oxyrinchus*. Ong et. al (1996), however, conducted extensive genetic analysis and concluded that their results were concordant with both morphological differentiation and geographic separation and therefore recommended maintaining the subspecies designations. Atlantic sturgeon herein refers to *Acipenser oxyrinchus oxyrinchus*.

Stabile et al. (1996) notes that the anadromous life style of sturgeons increases the probability that discrete populations develop. However, the highly migratory nature of Atlantic sturgeon introduces the potential for straying which leads to significant gene flow, especially among populations in proximal spawning systems. Our lack of knowledge regarding the homing fidelity of Atlantic sturgeon, or any sturgeon species, makes it difficult to assess the likelihood of this event. Limited results from genetic analysis of Atlantic sturgeon and striped bass suggest higher homing fidelity for these species compared to American shad (Waldman et al. 1996a). Mark-recapture studies suggest that coastal movements of Atlantic sturgeon are largely, but not completely, confined to biogeographic provinces in which their natal rivers belong. Biogeographic barriers such as Cape Cod and Cape Hatteras may act as coarse filters which influence, but do not completely restrict, sturgeon movements (Waldman et al. 1996b).

Vital life history characteristics of Atlantic sturgeon populations show clinal variation with faster growth and earlier age at maturation in more southern systems. For example, female Atlantic sturgeon mature in South Carolina at approximately 7-19 years, (Smith et al. 1982), in the Hudson River at approximately 15-30 years (Dovel 1979, Dovel and Berggren 1983; VanEenennaam et al. 1996), and in the St. Lawrence River at approximately 27-28 years (Scott and Crossman 1973). The timing of spawning migration also varies by geographic location. Upriver migration begins in February in southern systems, April in the mid-Atlantic rivers, and May in Canadian waters (Smith and Clugston 1997). It is unknown, however, how much of the variation in observed life history characteristics is due to genetic differences and how much is do to environmental differences.

Genetic diversity in Atlantic sturgeon could be restricted by the species' low effective population sizes and long generation. Extended generation times may decelerate rates of molecular evolution. This hypothesis is supported by studies indicating slow rates of DNA and protein evolution of sturgeons and paddlefishes (Birstein 1993). The genetic variation currently present in Atlantic sturgeon populations could be much lower than what was present historically. Some researchers have also speculated that such a reduction could have been caused by reduced population sizes following periods of high harvest and extirpation of some runs (Waldman et al. 1996a).

Stock discreteness can be indicated by phenotypic or genotypic differences. It has been postulated that the geologically young age of the Hudson River, and therefore of its Atlantic sturgeon population, would preclude accumulation of substantial genetic protein differences from other populations. The Hudson River became deglaciated less than 10,000 years ago; therefore, there has been a relatively short amount of time for the Hudson River population to have differentiated from other mid-Atlantic and northern populations (Waldman et al. 1996a). However, the rapidly evolving nature of mitochondrial DNA (mtDNA) makes it more sensitive and, therefore, better able to detect genetic differences (Billington and Hebert 1991).

Restriction fragment length polymorphism (RFLP) analysis of mtDNA using five diagnostic restriction enzymes was used to characterize stock structure of populations of Atlantic sturgeon along the Atlantic coast including the St. Lawrence River, Quebec; Saint John River, NB; Hudson River, NY; Edisto River, SC; and four rivers in Georgia; the Altamaha, Ogeechee, Savannah and Satilla (Waldman et al. 1996b). Analysis showed three highly differentiated ($p < 0.00001$) stocks: (1) Canadian (St. Lawrence and Saint John Rivers); (2) Hudson River; and (3) southeastern rivers (Edisto, Savannah, Ogeechee, Altamaha, and Satilla) (Wirgin et al. 1997). The mtDNA data showed that despite the geographic proximity of the southern rivers, stocks generally exchange less than one female per generation, a level sufficient to permit differentiation at the stock level (Atkinson 1996, Wirgin et al. 1997). Waldman and Wirgin (1998) cited these low gene flow estimates as strong evidence that natural recolonization of extinct populations of *A. oxyrinchus* will proceed slowly. Samples from the Edisto, Savannah, Ogeechee, Altamaha, and Satilla Rivers were found to have six rare haplotypes that were not seen in more northern samples. Delaware River fish were found to have one composite haplotype not observed elsewhere (Waldman et al. 1996b).

Results of the mtDNA analysis place the lower Delaware River between the Hudson River and southeastern stocks. This finding suggests that the Delaware River is an aggregation of either (1) the Hudson River and southeastern river stocks, or (2) the Hudson River stock and a relict Delaware River stock. The annual collection of subadults near the mouth of the Delaware River could reflect its use as one of a series of Atlantic estuaries seasonally inhabited by subadult Atlantic sturgeons (Kieffer and Kynard 1993 in: Waldman et al. 1996b).

Mitochondrial DNA analysis described above, indicate the existence of substructure below the subspecies level, but are not sufficient to delineate conservation units. Genetic data to characterize Atlantic sturgeon populations in Maine, North Carolina, and the Chesapeake Bay is currently unavailable; and, further analysis of southeastern stocks to ascertain presence of distinctions within that region is also needed. Microsatellite and mtDNA studies currently underway are expected to provide data to delineate distinct population segments in accordance with ESA policy and for application for other conservation efforts.

INTERNATIONAL GOVERNMENTAL BOUNDARIES

The Services' policy allows for the delineation of a DPS based on international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist. The reasons for creating a boundary based on political distinctions rather than biological is justified in situations where there are differences in management or status that are significant in light of Section 4(a)(1)(D).

In the event that a DPS, delineated based on discreteness and evolutionary significance as described above, straddles an international boundary, then the determination can be made to separate the DPS at the border. While the preliminary mtDNA genetic data indicate that the Canadian populations are genetically distinct from those in the Hudson River and southern U.S. populations, U.S. rivers north of the Hudson have not yet been thoroughly analyzed. Therefore, it is not possible to determine if a transboundary DPS of Atlantic sturgeon currently exists.

EVOLUTIONARY SIGNIFICANCE

The second element of the Services' DPS policy considers of a discrete population segment's biological and ecological significance to the taxon to which it belongs. Since discrete population segments have not been defined for Atlantic sturgeon, consideration of evolutionary significance of specific segments is premature. Future consideration may include, but is not limited to the following: (a) persistence of the discrete population segment in an ecological setting unusual or unique for the taxon; (b) evidence that the loss of the discrete population segment would result in a significant gap in the range of a taxon; (c) evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range; or (d) evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

SUMMARY

The Services' policy on delineating a DPS for consideration under the ESA contains the criteria that the population segment must be discrete and significant in relation to the remainder of the species or subspecies to which it belongs. With available scientific data, it is not possible at this time to delineate distinct population segments of Atlantic sturgeon. Additional genetic analysis of northern river populations and southern populations will provide greater insights into the appropriate delineation of DPS. The genetic analyses that have been conducted to date, together with the differences in life history, clearly indicate existence of substructure below the subspecies level, but are not yet sufficient to describe its form. It will be critical to the design, implementation, and success of biologically appropriate management strategies that DPS' be delineated when the necessary information becomes available. The team recommends that the needed sampling and genetic studies continued and that delineation of DPS' be incorporated into ongoing and future Atlantic sturgeon conservation strategies.

Analysis of 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 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. It should be noted that current and potential threats, along with current species 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.

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

Atlantic sturgeon, like all anadromous fish, are vulnerable to a variety of habitat impacts because they use rivers, estuaries, bays, and the ocean at various points of their life. Habitat alterations can be problematic for Atlantic sturgeon due to their long life span, late age at maturing, and reliance on multiple habitats. Habitat alterations potentially affecting sturgeon include dam construction and operation, dredging and disposal, and water quality modifications such as changes in levels of dissolved oxygen, water temperature, and contaminants.

Loss of habitat and poor water quality 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 twenty-five to thirty years. The status review team examined the impact of present or threatened destruction, modification, or curtailment of habitat or range on Atlantic sturgeon and 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 analysis 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.

DAMS

Dams for hydropower generation and flood control can have profound effects on anadromous species by blocking access to spawning habitat, changing free-flowing rivers to reservoirs, and altering downstream flows and water temperatures. Hill (1996) identified the following potential impacts from hydropower plants: altered dissolved oxygen 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. Intake structures at other power generation facilities, such as nuclear power plants, can entrain Atlantic sturgeon. The suitability of riverine habitat for Atlantic sturgeon spawning and rearing also depends on annual fluctuations in flow, which can be greatly altered or reduced by presence of dams (Beamesderfer and Farr 1997). Dam maintenance activities, such as minor excavations along the shore, can release silt and other fine river sediments which could be deposited in nearby spawning habitat. Perhaps the greatest potential impact to sturgeon from dams is denying access to any historic spawning habitat located upstream of a dam. This impact is difficult, if not impossible to mitigate, as Atlantic sturgeon are not known to successfully use any fish passageways.

It is difficult to assess the impact of dam construction on Atlantic sturgeon in rivers where historic spawning areas, prior to dam construction, are unknown. Due to the geomorphology of rivers north of South Carolina, waterfalls and rapids tend to be located in the vicinity of the fall line. Therefore, Atlantic sturgeon spawning sites above these areas are rare. In most cases, the first dam on a river was built at the site of natural falls and rapids, which were impassable to Atlantic sturgeon and often coincide with the head-of-tide in this region of the U.S. Atlantic coast. Atlantic sturgeon spawn in freshwater and both adults and juveniles tend to utilize habitat downstream, rather than upstream, of spawning sites. Although sightings of large sturgeon above the fall line attracted local attention and were sometimes reported in local newspapers, it is unlikely that these portions of the rivers represented significant Atlantic sturgeon habitat. In the southern region of the U.S. Atlantic coast, the fall line is commonly much farther inland (322 rkm on the Savannah River, SC/GA) or almost nonexistent (St. Johns River, FL). This potentially provided more freshwater (spawning) habitat than in many northern rivers. However, historical records of the amount of habitat actually used by Atlantic sturgeon are lacking. Thus, for most rivers, it is not possible to determine how much habitat was lost due to dam construction for southern rivers.

The best available estimates of the effects of dams on habitat accessibility are provided in Appendix B. Of the 25 rivers for which current Atlantic sturgeon habitat accessibility can be quantified, only three (the Merrimack, Housatonic, and Susquehanna Rivers) currently suffer loss of ≥ 30% of that habitat to dams. Dams impede access to 10-30% of habitat for Atlantic sturgeon on another three rivers (the Kennebec, Penobscot, and Salmon Falls Rivers) and < 10% of Atlantic sturgeon habitat is inaccessible in the Androscoggin, Sheepscott, Oyster, Connecticut, Hudson, Delaware, Potomac, Rappahannock, York, James, Neuse, Ashepoo, Combahee, Edisto, Savannah, Ogeechee, Altamaha, Satilla, and St. Marys Rivers. While not quantifiable, a substantial portion of sturgeon habitat in the Santee River is blocked by the Wilson Dam. With the exception of the Rodman Dam on a tributary of the St. Johns River (FL), all extant dams in the historic range of Atlantic sturgeon have been in place for ≥ 50 years. Several dams within the Atlantic sturgeon's historic range have been removed (Treat Falls Dam on the Penobscot River, ME; Enfield Dam on the Connecticut River, CT), are in the process of being removed (Quaker Neck Dam on the Neuse River, NC), or may be removed in the near future (Edwards Dam on the Kennebec River, ME). Based on this information, little Atlantic sturgeon habitat has been lost due to dams.

DREDGING

Riverine, nearshore, and offshore areas are dredged for commercial shipping and recreational boating, construction of infrastructure, and marine mining. Dredging activities pose significant impacts to aquatic ecosystems by removing, disturbing and resuspending bottom sediments. Environmental impacts of dredging include the following: direct removal/burial of organisms; turbidity/siltation effects; contaminant release and uptake; noise/disturbance; alterations to hydrodynamic regime and physical habitat and actual loss of riparian habitat (Chytalo 1996). According to Smith and Clugston (1997), dredging and filling disturbs benthic fauna, eliminates deep holes, and alters rock substrates; all habitat features important to sturgeon.

Dredging provides safe passage of commercial shipping and pleasure boat traffic. With the increase in boating traffic, the potential for sturgeon to be struck by propellers is greater. A male Atlantic sturgeon was found on May 19, 1997, just north of the mouth of the Cohansey River, on Beechwood Beach in the Delaware River. It appeared to have been cut in half by the propeller of a large vessel (W. Andrews, New Jersey Division of Fish, Game, and Wildlife, personal communication). Given that this is the only documented occurrence, boat propeller strikes do not appear to threaten the species.

Indirect harm to sturgeon from either mechanical or hydraulic dredging includes 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 sucking fish up through the dredge dragarms and impeller pumps. NMFS observers documented the take of one Atlantic sturgeon entrained in a hopper dredge operating in King's Bay, GA (C. Slay, New England Aquarium, personal communication, reported in SNS RP). Atlantic sturgeon have also been killed in both hydraulic pipeline and bucket-and-barge operations in the Cape Fear River, N.C. (M. Moser, University of North Carolina-Wilmington, personal communication). Imposing work restrictions during sensitive time periods (spawning, migration, feeding) when sturgeon are most vulnerable to mortalities from dredging activity can minimize impacts. Appendix C contains a summary of dredging activities in the U.S. rivers containing Atlantic sturgeon.

WATER QUALITY

The quality of water is affected by those activities conducted directly in the riparian zone and more remotely in the watershed. Industrial activities can result in discharges of pollutants, changes in water temperature and levels of dissolved oxygen, 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 which 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. Pulp mill, silviculture, agriculture, and sewer discharges can elevate temperatures or increase biological oxygen demand resulting in reduced dissolved oxygen levels which can be stressful to aquatic life.

Sturgeon may be particularly susceptible to impacts from environmental contamination due to their benthic feeding behavior and long life span. Contaminants, including toxic metals, polychlorinated aromatic hydrocarbons (PAHs), pesticides and polychlorinated biphenyls (PCBs) can have substantial deleterious effects on aquatic life including production of acute lesions, growth retardation and reproductive impairment (Cooper 1989, Sinderman 1994). 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), reduced egg viability (Von Westernhagen et al. 1981, Giesy et al. 1986, Mac and Edsall 1991), and reduced survival of larval fish (Berlin et al. 1981, Giesy et al. 1986). Early life stages of fish appear to be more susceptible to environmental and pollutant stress than are older life stages (Rosenthal and Alderdice 1976). Heavy metals and organochlorine compounds are known to accumulate in fatty tissues of sturgeon, but their long term effects are not yet known (Ruelle and Henry 1992, Ruelle and Keenlyne 1993).

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 St. Lawrence and Hudson Rivers. These compounds are now 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 they are linked to cancer, liver damage, skin lesions, and reproductive disorders. The U.S. Food and Drug Administration set the upper limit for PCBs in the edible portions of fish and shellfish at 5.0 parts per million (ppm) but reduced the limit to 2 ppm in 1984. Concerning effects on fish health, 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 egg mortality in salmon and reproductive failure in fathead minnows (Post 1987). Data from the St. Lawrence and Hudson Rivers reported by Spagnoli and Skinner (1977) showed that average levels of PCBs in all sturgeon sampled were higher than the FDA guidelines for edible portions of fish and ranged from 6.71 ppm in the Hudson River to 11.89 ppm in the St. Lawrence River. Belton et al. (1982) reported mean PCB levels in Atlantic sturgeon from the Hudson-Raritan estuary at 2.35 ppm. In the Hudson River there was a decline in PCB contamination from 1977-1988 where concentrations were found to be inversely proportional to body size of fish with Atlantic sturgeon PCB levels detected at less than 5 ppm (Sloan and Armstrong 1988).

Other contaminants identified in fish are heavy metals (mercury, cadmium, selenium, lead, etc.) and organochlorine compounds known as dioxin. 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 loss of reproductive capabilities, body malformation, inability to prevent predation, and susceptibility to infectious organisms. Rehwoldt et al. (1978) was the only reference found which specifically associated Atlantic sturgeon with any of these contaminants. The authors 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 which had been stored in preservation between 1924-

1953. These tissue samples were analyzed for cadmium, mercury, and lead and were 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 (micrograms/gram of fresh tissue) in Atlantic sturgeon tissue were as follows: cadmium = 0.02, mercury = 0.09, and lead = 0.16. 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.

No other references to additional contaminants present in Atlantic sturgeon flesh were found; however, the following information is available regarding contaminant levels in other sturgeon species. Dioxin and furans were detected in ovarian tissue from shortnose sturgeon caught in the Sampit River/Winyah Bay ecosystem (SC). Results showed that 4 out of 7 fish tissues analyzed contained tetrachlorodibenzo-p-dioxin (TCDD) concentrations > 50 ppt, a level which can adversely affect the development of sturgeon fry (J. Iliff, NOAA, Damage Assessment Center, Silver Spring, MD, unpublished data). Gulf sturgeon collected from a number of rivers during 1985-1991 were analyzed for pesticides and heavy metals (Bateman and Brim 1994). Concentrations of arsenic, mercury, DDT metabolites, toxaphene, polycyclic aromatic hydrocarbons, and aliphatic hydrocarbons were sufficiently high to warrant concern.

Other contaminants have been detected in fish species that, at times, share habitat with Atlantic sturgeon. These data are of some relevance to Atlantic sturgeon but the applicability is affected by differences in life history and habitat use. Arsenic, lead, cadmium, and selenium were the major inorganic contaminants found in striped bass sampled in the Hudson, Nanticoke, and Potomac Rivers (Mehrle et al. 1982). In the same study, the author 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. In South Carolina, Koli and Whitmore (1983) found that saltwater fish had higher levels of trace metals than freshwater fish, and that larger fish had higher levels than smaller fish. In addition, Kennelly (1996) found that prelarval and yearling striped bass can be severely impacted by metals and other contaminants in the Potomac River and Upper Chesapeake Bay. The authors reported low survival (1-20%) of prelarvae over 96 hour on-site tests in the Potomac and 57% survival of yearlings over 28 days in on-site tests in the Susquehanna River. The authors also stated that mortality of prelarvae was likely caused by a combination of cadmium, lead, chlordane, and sudden temperature drops while yearlings may have died as a result of copper, lead, or other non-identified factors.

River Specific Habitat Information

CANADIAN RIVERS

St. Lawrence River, Quebec

Dams have not been constructed on the St. Lawrence River within the 760 km range accessible to Atlantic sturgeon. The St. Lawrence River has undergone extensive dredging over the years to facilitate commercial traffic from the Great Lakes to the Atlantic Ocean. Caron and Trembly (1997) speculated that the disappearance of Atlantic sturgeon from the fisheries during 1967-1975 may have been due, in part, to dredging, sedimentation, and chemical pollution due to widespread pesticide application. Over the past 20 years, there has been a distinct improvement in water and sediment quality (Caron and Trembly 1997).

Saint John River, New Brunswick

In 1976, the Mactaquac Dam was constructed at the head-of-tide on the Saint John River. Atlantic sturgeon are not believed to have spawned above the site but could have migrated above this location prior to dam construction (M. Dadswell, Acadia University, personal communication).

U.S. RIVERS

Estuarial Complex of the Kennebec, Androscoggin, and Sheepscot Rivers, ME

The construction of Edwards Dam (rkm 71) in 1837 denied Atlantic sturgeon access to 28% of documented historical habitat in the Kennebec River. The historical limit of Atlantic sturgeon was at Ticonic Falls in Waterville, approximately 27 km upstream of the Edwards Dam. The MDMR captured adult Atlantic sturgeon in spawning condition at the base of Edwards Dam in 1994. The Federal Energy Regulatory Commission (FERC) had initially recommended a minimum flow of 4500 cfs to be released at the spillway during July to enhance Atlantic sturgeon spawning habitat (FERC 1995). FERC staff recently recommended, and the Commission approved, removal of the Edwards Dam, in part to increase chances for spawning success (FERC 1997).

In the Androscoggin River, the Brunswick Hydroelectric Dam is located at the head-of-tide at the site of natural falls. The limited storage capacity of the Brunswick Dam restricts its ability to influence river flows, therefore a minimum flow requirement is not necessary. It is unlikely that Atlantic sturgeon ever migrated above the dam site due the presence of natural falls. Therefore, dam construction did not deny Atlantic sturgeon access to historic habitat in this system.

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 is located, has been performed since 1963. In the lower Kennebec River, the U.S. Army Corps of Engineers (ACOE) conducts dredging operations to facilitate movement of Navy ships to Bath Iron Works (BIW) in Bath. Maintenance dredging is also conducted by BIW around its docking facilities. A recent 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.

State and federal resource agencies have recommended seasonal restrictions for dredging activities in the Kennebec River. Recommendations have restricted dredging activities to the time period November 1-April 1, the time of year when the least number of anadromous fish species would be present, with special emphasis on 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.

During the late 1960's and early 1970's, dissolved oxygen levels reached zero ppm in the Kennebec and Androscoggin Rivers from the head-of-tide to the mid-estuary during the summer months. This commonly caused fish kills. Dissolved oxygen levels improved significantly in the late 1970's and 1980's, coincident with improved point source treatment of municipal and industrial waste. Although the dissolved oxygen levels were severely low until the late 1970's, a large population of shortnose sturgeon managed to thrive in the system during this time period. The substrate in the upper freshwater section of both the Kennebec and Androscoggin Rivers was severely degraded by wood chips, sawdust and organic debris up until the late 1970's. This accumulation was quickly flushed from the river systems with 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 (Mower 1995). The levels of dioxin found in fish has declined significantly since sampling was initiated in 1984. The Androscoggin River has had the highest dioxin levels in fish in the State of Maine followed by the Kennebec River. Levels of tetrachlorodibenzo-p-dioxin (2,3,7, 8 TCDD) were as high as 10-12 ppt in fish sampled from the Androscoggin and Kennebec Rivers during 1984-1986, before dropping to 2-3 ppt in 1994 (Maine Department of Environmental Protection 1997). The discharge of dioxin into Maine river systems steadily declined during this time period. In 1997, the Maine Legislature passed LD 1633, An Act to Make Fish in Maine Rivers Safe to Eat and Reduce Color Pollution. This Act established specific enforceable milestones for eliminating dioxin discharges from Maine's bleached kraft mills. Those milestones are: in

1998, non-detectable dibenzo dioxin at bleach plants; in 2000, non-detectable dibenzo furan at bleach plants; and in 2002, fish at background levels for all 17 dioxin congeners. No sturgeon from these two rivers systems have been sampled for contaminants.

The Maine Department of Environmental Protection has conducted limited testing for heavy metals, PCBs, and organochlorine pesticides in the tidal waters of the Kennebec River; however, no sturgeon have been tested. 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 from the Kennebec River in 1995, were higher than EPA's screening value but much lower than the EPA's national median level (Sowles et al. 1997).

Despite water quality degradation in the past, the Kennebec and Androscoggin Rivers have continued to support sturgeon populations. Improvements in habitat quality from the 1980's to the present should facilitate recovery of the Atlantic sturgeon population in this estuary. The impacts of dredging projects to Atlantic sturgeon in the Kennebec and Androscoggin Rivers are minimized through the imposition of time of year restrictions. Dams on the Androscoggin River have not diminished the amount of habitat available to Atlantic sturgeon. Removal of Edwards Dam in the Kennebec River would provide access to an additional 28% of historical habitat, improve spawning, and accelerate recovery.

Penobscot River, ME

The first natural obstacle to Atlantic sturgeon migration on the Penobscot River may have been the falls at Milford, rkm 71 (L. Flagg, MDMR, personal communication). If Atlantic sturgeon were able to ascend the falls at Milford, they could have migrated without further obstruction to Mattaceunk (rkm 171). In 1830, the first dam was built on the mainstem of the Penobscot River in the Old Town-Milford area, followed by the construction of one at Veazie (rkm 56) in 1833. A dam was built at Treat's Falls in Bangor in 1874 (rkm 51) eliminating access to all freshwater habitat during the summer months. Treat's Falls Dam in Bangor was breached in 1977 the breach has increased in size over time. Currently the breach is large enough to allow all anadromous fish to gain access to the base of Veazie Dam, a gain of 5.0 km. Thus, there is currently approximately 14 km of tidal freshwater and 1.6 km of freshwater habitat available for spawning and nursery habitat.

Dissolved oxygen levels reached zero ppm in the Penobscot River estuary during the summer months during the late 1960's (Hatch 1971). These low dissolved oxygen 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 1970's and 1980's to a level sufficient to support aquatic life, coincident with improved point source treatment of municipal and industrial waste (Mitnik 1986). Although dissolved oxygen levels have improved in recent years, much of the substrate is still severely degraded (Squiers 1988), and has decreased the diversity of benthic fauna (U.S. Environmental Protection Agency 1994).

The predominant substrate types in the Penobscot River from Winterport to Bucksport consists of wood chips, silt/sawdust, and *Mytilus* 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 zone are impacted from organic debris deposits (Metcalf & Eddy 1994). Most of the bottom substrate is covered by bark and sawdust, which substantially reduces the diversity of benthic organisms. Also, a coal tar deposit has been discovered in the tidal section of the Penobscot River in Bangor, but the impacts are unknown. 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 (Mower 1993). The presence of dioxin in finfish is not unique to the Penobscot River and its impact on finfish has not been assessed.

The construction of dams on the Penobscot River reduced available habitat for potential use by Atlantic sturgeon. Water quality in the Penobscot River was severely degraded until recent years. With the breaching of Treat's Falls Dam in Bangor, and improvements in water quality, an estimated 79% of historic habitat in the Penobscot River is now accessible and suitable for Atlantic sturgeon. Further improvements to habitat quality, including flushing of wood chips and sawdust from the river, could enhance the area for potential use as a nursery area for migrating subadults.

Sheepscot River, ME

It is very unlikely that Atlantic sturgeon spawned above the Head Tide Dam on the Sheepscot River because the river is a relatively small watershed and becomes quite shallow near the head-of-tide in Alna, especially at low flows in June and July.

Merrimack River, NH/MA

Hoover (1938) identifies Amoskeag Falls (rkm 113) as the historical limit of Atlantic sturgeon in the Merrimack River. The Essex Dam in Lawrence (rkm 46) is the first upstream barrier, blocking the migration of Atlantic sturgeon to 59% of historically available habitat. Tidal influence extends to rkm 35. In the summer months during lowest river discharges, the salt wedge extends upriver to rkm 16, resulting in approximately 19 km of tidal freshwater and 11 km of freshwater habitat (Kieffer and Kynard 1993).

There are no current proposals for dredging in the Merrimack River. Past dredging projects were limited to the mouth of the river and not within potential spawning habitat (R. Iwanowicz, Massachusetts Division of Marine Fisheries (DMF), personal communication). Based on a detailed description by Kieffer and Kynard (1993), the bottom substrates are dominated by sand and gravel with depths less than three meters, and are considered suitable for Atlantic sturgeon spawning and nursery habitat. There are no known water quality limitations that might impact the use of the available habitat (R. Iwanowicz, Massachusetts DMF, personal communication).

Connecticut River, MA/CT

Some question exists over the historical 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 area prior to dam construction, which occurred in three stages between 1829 and 1881 (Judd 1905). The falls at South Hadley, MA, 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. The Enfield Dam was initially breached in 1977 and is no longer a barrier to migration. Since the Enfield Dam has been breached, an additional 90 km, from the Enfield Rapids in Connecticut to the base of the Holyoke Dam in Massachusetts, of habitat (100% of what was available pre-dam) are now available to Atlantic sturgeon.

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 extensive fish consumption advisories in Connecticut (J. Rowan, USFWS, personal communication). There is a Federal Navigation Project in the lower river from Hartford, CT to the mouth of the river, which requires dredging every six to seven years. In the past, time restrictions have been placed on dredging to protect shad and Atlantic salmon (W. Neidermyer, USFWS, personal communication).

Thames River, CT

The Thames River is created by the joining of the Yantic and Shetucket Rivers in Norwich Harbor, CT. The Thames River is actually an estuary with a salt wedge which extends up into the Shetucket River during low flows. The Greenville Dam in Norwich, CT located on the Shetucket River was constructed in 1830 and is just above the head-of-tide. There have been some reports of low dissolved oxygen levels during the summer months. The mouth of the river is dredged to accommodate the shipyard and the channel was recently dredged deeper than historical limits to accommodate the Sea Wolf submarine.

Housatonic River, CT

The Housatonic River is 212 km long and had a large amount of area (10 km) between saltwater and the fall line at Falls Village until the Derby Dam (rkm 23.5) was constructed in 1870. Whitworth (1996) stated that, unlike most other anadromous fish, sturgeon were not able to pass the falls (Great Falls) at New Milford, CT (rkm 123) prior to dam construction. The Derby Dam resulted in denying access to approximately 100 km of riverine habitat (approximately 81% of historically accessible habitat).

Hudson River, NY

The first dam on the Hudson River is the Federal Dam, located at Troy (rkm 246) significantly upstream of Catskill (rkm 181), 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, personal communication). Dredge and fill operations altered the river north of Catskill, but this is upstream from spawning and nursery habitat. No dredging occurs anywhere in spawning habitat.

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). Improved sewage treatment essentially eliminated the problem near Albany by the late 1970's and the problem near New York City by the middle to late 1980's. At the present time, 100% of historical Atlantic sturgeon habitat in the Hudson River, from Haverstraw to Catskill, is thought to be capable of providing suitable spawning and nursery habitat. Incidental takes in nuclear power plants has occurred but the severity of impacts have not been evaluated.

Delaware River, NJ/DE/PA

The portion of the Delaware River and Bay that is available to Atlantic sturgeon extends from the mouth of Delaware Bay to the fall line at Trenton, NJ, a distance of 220 km. There are no dams within this reach of the river. The freshwater tidal river, approximately 85 km in length from the Pennsylvania-Delaware border to Trenton, NJ, probably includes the primary spawning and nursery area for Atlantic sturgeon. The navigation channel is routinely dredged from the river mouth to just north of Trenton. The Delaware Basin Fish and Wildlife Management Cooperative has imposed "no work" windows to reduce impacts from dredging on anadromous species.

Shoreline development has become extensive throughout the middle and upper reaches of the estuary. Until recent years, 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 were a factor in the decline of Atlantic sturgeon from the estuary. As late as the early 1970's, levels of dissolved oxygen between Wilmington and Philadelphia, the historic spawning grounds, routinely dropped below levels that could support aquatic life from late spring through early fall. These problems likely affected the use of the river and estuary by Atlantic sturgeon for spawning and as a nursery. Since 1990, dissolved oxygen levels have remained above minimum State standards throughout the entire year (R. Green, Delaware DNREC, personal communication). Other anadromous fish stocks, such as striped bass, which utilize the mainstem Delaware River for spawning and nursery habitat, have recently been restored to harvestable abundance as water quality has improved. This suggests that environmental conditions are now adequate to support growth of the Atlantic sturgeon population if the remaining population is allowed to reach maturity and spawn.

Chesapeake Bay and Tributaries (Potomac, Rappahannock, York, James, Susquehanna, Nanticoke), PA/MD/VA

Due to their upriver locations, most dams in the Chesapeake Bay have large freshwater tailways and probably did not obstruct Atlantic sturgeon spawning runs. A notable exception were four dams constructed from 1904-1932 in the Susquehanna River. Approximately 50 km of habitat were available to Atlantic sturgeon in the Susquehanna River prior to the construction of Holtwood Dam (rkm 39) in 1910. Access was further restricted in 1928 with the construction of Conowingo Dam (rkm 16) (Carricata 1997). Since 1965, fish lifts have intermittently operated at the Conowingo Dam. During years of fish lift operation, 1965-1966 and 1972 to the present, over 50 million fish representing 70 taxa, but no sturgeon, have been collected at the dam. Other major Chesapeake tributaries, including the James, York, Rappahannock, Potomac, Patuxent, Choptank, and Nanticoke Rivers were never impounded below tidal areas and should have continued to function as spawning migration corridors.

The Chesapeake Bay is the largest estuary in the United States with a watershed including 20 major tributaries and draining 175,000 km^2 in Maryland, Pennsylvania, New York, and Delaware (Murdy et al. 1997). During the past 100 years, increased rates of urbanization, 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 spatial and temporal frequency of hypoxia (Officer et al. 1984, Mackiernan 1987, Kemp et al. 1992, Cooper and Brush 1993). Secor and Gunderson (in press) showed that juvenile Atlantic sturgeon were less tolerant of summer-time hypoxia than juveniles of other estuarine species. In recent times (last 50 years), high nutrient inputs have contributed to high spatial and temporal incidence of summer-time hypoxia and anoxia in bottom waters (Officer et al. 1984). 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.

Since 1984, the Chesapeake Bay Program and its member states (PA, MD, D.C., and VA) instituted programs of nutrient abatement (Cooper and Lipton 1994). In Chesapeake Bay tributaries, improving conditions for macrobenthos have been observed recently, perhaps the result of nutrient abatement programs (Dauer 1995). Furthermore, the survival and growth rates of Atlantic sturgeon stocked in the Nanticoke River in 1996 provides some evidence of, at least, the suitability of nursery habitat.

The most limiting habitat requirement for Chesapeake Bay sturgeons may be the availability of clean hard substrate for attachment of sticky benthic eggs. Rubble, cobble, and gravel size rock as well as shell, forest litter, and submerged vegetation (Dean 1894) provide substrate for egg attachment. In the Chesapeake Bay's watershed, 18^{th} and 19^{th} century agricultural clear-cutting (Miller 1986) contributed large sediment loads which presumably have buried and reduced most sturgeon spawning habitats. Because Atlantic sturgeon spawning sites are often adjacent or down-river to areas of high urbanization, they would have been impacted by urban and industrial run-off, siltation, deforestation, pollution, and eutrophication.

No dredging is currently conducting within potential Atlantic sturgeon spawning habitat on the Rappahannock, Potomac, James, York, or Nanticoke Rivers (J. Gill, USFWS, personal communication).

Albemarle Sound and Tributaries, NC

The construction of Roanoke Rapids Dam in 1955 on the Roanoke River blocked access beyond rkm 220. It is likely that Atlantic sturgeon ascended the rapids at Weldon, at least during the years of high flows, based on location of sturgeon related names upstream and the capture of sturgeon in fish slides at Roanoke Rapids and/or Weldon as they were coming downstream. Two additional dams, Gaston and Kerr, are immediately above Roanoke Rapids. The Gaston and Roanoke Rapids Dams are currently undergoing relicensing, and fish passage is being discussed with the operator, Virginia Electric and Power Company (VEPCO). It is uncertain how spawning has been affected by these dams. Since age one juveniles still occur in the system, spawning must be continuing below the dams.

Flow, temperature and oxygen levels in the Roanoke River are also affected by Kerr Dam and the Gaston and Roanoke Rapids facilities which engage in peaking operations. The USFWS and other federal and state fishery management agencies are currently working with the ACOE, Wilmington District, and VEPCO to rectify concerns through modification of the operations of the reservoirs. Flows in the river have been modified during the striped bass spawning window to approximate the natural pattern, which undoubtedly benefits Atlantic sturgeon. Despite these modifications, lower water temperatures resulting from the hypolimnetic discharge from Kerr Dam have caused temporal shifts in the peaks of spawning for both American shad and striped bass, and likely do so for Atlantic sturgeon as well. Atlantic sturgeon tracking studies, to locate spawning areas, are ongoing in the Albemarle system.

The ACOE conducts extensive annual dredging operations in order to maintain navigational access through Oregon Inlet and the channels leading to the 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 1940's. The USFWS, NMFS, ACOE, North Carolina DMF, NC Wildlife Resources Commission, and NC Division of Coastal Management all support a dredging moratorium in certain coast waters during the spring spawning season (K. Moody, USFWS, personal communication).

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 at Weldon and Plymouth have caused some localized areas of contamination, and a fish consumption advisory has been in effect for some years. The effect of the contaminants in the system on Atlantic sturgeon is unknown, since no samples have been collected or analyzed from that species. The sudden cessation of high flows from Kerr Dam during the summer of 1995 coupled with high ambient temperatures and an influx of low dissolved oxygen waters from back swamps, resulted in a major kill of striped bass and other species. No Atlantic sturgeon carcasses were observed during clean-up activities.

Pamlico Sound and Tributaries, NC

Both the Tar-Pamlico and Neuse Rivers, the two major tributaries to Pamlico Sound, are dammed. Migration up the Tar-Pamlico is blocked by low-head Rocky Mount Dam (rkm 136). It is likely that historically Atlantic sturgeon utilized habitat in the Neuse River up to the falls at rkm 378 where a dam (Falls Dam) is now located. 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 is currently being removed which will then allow Atlantic sturgeon access to the base of Milburnie Dam. Flows on the Neuse and Tar-Pamlico are altered by operation of the dams, but the extent to which Atlantic sturgeon are affected is unknown. It is unknown to what extent the flow regime on the Neuse departs from historical patterns. Flows on the Tar-Pamlico River at Rocky Mount are currently being negotiated by federal and state fishery management and water resource agencies while flows on the Neuse are regulated by the ACOE, Wilmington District, at the Falls of the Neuse Dam.

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 anadromous species, including Atlantic sturgeon.

Water quality in the Pamlico system, especially in the lower Neuse River, is of serious concern. 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*;

but this disease has not been detected in Atlantic sturgeon even during severe outbreaks. The entire basin has been designated nutrient-sensitive waters, and additional regulatory controls are being implemented to clean up the entire system. Both the Neuse and Pamlico portions of the estuary have been subject to seasonal episodes of anoxia, which significantly affects the quality of these areas as nursery habitat for Atlantic sturgeon. At least some portion of the water quality problems in the Pamlico system appears attributable to the proliferation of animal production operations. Farms which 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 recently passed a two year moratorium on additional hog operations and is conducting a study of measures to address the problem.

Cape Fear River and Tributaries, NC

The Cape Fear River has three locks and dams between Wilmington and Fayetteville and two additional dams, Buckhorn and B. Everette Jordan, located above the fall line. Atlantic sturgeon access is blocked beyond the first lock and dam at Acme, NC (rkm 90). Species other than Atlantic sturgeon routinely make it above the three locks and dams during high water but are prevented from passing by Buckhorm Dam (rkm 292). Historical spawning locations are unknown in the Cape Fear River, therefore there is no means of calculating habitat losses. No Atlantic or shortnose sturgeon have been captured upstream of Lock and Dam #1 despite extensive sampling efforts. Although locks are operated during spring in an effort to provide upstream fish passage, they are not utilized by sturgeon. It has been recommended that the locks be operated year round based on the observation of an upstream fall migration. Flows on the river are regulated from the B. Everette Jordan Dam on the upper river; however, the extent to which the flow departs from the historical hydrography has not been evaluated.

Some Atlantic sturgeon captured during the 1997 study in the Cape Fear River resembled shortnose sturgeon. In general, scute patterns of these fish matched those of Atlantic sturgeon with the exception of a few fish with no pre-anal shields. However, the head shape and mouth width:interorbital distance of some fish were representative of shortnose sturgeon. It was speculated that the presence of the dam at rkm 90 had restricted spawning of both species to a small area at the base of the dam and led to hybridization. If this situation had developed on the Cape Fear River, it may have had dire consequences for the maintenance of genetic integrity of these two species that, under normal circumstances, would have spatially segregated spawning areas (Dadswell et al. 1984, Kynard 1997, Moser et al. 1998). Genetic samples from these sturgeon were collected and submitted to Dr. Isaac Wirgin, New York University Medical Center, for nuclear DNA analysis and later were confirmed to be shortnose sturgeon.

Dredging operations 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 anadromous fish, restrictions are placed on dredging to avoid sensitive seasons and locations, such as potential spawning habitat (K. Moody, USFWS, personal communication). Currently, there are plans to expand the navigational channel which would require the blasting of rock. Atlantic sturgeon will need to be considered during the planning of this project to prevent impacts to the species. Dredging activities above Lock and Dam #1 in the Cape Fear River are unlikely to impact either sturgeon species.

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 animal production operations in the coastal portion of the Cape Fear River basin has also been especially heavy and contributes to both atmospheric and aquatic inputs of nitrogenous contamination causing dissolved oxygen levels to regularly fall below the 5 ppm state standard.

Winyah Bay Rivers (Waccamaw, Great PeeDee, Black and Sampit), SC

The only river in this system that is dammed is the Great PeeDee River, and that dam is well upriver in North Carolina. It is unknown how much of the river was used by Atlantic sturgeon prior to dam construction. There appears to be adequate spawning habitat for Atlantic sturgeon in all the above named rivers.

Winyah Bay and its shipping channel, which includes the salinity regime commonly inhabited by age 1-4 juveniles, is dredged with some regularity to accommodate the Port of Georgetown. In the bay, a seasonal restriction to protect sea turtles does not allow dredging during the summer months. Dredging does not occur in Winyah Bay rivers where Atlantic sturgeon spawning habitat is located.

Industrialization, including paper and steel mills, in the upper portion (Sampit River arm) of Winyah Bay has reduced water quality. Sediments from certain areas contain high levels of various toxins including dioxin. The effects of these contaminants on sturgeon are not known.

Santee River, SC

The Santee River, together with its tributaries (especially the Congaree and Wateree), was one of the larger rivers of the region prior to the construction of the Wilson Dam. Much of the flow was diverted into the Cooper River. Although it is not known to what extent the Santee River system was used by Atlantic sturgeon, it is likely that more potential habitat was lost due to dam construction in this river than in any other in the southeast. 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. However, three dead Atlantic sturgeon, one per year and all approximately five feet total length, were found during 1995-1997 in Lake Marion above the Wilson Dam. In 1985, most water from the Santee-Cooper Lakes was rediverted to the Santee River which may assist in recovery of anadromous species. However, flows fluctuate drastically depending on discharge from the dam (which is dependent on precipitation and electrical power demand), and the effects of these fluctuations on spawning success, egg survival, and other aspects of the sturgeon's life cycle are unknown. There is no dredging in the Santee River that would have the potential to affect Atlantic sturgeon habitat.

Cooper River, SC

The Cooper River was historically a relatively small, short blackwater river. After construction of the Pinopolis Dam during the 1940's as part of the Santee-Cooper Reservoir, much of the Santee River flow was diverted into the Cooper River. This is thought to have enhanced anadromous fish populations, but no information is available on pre-or post-diversion population status of Atlantic sturgeon. The diversion was reversed in 1985, and spawning runs of some anadromous species (e.g. blueback herring) have declined substantially. Limited sampling at the base of the dam and certain locations downriver in 1997-1998 produced large numbers of mature shortnose sturgeon (spawning confirmed at the dam) and a subadult Atlantic sturgeon, but no mature adult or age $\leq$ 1 Atlantic sturgeon. Results of telemetry studies on shortnose sturgeon suggest that sturgeons do not pass through the lock even when they congregate nearby, probably because passage would require swimming upward along a vertical wall 15 m high. Sturgeon that passed would have access to the upper Santee, Congaree, and Wateree Rivers, but that access was not present before reservoir construction.

The Cooper River flows into Charleston Harbor, one of the busiest ports on the Atlantic coast, which is dredged regularly. The river channel is maintained by dredging all the way to the 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.

ACE Basin Rivers (Ashepoo, Combahee, Edisto), SC

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 no dams present within the historic range of Atlantic sturgeon in the ACE Basin Rivers. Populations in this system have received little impact from dredging, dams, or diminished water quality.

Savannah River, SC/GA

The New Savannah Bluff lock and dam at the city of Augusta (rkm 299), is located just a few kilometers below impassible rapids, denying Atlantic sturgeon access to 7% of historically available habitat. It is possible that during high flow years, prior to dam construction, Atlantic sturgeon could have occasionally passed the rapids and gained access to much more of the river. Discharge fluctuations (primarily from reservoirs above Augusta) may impact spawning success. Maintenance dredging, occurring primarily in nursery habitat, is frequent, and substantial channel deepening took place in 1994. Port expansion and further channel deepening are planned. A seasonal restriction has been placed from March 16-May 31 to protect striped bass. This spring closure may be beneficial in that it prevents interference with any Atlantic sturgeon spawners transiting the area (M. Collins, South Carolina DNR, personal communication). A summer closure would protect Atlantic sturgeon nursery habitat.

In the lower river, Savannah, GA is heavily industrialized and serves as a major shipping port. The vicinity of the age 1-4 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 dissolved oxygen levels and upriver movement of the salt wedge may result from channel deepening. A five year study of sturgeon is recommended to provide better information to assess the impact of planned channel deepening by the Georgia Ports Authority and ACOE on Atlantic sturgeon.

Altamaha River, GA

The Altamaha River drainage basin is the largest east of the Mississippi River. Although the two major tributaries are impounded, all dams are well upriver at or above the fall line and the historic extent of Atlantic sturgeon habitat. The drainage basin is dominated in areal extent by silviculture and agriculture, 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). No dredging has occurred in this river in the last twenty years (D. Harris, USFWS, personal communication).

Ogeechee River, GA

There is no habitat loss due to dam construction on the Ogeechee River. It has been hypothesized that the function of the nursery habitat in the Ogeechee River during hot, dry summers has been compromised by reduced dissolved oxygen levels from non-point source pollution and loss of thermal refugia from lowering of the aquifer (Rogers et al. 1994). No dredging has occurred in this river in the last twenty years (D. Harris, USFWS, personal communication).

Satilla River, GA

There is no habitat loss due to dam construction on the Satilla River. Sampling in the early 1990's suggested a stressed population of Atlantic sturgeon, probably because of the same problems observed in the Ogeechee River. No dredging has occurred in this river in the last twenty years (D. Harris, USFWS, personal communication).

St. Marys River, GA/FL

There is no habitat loss due to dam construction on the St. Marys River. It appears that the extirpation of the Atlantic sturgeon population from this river system was caused by reduced dissolved oxygen levels during summer in the nursery habitat, probably due to eutrophication from non-point source pollution, as in the Ogeechee River.

St. Johns River, FL

Rodman Dam construction, which blocked access to potential spawning habitat, would have eliminated any spawning population if one was present.

SUMMARY and EVALUATION

Loss and/or degradation of habitat has contributed to the decline of Atlantic sturgeon and may retard recovery of populations at depressed levels. Increased efforts to restore habitat and improve water quality can make important contributions to the rate and extent of Atlantic sturgeon recovery. Although a number of sources have cited habitat degradation as a contributor to Atlantic sturgeon decline, there is no evidence that habitat loss and degradation are threatening the species. Evidence supporting this determination includes the fact that Atlantic sturgeon persisted during the first half of the 20th century when habitat conditions were generally much worse. Habitat quality has improved significantly since that time, except in certain southern rivers, and now provides a favorable environment for recovery of Atlantic sturgeon. Concurrent improvements in habitat quality and populations of anadromous species that share habitats with Atlantic sturgeon, such as shortnose sturgeon and striped bass, provide evidence that, with elimination of other pressures, Atlantic sturgeon will also respond to improved habitat conditions.

While current threats from habitat loss and degradation are below the threshold at which the species is likely to become endangered in the foreseeable future throughout all or a significant portion of its range, continued conservation and/or restoration of Atlantic sturgeon habitat will play an important role in the recovery of populations and should remain a priority. Slow rates of population growth inherent to the species' biology necessitate long-term commitments to habitat protection. Habitat improvement opportunities include the following: (1) elimination of barriers to spawning habitat either through dam removal or breaching, where feasible, or design and installation of effective upstream and downstream passageways for sturgeon; (2) operation of water control structures to provide flows compatible with Atlantic sturgeon use in the lower portion of a river; (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. In addition, acquisition of data on sturgeon use of riverine and estuarine environments is needed.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Atlantic sturgeon have been directly harvested utilizing 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 1996). The ASMFC 1990 Fishery Management Plan (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 (Donavan 1989). There is no evidence that a recreational fishery ever developed in the U.S. for Atlantic sturgeon. General information is presented in this section on both directed and incidental catch of Atlantic sturgeon, followed by more specific information on harvest by river system.

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 million lbs) were landed in 1890 (Smith and Clugston 1996). The majority of the fishery for a fifty 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, and therefore harvest was illegal in subsequent years. During the 1970's and 1980's, the focus of fishing effort shifted to South Carolina, North Carolina, and Georgia, which accounted for nearly 80% of the total U.S. landings. Catch between 1990 and 1996 was centered in the Hudson River and coastal New York and New Jersey (Smith and Clugston 1996). Appendix C presents available information on landings of Atlantic sturgeon coast wide from 1962-1997.

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 significant depletion. By 1990, six jurisdictions prohibited sturgeon landings: Pennsylvania, District of Columbia, Potomac River, Virginia, South Carolina, and Florida. There were two main kinds of protection in states which 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. The 1990 FMP 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 meters) and institute a monitoring program with at least 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 Maine, New Hampshire, Massachusetts, Pennsylvania, the District of Columbia, the Potomac River Fisheries Commission, Virginia, North Carolina, South Carolina, and Florida (ASMFC 1996). Rhode Island, Connecticut, Delaware, Maryland, and Georgia had adopted a seven foot (2.13 m) minimum size. 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.

The 1996 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 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 which would help restore the Hudson stock. The 1997 draft review of the FMP stated that most participating states had closed their Atlantic sturgeon commercial fisheries or reduced the allowable quota to zero. At that time only Delaware had an open fishery with a seven foot (2.13 m) minimum size; but, according to ASMFC, no landings have been reported in that state since 1993.

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 draft 1997 Review of the FMP states that the 1990 FMP for Atlantic sturgeon will not lead to the recovery of the east coast stocks and should be amended. Recommendations in the Plan Amendment include a complete moratorium on harvest, 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. A draft of this amendment was approved by the ASMFC Sturgeon Management Board on April 7, 1998. Several public hearings were scheduled as required by the ASMFC and, following final review, the amendment was adopted in early June, 1998.

BYCATCH

Insight into the extent to which Atlantic sturgeon are caught as bycatch in fisheries directed at other species and the percent released alive can be obtained from examining (1) landings records for states without directed sturgeon fisheries, (2) tagging and recapture studies, (3) log books completed by fishermen, and (4) the reward program instituted by the USFWS. 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 population; but this would require the following data: (1) the size of the population 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 effort level in each of those fisheries; and (4) the mortality rate of sturgeon caught by each gear type. The status review team recommends that such information be sought to better quantify the impact of bycatch at the population and species level. Available information on bycatch levels and mortality is presented below by geographic area, gear type, and season of fishery.

Area and Season

Bycatch of Atlantic sturgeon has been reported in many different fisheries conducted in rivers, estuaries, the nearshore ocean, and the exclusive economic zone (EEZ). Since Atlantic sturgeon spend portions of their lives in all these areas, they are subject to incidental capture. Relative importance of commercial bycatch in the northeast from rivers and 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. Recaptures came from commercial fisheries ranging from Maine to North Carolina with most recaptures occurring relatively close to the release site. While 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 unknown locations. Landings data and area caught are presented in tables and graphs in Appendices E and F.

The season in which a fishery is conducted, and therefore when it can potentially intercept Atlantic sturgeon, can affect survival rates. Generally, survival increases in cooler water temperatures. The time of year and location of a fishery also determines the size and age at which Atlantic sturgeon are captured. 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 out migrating from nursery habitats. Fisheries conducted within rivers can intercept any life stage, while fisheries conducted in the nearshore and ocean can intercept migrating juveniles or adults. The loss of a mature individual has a greater impact on the population’s persistence than the loss of a juvenile.

Gear

Reported landings by gear type are presented in Appendix G.

Gill nets

Survival of Atlantic sturgeon caught incidentally in gill nets is variable depending on the manner in which the gear is set and the length of time it is left before being tended. The greatest observed mortality was from gill nets utilized for the monkfish fishery which were set for three days (40% mortality). The lowest mortality rate was observed for shad anchored gill nets (10%). For purposes of the ASMFC Stock Assessment, a range of 10%-40% was used for mortality in gill nets.

During the fall and winter of 1997, observers noted a mean survival of Atlantic sturgeon caught in monkfish gill nets of 60% (Manomet 1998). Survival was highest in nets set between one or two days, and lowest in nets set over three days. Observers on sink gill net vessels fishing from Maine to Rhode Island in 1990-1994 reported bycatch rates of less than 0.5 kg per day (Kennelly 1996). Nine sturgeon were observed in 21 sea-days on vessels fishing for monkfish in the New York Bight (Manomet 1998). Bycatch information in the Chesapeake Bay system is available from the reward programs conducted by the USFWS for access to live Atlantic sturgeon. All of the wild captures in this program (n=360) were caught as bycatch from commercial gears. Most captures in Maryland and Virginia were from gill nets and pound nets. Since the USFWS reward program was restricted to live captures, few dead sturgeon were reported. It is likely, however, that rates of mortality were low. The gill net fishery, where highest mortality is expected, occurs during cold water months when increases in bycatch survival occur. Most captures in warm water months occurred in pound nets which have zero mortality.

Most Atlantic sturgeon tagged and recaptured by the Delaware DFW occurred in gill nets (78%) and survival in anchored gill nets was 90% (C. Shirey, Delaware DFW, personal communication). Collins et al. (1996) reported a mean of 16% mortality and 20% injury in shad anchored gill nets in Winyah Bay in 1994, 1995, and 1996. Atlantic sturgeon were tagged in the Altamaha River, GA in 1986-1992 (Collins et al. 1996) with most recaptures (52%) coming from gill net fisheries in Georgia for American shad and the majority of the remainder coming from the shrimp trawl fishery. 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, weakfish, and monkfish. Mortality of those taken in gill nets is higher than in trawls, especially in anchored nets fished for extended periods (one-two days) (C. Shirey, Delaware DFW, personal communication). 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 fishermen, is low. Of ten Atlantic sturgeon reported captured in anchored gill nets, only one was reported as dead (C. Shirey, Delaware DFW, personal communication).

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 south. Bycatch survival is higher in the colder water temperatures of the north, but survival of sturgeon bycatch is likely to be enhanced by use of various bycatch reduction devices in the south. The ASMFC Stock Assessment assumed a coast wide value of 5% mortality in trawl fisheries.

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-November, 1996. Recent 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. Based on empirical data, mortality of Atlantic sturgeon bycatch appears to be low in trawl captures.

Of the recaptures that occurred from Maine to North Carolina in Delaware DFW's 1997 study, the trawl fishery accounted for 15%. Survival in trawl nets was estimated to be 100%. Atlantic sturgeon were tagged in the Altamaha River, GA during 1986-1992, and 41% 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 devices (TED) and bycatch reduction device (BRD) requirements may have reduced Atlantic sturgeon bycatch in southeast trawl fisheries.

Pound nets

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).

Impacts of Bycatch at the Species Level

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 of Atlantic sturgeon range-wide due to lack of data, we can calculate bycatch mortality on the most data-rich system, the Hudson River. This river's population level gives an approximation of the impact to the overall species. To estimate the effects of Atlantic sturgeon bycatch on the Hudson River population, the ASMFC Stock Assessment Team revised its yield and egg-per-recruit model to identify a F_{50} value for bycatch of the Hudson River stock. 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. 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 population can be removed as bycatch mortality, while allowing the population 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). This analysis supports the conclusion that current levels of bycatch are not threatening the continued existence of the species, but the results should be used with caution due to the many assumptions and estimates involved. Any level of bycatch mortality will delay recovery. Continued efforts are needed to quantify bycatch mortality and minimize bycatch mortality through gear modifications or seasonal/area restrictions.

River Specific Overutilization Information

CANADIAN RIVERS

Currently, there are no data to indicate that Atlantic sturgeon of U.S. origin migrate to areas where they may be intercepted by fishermen in Canada. In the most extensive tagging to date, Dovel and Berggren (1983) tagged and released over 4,000 Atlantic sturgeon of various juvenile size classes in the Hudson River during 1975-1977. Over the course of the next several years, 60 tags were returned from Atlantic coast locations outside the Hudson River. Although out-of-basin return locations spanned from Marblehead, MA to Ocracoke, NC, no tags were returned from Canadian rivers and most tag returns came from the relatively nearby Chesapeake Bay and tributaries (n=22) and Delaware Bay (n=19). Of 1,700 subadult fish tagged and released in the lower Delaware River between 1991-1997, no tags were returned from Canadian rivers and only one from the Gulf of Maine (Shirey et al. 1997). Reported incidental catch of sturgeon, regardless of origin, in coastal areas of Canada was minimal and retention of sturgeon as bycatch was prohibited in 1995 (Jessop, *in litt.*, 1998). Genetics work by Waldman et al. (1996b) showed complete separation (no intergrade) between Saint John River, New Brunswick and Hudson River stocks. However, without tagging and/or genetics data for populations north of the Hudson, we cannot confidently say that the U.S. and Canadian populations are completely separate. Mixing of U.S. and Canadian stocks is of interest if it results in the U.S. stocks being impacted by particular activities in Canada (such as a fishery in Canadian waters) or if it results in the exchange of genes.

St. Lawrence River, Quebec

There is very little information on the abundance or dynamics of Atlantic sturgeon in the St. Lawrence River (Caron 1998). The directed fishery, which concentrates on subadult Atlantic sturgeon, is carried out in a stretch of the upper estuary which extends about 150 km from just south of Quebec City to about Trois-Pistoles (Caron and Trembly 1997). The fork length of captured fish ranges from 50-170 cm with most being between

80-140 cm. Landings since 1940 can be characterized by three major periods: from 1940-1960, the fishery yielded 20- 40 tons annually; from 1967-1975, sturgeon was almost absent from the fishery; then increased from the time period 1988- 1993 to between 100-120 tons. The median nominal age of captured sturgeon from 1984-1988 was 12 years but dropped to 6-8 years from 1989-1994 as landings increased (Caron and Trembly 1997).

The increase in landings and decrease in median age of captured fish prompted the implementation of more stringent regulatory measures. Before 1994, conservation measures consisted of limiting the number of fishing permits to 35 and a minimum mesh size of 18 cm stretch mesh. In 1995, fishing regulations established a season from May 1-September 30 and set a slot size limit of 100-170 cm fork length, which was reduced in 1996 to 100-150 cm. The 1997 fishing regulations established a maximum size of 150 cm fork length, and a total harvest quota of 6015 fish (approximately 60 tons). All sturgeon that are captured and retained must be tagged with a market tag (Caron and Trembly 1997).

Saint John River, New Brunswick

A limited directed commercial fishery for Atlantic sturgeon occurs in the Saint John River, with only 9 licensed fishermen. The number of sturgeon licenses issued in New Brunswick grew from 2 in 1975 to 12 in the mid-1980's, 10 in 1996 and dropped to 9 in 1997. The landings from 1975-1978 were less than 10 tons, increased in 1979 to 15 tons, and peaked in 1988 to 44 tons. Recent landings (1994-1997) have been in the range of 10-14 tons. There are no data available on the size and age structure of the catch, but the minimum mesh size limitation of 33 cm would target adult fish.

The following summary was provided by Brian Jessop (DFO, personal communication). Angling and gill nets are the only legal methods to fish for sturgeon. The fishery for Atlantic sturgeon is regulated by permit, gear restriction, size restriction, and seasonal closure. The legal minimum mesh size is 33 cm (13 inches), the minimum size limit is 120 cm (48 inches), and there is an annual closed season from June 1-30 to protect spawning fish. In the Scotia-Fundy area, no new sturgeon licenses have been issued since the mid-1980's. The licenses, which authorize various amounts of gear, are non-transferable and terminate with the death of the existing license holder. Thus, in New Brunswick, the 10 (now 9) licensees were authorized a total of 3,350 (now 2,800) meters of gill net, while in Nova Scotia the single licensee is authorized two set gill nets of unspecified length. Since 1995, the retention of sturgeon as bycatch has been prohibited throughout the Maritime Provinces.

Shubenacadie River, Nova Scotia

There is currently only one licensee who is authorized to fish two gill nets of unspecified length in the Shubenacadie River. The regulations on the Shubenacadie River in Nova Scotia are the same as they are on the Saint John River in New Brunswick. Gill nets and angling are the only legal methods to fish for sturgeon. The legal minimum mesh size is 33 cm (13 inches), the minimum size limit is 120 cm (48 inches), and there is an annual closed season from June 1-30 to protect spawning fish.

U.S. RIVERS

Maine Rivers

Maine had one of the earliest sturgeon fisheries with export back to England taking place as early as 1628. Commercial sturgeon landings statistics (shortnose and Atlantic sturgeon) are generally only available from the late 1800's. Landings peaked in the late 1800's and early 1900's and collapsed by the 1920's. Although there is the occasional story of anglers foul hooking large sturgeon, there is no documented record of Atlantic sturgeon being landed incidentally in any recreational fishery. Regulations were passed in 1992 to make it illegal to take, catch, or possess Atlantic sturgeon in the State of Maine.

Estuarial Complex of the Kennebec, Androscoggin and Sheepscot Rivers, ME

In 1628, the estuarial complex of the Kennebec River probably supported the major 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 18^{th} and early part of the 19^{th} century. 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 which do not exceed a maximum stretch mesh measure of 87.5 mm, is prohibited. If the nets are fixed or anchored to the bottom, they have to be tended continuously and hauled in and emptied every two hours. There has been no reported or observed bycatch of Atlantic sturgeon in the Kennebec and Androscoggin Rivers.

From 1977-1997, a total of 20 mortalities of subadult Atlantic sturgeon occurred in the MDMR gillnet sampling program out of a total catch of 117 subadults. The relatively high mortality rate of subadult Atlantic sturgeon has been noted by other researchers. Kieffer and Kynard (1993) attributed the high mortality rates of subadult Atlantic sturgeon captured in gillnets to the presence of dense dermal ossifications which prevented the net strands from sliding beyond the operculum, thus restricting ventilation.

Penobscot River, ME

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

Merrimack River, NH/MA

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 1800's. In the early 1600's, 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") stretch mesh measure for taking sturgeon. In 1887, only 2 tons were taken by 'visiting fishermen' and it was generally considered that the fishery was eliminated. There are currently no commercial fisheries in the Merrimack River which might take Atlantic sturgeon directly or incidently as bycatch (R. Iwanowicz, Massachusetts DMF, personal communication).

Connecticut River, MA/CT

Reported landings are only available since 1989. Prior to a Connecticut harvest moratorium in 1997, licensed fishermen were limited to a catch of 3 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 122-213 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 which operates in the lower Connecticut River from April-June with large mesh gillnets (14 cm minimum stretches mesh measure).

Scientific monitoring for shortnose sturgeon and other species has resulted in the capture of 99 Atlantic sturgeon in the Connecticut River, and 288 in Long Island Sound since 1983. Several mortalities have occurred, but scientific monitoring is not thought to be a significant source of mortality. Collection of sturgeon for research purposes would require a scientific collectors permit and an annual report of the collection made. Only a single permittee is known to have collected sturgeon within the last ten years. One immature Atlantic sturgeon was captured and released in the Housatonic River in 1995.

Hudson River, NY

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. Highest annual landings of the time series (231,000 kg) occurred in 1898, after which landings quickly dropped to 15,000 kg or less per year and remained at low levels through the early 1980's. 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.

Fishing has been an important factor affecting abundance of Atlantic sturgeon in the Hudson River estuary for most of this century. Overfishing was probably the dominant factor in the dramatic decline in landings and presumably in abundance at the end of the 1800's. Harvest of Atlantic sturgeon from the Hudson River estuary remained at relatively low levels from the early 1900's through 1980. In 1985, harvest began to increase after fishery closures in southern states. 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 population modeling 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 commercial gill net fishery in the Hudson River Estuary exploits the spawning migration of American shad, and young (< one meter) Atlantic sturgeon are caught as bycatch. Atlantic sturgeon bycatch was highest (CPUE = number of fish collected per yd^2 x hrs x 10^{-3} of net fished) in the early 1980's and steadily decreased through the present.

It is likely that the drop in abundance of juveniles in the late 1980's was in response to accumulated removals of older immature and mature fish from the population starting in the early to mid-1980's. Data on fishing rate and total harvest indicate that the Hudson River Atlantic sturgeon stock was over harvested by the commercial fisheries in New York and New Jersey in at least the last six years (1990-1995). Overfishing may also have been the cause of the recent reduction in production of young in the Hudson River estuary.

Delaware River, NJ/DE/PA

Landings data in the Delaware estuary are available from 1880 through the present, and the highest landings (2,968,000 kg) occurred 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 1900's. More recently, highest landings from the Delaware River were recorded from the late 1980's and early 1990's. No landings were reported after 1993 and the directed fishery was closed on April 1, 1998.

Almost 90% of Atlantic sturgeon caught as bycatch in coastal fisheries were reported to be released alive. About 1,700 immature fish tagged by the Delaware DFW in the lower Delaware River from 1991-1997 were taken in a wide range of commercial gears in estuaries and the near shore ocean from Maine through North Carolina (C. Shirey, Delaware DFW, personal communication). Poorest survival of sturgeon captured as bycatch occurred in gill nets (87%), and highest survival (100%) occurred in pound nets. Although Atlantic sturgeon are intercepted by a number of existing commercial fisheries, the low level of resulting mortality does not appear to pose a threat to the Delaware River population.

<u>Chesapeake Bay and Tributaries (Potomac, Rappahannock, York, James, Susquehanna, Nanticoke), PA/MD/VA</u>

During the late 19th century, the Chesapeake Bay supported the second greatest caviar fishery in the eastern United States (Murawski and Pacheco 1977). In the early 1900's, the population 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 19th century (Murawski and Pacheco 1977; Secor and Waldman *in review*). 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 (J. Skjeveland and A. Spells, USFWS, personal communication).

<u>Cape Fear River and Tributaries, NC</u>

During a research gill net survey in the Cape Fear River, twenty-five percent (22/88) of sturgeon intercepted 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).

<u>Winyah Bay Rivers (Waccamaw, Great PeeDee, Black, Sampit), SC</u>

During the mid-1970's, nearly 50% of all U.S. landings of Atlantic sturgeon came from this area (Smith et al. 1984). However, the fishery was almost entirely restricted to coastal waters outside the bay, making it impossible to assign landed fish to a particular population. The fishery in South Carolina was closed in 1985. The bay is currently fished by gillnet fishermen targeting American shad (*Alosa sapidissima*). This fishery, in the bay, has an estimated annual bycatch of 83-171 juvenile Atlantic sturgeon of which about 16% die and another 20% are injured to some degree (Collins et al. 1996). Shad fishermen 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 where carcasses of large females have been found with the ovaries (caviar) removed.

Santee River, SC

The mouth of this river is just south of Winyah Bay and is fished by Winyah Bay shad fishermen, resulting in similar mortality and injury. Upriver bycatch levels are unknown.

Cooper River, SC

The Cooper River is closed to the shad gillnet fishery and shrimp trawling is not allowed in Charleston Harbor, so bycatch is not a concern.

ACE Basin Rivers (Ashepoo, Combahee, Edisto), SC

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 capture some juvenile Atlantic sturgeon, but most fishermen operate upriver from the areas of highest abundance during that time of year. The shrimp trawl fishery in St. Helena sound also captures juveniles, as evidenced by tag returns.

Port Royal Sound Rivers (Broad, Coosawatchie), SC

Although a few commercial sturgeon fishermen apparently operated in this area prior to 1985, the landing of only one Atlantic sturgeon has been recorded (Smith et al. 1984). Little if any shad fishery 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, SC/GA

During 1989-1991, the commercial shad gillnet fishery's bycatch included more of the endangered shortnose sturgeon than juvenile Atlantic sturgeon, which is considered unusual (unpublished data). Annual bycatch of both species combined by a single fisherman in the lower river was 39-102 sturgeons (Collins et al. 1996).

Altamaha River, GA

Juvenile Atlantic sturgeon tagged in this river were recaptured primarily by shad gill nets (52%) and shrimp trawls (39%). Estimated annual total bycatch of sturgeons (both species) in the shad gill net fishery in the tidal portion of the river during 1982-1983 was 0-270 individuals in drift gill nets and 53-247 individuals in set gill nets (Collins et al. 1996). Percent mortality was not determined and was probably minimal in drift gill nets, but results from a similar fishery in Winyah Bay, SC suggest that it could have been substantial in set gill nets. 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 in this area are likely from this river. Most sturgeon occurring as shrimp trawl bycatch are from the mixed stock aggregations.

Ogeechee River, GA

Bycatch in the shad fishery is a concern because evidence suggests that this Atlantic sturgeon population is stressed, and that complete recruitment failure has occurred in some recent years. Bycatch mortality in the estuarine and lower river shad fishery is of particular concern.

Satilla River, GA

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

SUMMARY and EVALUATION

Commercial fisheries for Atlantic sturgeon in the late 1800's led to significant reductions in population size. Population sizes were further reduced by overfishing during the 1970's and early 1990's. In 1990, the ASMFC adopted a FMP which made mandatory management recommendations to the coastal states for greater reduction of exploitation. At this time, all U.S. coastal states have instituted a moratorium on possession of Atlantic sturgeon which eliminates the threat from the directed catch as well as the incentive to retain sturgeon obtained as bycatch. Furthermore, the recently adopted Amendment #1 to the ASMFC's FMP formalizes the moratorium as a mandatory compliance measure in all jurisdictions and cannot be lifted for a spawning stock until 20 protected year classes of females are established.

Atlantic sturgeon are caught as bycatch in various commercial fisheries along the entire U.S. Atlantic coast within inland, state, 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. Estimated levels of mortality associated with bycatch on the Delaware and Hudson Rivers indicate that bycatch is not a significant threat to the species survival but could impede recovery. Efforts should be made to better quantify data on bycatch levels, fishing effort, and river population levels to ensure that assumptions made using Hudson and Delaware River information are valid for other river populations. This information will also allow more refined estimates to be made of impacts of bycatch on the rate of recovery of individual river populations.

There is no evidence that mortality associated with scientific research poses a significant threat to the species, or to individual river populations. However, the experience on the Kennebec River, ME suggests that methods such as setting gillnets overnight as a method to capture Atlantic sturgeon should be used sparingly. There is also no evidence that recreational fishing poses a threat to Atlantic sturgeon.

Competition, Predation, And Disease

COMPETITION AND PREDATION

Atlantic sturgeon are benthic predators and may compete for food with other bottom feeding fishes and invertebrates including suckers (*Moxostoma* sp.), winter flounder (*Pleuronectes americanus*), tautog (*Tautoga onitis*), cunner (*Tautogolabrus 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.

The relationship between the federally endangered shortnose sturgeon *Acipenser brevirostrum* and the Atlantic sturgeon has recently been explored to some extent. Shortnose sturgeon are sympatric with Atlantic sturgeon throughout most of their range. Larger, adult shortnose sturgeon are suspected to compete for food and space with juvenile Atlantic sturgeon in rivers of co-occurrence (Bain 1997). Haley and Bain (1997) found that while shortnose and Atlantic sturgeons 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 occupy rkm 47- 61 (rmi 29-38) in water depths less than 4 m (13 ft), and most Atlantic sturgeon occupy rkm 55-60 (rmi 34-37) in water depths of greater than 6 m (20 ft). 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. Rogers, Georgia DNR, personal communication).

Juvenile shortnose sturgeon apparently avoid competition for food with Atlantic sturgeon in the Saint Johns 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 sturgeons in the Hudson River 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 (Haley *in press*).

Very little is known about natural predators of Atlantic sturgeon. The presence of bony scutes and the Atlantic sturgeon's large size are effective adaptations for minimizing predation of sturgeon age $\geq$2 years. Documented predators in freshwater include sea lampreys (*Petromyzon marinus*) (Scott and Crossman 1973) and gar (*Lepisosteus* sp.)

(Hoff 1980). Dadswell et al. (1984) lists gars and alligators as known predators of shortnose sturgeon, and striped bass (*Morone saxatilis*) as suspected predators. These species may also prey on juvenile Atlantic sturgeon, but there is no evidence that predation rates are elevated above "natural" levels.

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 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). 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 62 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. The data comprise details on disease assays conducted on 15 captive adults, 65 juveniles and subadults, 125 yearlings, 80 fingerlings, and 200 fry sampled between 1991-1997. 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* sp. was observed in the intestinal tract. Numerous bacteria were also isolated from these cases. The following list comprises those species of bacteria which 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* spp.; *Vibrio* spp.; *Aeromonas hydrophila*; *Serratia liquefaciens*; *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 O+ progeny cultured from eggs taken from Saint John River adults has also been observed (M. Litvak, University of New Brunswick, personal communication). An unidentified systemic fungus infection was observed histologically throughout many organs of fingerling Atlantic sturgeon which were subjects in a feed experiment (V. Blazer, Leeton Science Center, personal communication).

Susceptibility of Atlantic sturgeon to some known fish pathogens has been tested at the Leeton Science Center, Leeton, WV and at the University of California at Davis, CA. Cipriano (1996) conducted experimental challenges with the bacterium *Aeromonas salmonicida*, cause of the disease commonly known as fish furunculosis. Bacteria were injected into sturgeon to assess virulence and infected brook trout were placed with sturgeon to attempt contagion by horizontal transmission. In laboratory trials, *A. salmonicida* can infect and kill Atlantic sturgeon and the disease can be transmitted by other infected fish. Cipriano felt that while experimental tests do not mimic what occurs in the natural environment, infected fish occurring in either hatcheries or rivers may serve as potential reservoirs of infection.

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, personal communication).

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 thought 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 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 very real. Currently, there are several regulations or documents that apply to movement of fish or fish eggs from one area to another 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 U.S. Fish and Wildlife Service Fish 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 U.S. Fish and Wildlife Service Fish 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. However, CITES permitting requirements for moving sturgeon from one country to another do not have a fish health component (M. Maltese, USFWS, personal communication). 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 draft further recommends that member states annually report 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; others require a permit only if a species appears on their exotic species list (sturgeon generally do not appear on those lists); 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.

Another potential threat to Atlantic sturgeon comes from recent outbreaks of the toxic dinoflagellate, *Pfiesteria piscicida*, which has resulted in major fish kills in Atlantic Coast estuaries, primarily in North Carolina. *Pfiesteria* lives in the bottom sediment and is stimulated to bloom and produce toxins in the presence of live fish. These toxins initially stun fish by causing them to lose equilibrium and develop respiratory stress, and then dissolve the skin epithelium resulting in severe lesions. Increased outbreaks of this dinoflagellate, first identified in the 1980's, are being blamed on elevated nutrient loading caused by the growth of hog and chicken farms. Estuaries most susceptible to *Pfiesteria* blooms are those with warm water and slow moving currents. If Atlantic sturgeon are in areas where *Pfiesteria* blooms occur, they could be affected. However, sturgeon generally inhabit deep water and swift currents and are less likely to be in areas conducive to *Pfiesteria* blooms than other species such as menhaden, spot, or summer flounder.

Burkholder et al. (1995) listed affected taxa from 20 *Pfiesteria* linked fish kills occurring from 1991-1993, and Atlantic sturgeon were not among them. In addition, there were no sturgeon found among an estimated 450,000 fish that died in 1997 from *Pfiesteria* blooms in the Neuse River, NC, where juveniles are known to occur (J. Burkholder, North Carolina State University, personal communication). A *Pfiesteria* linked fish kill of about 15,000 also occurred in 1997 in the Pocomoke River, MD; and no sturgeon were reported among those mortalities (E. May, Maryland DNR, personal communication). Only one Atlantic sturgeon tagged through the Chesapeake Bay reward program during this same time showed evidence of lesions that might have been related to *Pfiesteria*.

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 inter-specific 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 food preference.

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, personal communication).

Since Atlantic sturgeon inhabit deep water in swift currents or the open ocean, toxic dinoflagellates such as *Pfiesteria* are not expected to pose a serious threat to wild populations.

Existing Regulatory Authorities, Laws and Policies and Their Adequacy to Protect Atlantic Sturgeon

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.

INTERNATIONAL AUTHORITIES

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

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 export 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. CITES Secretariat records monitored by TRAFFIC International for the period 1990-96, show export from Canada to the U.S. of 2161 kilograms of Atlantic sturgeon, all occurring in 1996. The most recent records of Atlantic sturgeon exports from the U.S. date from 1976 but it is unknown whether these records are complete (C. Hoover, TRAFFIC USA, personal communication). Effective April 1, 1998, all sturgeon and paddlefish worldwide are listed under CITES Appendices I or II; which strengthens CITES enforcement for these valuable fishes by requiring permits for all international trade in sturgeon .

CANADIAN AUTHORITIES

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

Maritime Provinces

As of 1997, there were ten commercial licenses for directed Atlantic sturgeon harvest in the Maritimes, nine on the Saint John River, New Brunswick and one on the Shubenacadie River, Nova Scotia. There are no sturgeon licenses in the Gulf of St. 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 ten 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 (Jessop, *in litt.*, 1998).

Quebec

The Quebec Ministere de l'Environnement et de la Faune regulates the St. Lawrence River Atlantic sturgeon fishery. A total harvest quota of 6,000 fish (approximately 60,000 kg) has been in effect since the spring of 1997, along with a maximum size limit of 1.5 m 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, personal communication).

U.S. INTERSTATE/FEDERAL AUTHORITIES

Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA)

Authorized under the terms of the Atlantic States Marine Fisheries Compact, as amended (P.L. 103-206), the Secretary of Commerce can implement EEZ regulations that are compatible to ASMFC fishery management plans in the absence of an approved Magnuson-Stevens fishery management plan. Also, funding is provided to ASMFC, Atlantic Coast states, NMFS, and USFWS to conduct activities that are supportive of ASMFC fishery management plans.

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; 16 U.S.C. 5101-5108), 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."

In 1990, ASMFC adopted a Fishery Management Plan for Atlantic Sturgeon (FMP No. 17) regulating harvest and coordinating stock assessment from Maine to Florida. The goal of the plan, which offered states three options for managing harvest, is to restore Atlantic sturgeon to fishable abundance throughout its range. Under 1993 amendments to P.L. 81-721, referenced as the Atlantic Coastal Fisheries Cooperative Management Act, the Secretary of Commerce is empowered to enforce mandatory compliance recommendations in approved ASMFC plans by declaring a moratorium on fishing of the applicable species within the waters of any noncomplying state. As of April 1, 1998 all 15 states, the District of Columbia, and the Potomac River Fisheries Commission have implemented total closures (either by imposing moratoria or by setting a quota of zero fish) of their fisheries.

In April 1998, ASMFC's Sturgeon Management Board voted to hold public hearings, as required by ASMFC Charter, on an Amendment to the Atlantic Sturgeon Fishery Management Plan. Objectives of the proposed Plan Amendment are to establish at least 20 protected year classes of females in each spawning stock. Since average age at maturity for Atlantic sturgeon is 18 years, it is anticipated that the moratorium will be in effect for at least 41 years, although consideration of lifting the moratorium in some rivers is conceivable in areas where fish reach maturity at relatively younger ages and/or where fisheries have already been closed for some time. The Amendment, which was submitted and approved by the full Commission in June 1998, includes:

- A complete ban on possession of U.S. origin wild Atlantic sturgeon or their parts, effective immediately upon adoption of the Plan Amendment.

- A request to the Secretary of Commerce to ban harvest and possession of Atlantic sturgeon in the exclusive economic zone (EEZ), thereby enabling the Secretary to promulgate regulations accordingly.

- Requirements that the States assess, and annually report capture and mortality of Atlantic sturgeon caught as bycatch in other fisheries. Furthermore, ASMFC has already indicated its intent, if future monitoring and evaluation of bycatch mortality from one or more fisheries is found to be of concern, to mitigate such threats through regulation of the relevant fishery (if under its direct jurisdiction) and/or to recommend appropriate regulation to the Secretary of Commerce or the Fishery Management Councils (for the EEZ).

- Requirements that any States authorizing culture of sturgeons (either Atlantic sturgeon or non-indigenous sturgeons) require permittees to implement all appropriate measures to prevent escapement to the wild or accidental transmission of disease to wild stocks. States will require any entities authorized to culture sturgeon to implement secure marking and record keeping practices so that enforcement of the moratorium on harvest of wild stocks will not be compromised. Sources of brood stocks must also be consistent with conservation of wild populations.

- Requirements that States report annually to ASMFC on their habitat protection and enhancement efforts, including interactions with State and Federal agencies conducting or authorizing projects that may affect Atlantic sturgeon habitat.

- Requirements that States conduct periodic monitoring of populations to document responses to the harvest moratorium.

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, including freshwater habitats for anadromous species, may also be delineated for species with approved federal fishery management plans. Federal fishery management plans, approved by regional fishery management councils (different from the ASMFC) focus on management in the EEZ. An alternative mechanism for restricting harvest in the EEZ exists through NMFS' regulations based on recommendations in an ASMFC approved fishery management plan. 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 measures that, to the extent practicable, minimize unavoidable bycatch and bycatch mortality. To date, the is no federal Atlantic sturgeon fishery management plan. The only East Coast anadromous fishery covered by a federal fishery management plan is Atlantic salmon, under the jurisdiction of the New England Fishery Management Council.

The Magnuson-Stevens Act was reauthorized on October 11, 1996. The reauthorization directs the Regional Fishery Management Councils (Councils) and the Secretary of Commerce to describe and identify essential fish habitat (EFH) in fishery management plans, including identification of adverse impacts from both fishing and non-fishing activities on EFH, and identification of actions required to conserve and 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 waters 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.

Lacey Act of 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, 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, personal communication). 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. One study funded by the ACOE and prompted by several maintenance dredging, new dredging, and dredged material disposal projects, is gathering information about habitat use by both shortnose and Atlantic sturgeon in the Chesapeake Bay (J. Gill, USFWS, personal communication). In rivers, such as the Tar-Pamlico, Neuse, and Roanoke Rivers in North Carolina, where only Atlantic sturgeon occur, no protection via the ESA is afforded (W. Laney, USFWS, personal communication). Atlantic sturgeon may not benefit from seasonal dredging restrictions to protect shortnose sturgeon spawning when spawning seasons for the two species do not coincide (T. Squiers, MDMR, personal communication).

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

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 the 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 documents 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. Lack of proven fish passage devices that facilitate ready passage of Atlantic sturgeon, as well as 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 relicensing of existing hydroelectric dams. However, FERC's recent (1997) determination that the Edwards Dam on the Kennebec River, ME should be removed, creates the possibility that historic spawning habitat currently impounded by that dam may be restored (Estabrook, *in litt.*, 1997).

Atlantic sturgeon movements are currently being monitored with radiotelemetry tags in Albemarle Sound pursuant to FERC relicensing of hydroelectric projects on the Roanoke River, NC (Kornegay, *in litt.*, 1997).

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 the 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, MDMR, personal communication), tag and release studies in Delaware Bay (C. Shirey, Delaware DFW, personal communication), and research on juvenile Atlantic sturgeon in the ACE Basin, SC (M. Collins, South Carolina DNR, personal communication) are examples of work funded by NMFS under this law. See Appendix D, Table 4 for other examples of studies funded 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, personal communication).

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

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, report 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 of these 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 (33 U.S.C. 1251-1376) (FWPCA)

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(c) 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 Rivers 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 effecting 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, personal communication) and nutrient reduction strategies implemented in the Chesapeake Bay (R. St. Pierre, USFWS, personal communication).

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, 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 dredged 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.

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 six of these jurisdictions (Pennsylvania, District of Columbia, Potomac River Fisheries Commission, Virginia, South Carolina, and Florida) pre-date 1990.

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, personal communication). 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, personal communication). 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, personal communication). 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, personal communication).

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, *in litt.*, 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 affect the habitat of Atlantic sturgeon. These include laws affecting development in sensitive watersheds, forest practices, waste water discharges, and other activities. Efficacy of these laws to protect sturgeon habitat may be highly variable, and depends on the standards imposed, the types of activities and land areas subject to regulation, consistency of implementation, and other factors. Protective land and water designations by states, such as the designation of Significant Tidal Habitat on the Hudson River in New York and designation of Primary Nursery Areas in North Carolina also contribute to Atlantic sturgeon habitat quality (A. Kahnle, New York State DEC, personal communication).

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. Although the current ban on landings and possession virtually eliminates all incentives for directed harvest or bycatch retention in the EEZ, the ASMFC has requested that the Secretary of Commerce promulgate a ban on possession in the EEZ. Atlantic sturgeon fisheries in Canada are almost exclusively located at or above estuarine reaches of the rivers and we do not currently have evidence that sturgeon of U.S. origin migrate into Canadian rivers, therefore it is unlikely that Canadian fisheries pose a meaningful threat to fish of U.S. origin.

Current information indicates that accidental mortality of Atlantic sturgeon bycatch does not threaten or endanger Atlantic sturgeon populations. If the evaluation of bycatch mortality from one or more fisheries is found to be of concern, ASMFC has already indicated its intent to mitigate such threats through regulation of the relevant fishery (if under its direct jurisdiction) and/or to recommend appropriate regulation to the Secretary of Commerce or the Fishery Management Councils (for the EEZ). Thus, there are regulatory mechanisms in the U.S. to prevent or minimize any bycatch threats that may be detected in the future.

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, its various Atlantic sturgeon committees, and the Sturgeon Management Board. Due to existing state and federal laws, water quality and other habitat conditions have improved in many riverine habitats where Atlantic sturgeon reproduce or historically reproduced. 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.

Other Natural or Manmade Factors Affecting its Continued Existence

ARTIFICIAL PROPAGATION AND ATLANTIC STURGEON

Artificial propagation of Atlantic sturgeon for use in restoration of extirpated populations or recovery of severely depleted wild populations 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 (the ASMFC Special Report #22 - Recommendations concerning culture and stocking of Atlantic sturgeon), and as part of a planned recovery program, artificial propagation can increase population numbers, at least temporarily. 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 harvest wild stocks. However, aquaculture can make enforcement of the regulations that protect wild stocks more difficult. 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 which 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 spawning migration, about 100,000 fry were hatched over a two-week period as reported in the book: Fish Hatching and Fish Catching (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 severe fungal infestation 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 was 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 fry 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, South Carolina, where injections of sturgeon pituitary 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 highly 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 hours 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 of capture, transport, spawning, and culture of Atlantic sturgeon. This program was in response to recommendations by the ASMFC in the 1990 FMP (ASMFC 1990) and Special Report No. 22: Recommendations 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 hours by truck to NEFC's facility and given injections of luteinizing hormone releasing hormone analog (LHRHa) 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 100 fish of this year class are currently being maintained at NEFC for use as future broodstock.

Subsequent propagation attempts in 1994, 1995, 1996, and 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 ration and rearing temperature (McPeck 1995). Aside from experience in spawning and culturing propagated fish, knowledge of long-term holding of captive wild fish was obtained. J. Mohler (USFWS-NEFC, personal communication) found that mature males captured from the Hudson and Delaware Rivers in 1991 could be maintained for at least 6 years in captivity and induced to produce viable milt.

Recently, 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 LHRHa 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, personal communication).

Since NEFC's first successful spawning in 1993, many requests were made for excess progeny by organizations 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 18 different organizations including federal and state agencies, universities, public aquaria, and independent researchers. Some examples of research or education/outreach performed by outside organizations using NEFC-produced juvenile sturgeon are: (1) swimming performance and velocity preference of larvae (ACOE); (2) tracking, recapture, growth, and survival of juveniles released into the Chesapeake Bay (Md. Dept. Of Natural Resources); (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 to determine survival of hatchery fish and recruitment of wild Atlantic sturgeon in the Hudson River (New York State DEC); (8) susceptibility of Atlantic sturgeon to *Aeromonas salmonicida*, the causative agent of furunculosis in fish (Leeton Science Center); and (9) public display in aquaria (New York City Aquarium, NY and Maritime Center, Norwalk, CT).

Conservation and Restoration Options

The Fishery Management Plan for Atlantic sturgeon (ASMFC 1990) contains many management recommendations, including one which encouraged 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. Specific recommendations in this protocol (ASMFC 1996) relate to:

(1) Source of brood stock - preference is given to fish from the river being stocked but allowing for use of brood fish from regional genetic groupings;
(2) Minimum effective population size - a minimum of six brood fish, preferably three of each sex, are required for production of progeny to be stocked into the wild;
(3) Multiple year commitment - depending on the number of brood fish used each year, agencies must commit to many consecutive years of stocking to achieve a generational effective population size of 100;
(4) Stocking numbers - to avoid gene swamping, the number of stocked fish from individual matings should be within 50% of each other and not exceed 50,000 fish/pair;
(5) Tagging - all stocked cultured sturgeon must be adequately marked to indicate at least hatchery, year-class, release location, and parental origin;
(6) Monitoring and reporting - agencies must provide detailed study proposals with objectives, monitoring plans, and annual reports to ASMFC.

In a recent reassessment, Waldman and Wirgin (1998) reported that while their earlier genetic analysis (Waldman et al. 1996b) determined strong regional stock structure for Canadian, Hudson River, and southern Atlantic sturgeon populations, low gene flow rates suggested very slow natural recolonization potential. While stock rebuilding based solely on elimination of harvest avoids genetic risks associated with inter-stock transfer and inbreeding, which may occur in hatchery-based programs, natural restoration of some stocks may take decades to centuries. 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 among and within stock genetic variation;
(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 but eliminate fishing;
(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 population onto another if significant genetic differences exist between the two. Second, the difficulty in acquiring sufficient numbers of male and female broodstock required for a biologically sound breeding protocol (one designed to prevent loss of genetic diversity within populations 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, personal communication). 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.

Two experimental releases provide some insight into the feasibility of 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; and the second release of 3,275 yearling fish took place on July 8, 1996 in the Nanticoke River, a tributary to the Chesapeake Bay, MD. These studies are discussed below in more detail.

Hudson River

With assistance from NEFC, the New York State DEC stocked 4,929 three-month old Atlantic sturgeon within the known nursery area of the Hudson River in October, 1994. These fish 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-fresh transition zone near the sturgeon stocking area. Of the 29 yearling sturgeon collected in 1995, 15 (52%) were hatchery fish (identified by wire tags and fin clips). These fish grew an average of 335 mm fork length 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% survival for cultured 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. *in press*). 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 fork length and 617 g.

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 highest 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 (now 3 years old). While survival and migration rates of these cultured fish is unknown, they are still smaller than the wild fish. Cold water rearing conditions best explains the smaller size of stocked fish. The scarcity of wild juveniles in year classes born after 1994 suggests poor recruitment in recent years.

Chesapeake Bay

Maryland DNR requested cultured sturgeon from NEFC for an experimental stocking in the Nanticoke River, 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, about 3,300 yearling Atlantic sturgeon of Hudson River origin (1995 year class) were stocked into the Nanticoke River at two sites located 40 and 52 km above the river mouth. Because the fish were reared in different water temperatures, two size groups were represented. Smaller fish (n=2,400), averaging 100 mm TL, were injected with coded wire tags. Larger fish (n=900), averaging 330 mm TL, also received external 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 October 1996 and April 1998, over 500 live juvenile Atlantic sturgeon from the Maryland waters of the Bay were examined and it was determined that approximately 85% carried hatchery tags (J. Skjeveland, USFWS, personal communication). 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 concentration 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; however, their rapid dispersal indicates it is unlikely that these yearlings will imprint to the Nanticoke

River. It was recommended that future stockings involve younger 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, personal communication). Tissue samples from small sturgeon taken in Maryland and Virginia have been archived for future genetic analysis to confirm whether one or more discrete Chesapeake Bay sub-populations exist.

Commercial Aquaculture

At this time, the only known commercial aquaculture activity involving Atlantic sturgeon is in Canada. 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, personal communication). 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.

Commercial culture of other sturgeon also has the potential to impact wild Atlantic sturgeon. White sturgeon escaped from an aquaculture facility in Georgia in the early 1990's, 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, personal communication). While this particular incident is unlikely to impact *A. oxyrinchus oxyrinchus*, it illustrates the potential for escapement of non-native sturgeon from aquaculture facilities that could have negative impacts on Atlantic sturgeon through competition for food and habitat, hybridization, and the spread of fish pathogens. 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 Concerning the Culture and Stocking of Atlantic Sturgeon (1992). One recommendation in Special Report No. 22 states, "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".

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 1992, Waldman and Wirgin 1998), consistency with best management practices to minimize or avoid risk to wild stocks, and compatibility with programs for wild stock. There are currently no Atlantic sturgeon commercial aquaculture activities in the U.S. and any proposed production will need to address the potential impact of commercial culture on the wild stock including the following aspects: (1) acquisition of broodstock, (2) escapement of farm raised fish and resulting genetic concerns, (3) law enforcement, and (4) fish health.

Current Conservation Efforts

Preservation and enhancement of sturgeon stocks requires reduction and elimination of human-induced mortality and identification, improvement, and augmentation of essential habitats. The content of the recent Amendment to the ASMFC FMP for Atlantic sturgeon is presented in the section discussing regulatory authorities. The Plan Amendment includes a stock rebuilding target of at least 20 protected age classes in each spawning stock, achieved by imposing a harvest moratorium. The Plan Amendment requires States to monitor, assess, and annually report Atlantic sturgeon bycatch and mortality in other fisheries. The Plan Amendment also requires that States annually report habitat protection and enhancement efforts. Finally, each jurisdiction with reproducing populations should conduct juvenile assessment surveys (including CPUE estimates, tag and release programs, and age analysis). States with rivers that lack reproducing sturgeon populations but support nursery habitat for migrating juveniles, should also conduct sampling at least every five years. The Plan Amendment strengthens conservation efforts by formalizing the closure of the directed fishery; and, by banning possession of bycatch, eliminates any incentive to retain Atlantic sturgeon. Additional elements of the Plan Amendment related to habitat, stock assessment, and stocking offer the species wider protection beyond closing a directed fishery and improve its chances for recovery.

State and federal jurisdictions and private partners involved in the Chesapeake Bay Program initiated development of a separate Atlantic Sturgeon Restoration Plan with a goal of "restoring a self-sustaining population of Atlantic sturgeon to the Chesapeake Bay and its tributaries". The Plan is being developed by the Fishery Management Planning Workgroup of the Bay Program's Living Resources Subcommittee. A coordination meeting was held in April, 1997, to review the known status of the stock(s), results from the 1996 release of cultured sturgeon in the Nanticoke, and the reward programs in Virginia and Maryland. Other topics included genetic analysis and considerations for broodstock selection, projection of a timetable for stock recovery based on hatchery introductions, development of a logistical plan for handling mature Chesapeake broodfish, investigations to identify and characterize spawning and nursery habitats, and monitoring plans and long-term commitments from the involved parties.

A Hudson River Estuary Management Action Plan was adopted by the New York State DEC 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. Sturgeon investigations already initiated in response to this Plan include an assessment of bycatch of Atlantic sturgeon in offshore commercial fisheries, the examination of habitat and water quality to determine whether contaminants are affecting early life stages, and the evaluation of several sampling techniques used to determine abundance of juveniles.

OTHER RESEARCH AND MONITORING ACTIVITIES

Canadian Rivers

Canada's commercial fishery for Atlantic sturgeon in the St. Lawrence River estuary in the Province of Quebec targets subadult fish. Landings exceeding 100 tons in the early 1990's led to restrictions including a harvest limit of 60 tons (about 6,000 fish) and a maximum size limit of 1.5 m TL. Until 1997, all efforts by the Ministere de l'Environnement et de la Faune du Quebec to collect mature fish and to locate spawning grounds were unsuccessful.

Using habitat information from the known spawning reach of the Hudson River at Hyde Park, Canadian researchers collected, tagged, and released 13 ripe male sturgeon in July, 1997, at a location 100 km upstream from the salt front in the St. Lawrence River. The capture area averaged 17 m deep, with substrate mostly consisting of rocks and some sand and clay, and water temperatures between 20.6 - 22.8°C. No eggs were collected and the precise location of the spawning site(s) remains unknown. Ultrasonic telemetry will be used in 1998 to better define areas of adult sturgeon concentration. This project is considered urgent to avoid disturbances related to dredging (Caron 1998).

Maine Rivers

During 1994 and 1996, ripe adult Atlantic sturgeon were collected at the base of Edwards Dam at the head-of-tide in the Kennebec River. In 1997, MDMR was contracted by the state transportation department to identify spawning habitats and collect sturgeon eggs at Edwards Dam. Eight fish were captured and radio tagged (four also carried sonic tags), but all fish left the river with two staying in the estuary. No information was obtained on spawning and the study may be repeated in 1998. In late 1997, the FERC ruled that Edwards Dam should be removed. Removal will open an additional 17 miles of freshwater habitat for sturgeon and other anadromous species (T. Squiers, MDMR, personal communication).

Southern New England Rivers

Researchers from the USGS-BRD lab at Turners Falls, MA and the University of Massachusetts studied movements and distribution of subadult Atlantic sturgeon in the lower Connecticut and Merrimack rivers. Sturgeon in the Merrimack typically used the lower saline to tidal freshwater section above the river mouth (rkm 5-20) preferring channels with sandy substrates and mean depths of 7 m (range 2-12 m).

Hudson River

In a four year study sponsored by the Hudson River Foundation, researchers from the University of California at Davis assessed reproductive conditions of Atlantic sturgeon in the Hudson River Estuary. During 1992-1995, 305 sturgeon (153 in the Hudson River and 152 in the ocean off Long Island and New Jersey) were sampled for age, body size, gonadal histology, egg morphometry, and plasma concentrations of gonadotropins, sex steroids, and vitellogenin. Fish ranged from 1.5-43 nominal years in age and 48-244 cm in fork length. Individual fecundity ranged from 0.4-2.6 million eggs and egg diameter was from 2.4-2.9 mm.

All females with mature eggs were captured at river kilometer (rkm) 137 suggesting that sturgeon spawning sites in the Hudson River are located at least 48 km upstream from the tidal saltwater front. Twenty of 38 females sampled for fecundity in the river showed signs that non-annual spawning occurs in females, as has been shown in white sturgeon. Males have a relatively shorter life span, mature earlier and at smaller sizes, and appear to spawn annually (VanEenennaam et al. 1996).

Delaware Estuary

Since 1991, Delaware DFW personnel have conducted extensive netting of subadult Atlantic sturgeon in the upper Delaware estuary in an effort to determine abundance and distribution using tag, release, and recapture methods. Numerous sturgeon tagged in the Delaware survey were recaptured from distant coastal waters (Maine to North Carolina) after being at-large for as much as 4.5 years. Some recoveries of tagged and fin clipped sturgeon released in the Hudson River, suggest as expected, considerable interchange of subadults between these two estuaries. To some extent, apparent stock declines (subadults) observed in the Delaware River system may be a reflection of reproductive failure in the Hudson River.

A few sturgeon tagged in the Delaware River were recovered in the upper Chesapeake Bay. Hundreds of tissue and spine samples are available for future assessment of genetics and age structure of the Delaware population. In 1997, DFW expanded sturgeon tagging operations to include sonic telemetry to better understand inter-tidal and seasonal movements within the Delaware estuary and to locate other important sturgeon habitats. The Delaware DFW identified one additional area of concentration (C. Shirey, Delaware DFW, personal communication).

Chesapeake Bay and Tributaries

Under auspices of the EPA-sponsored Chesapeake Bay Program, major habitat improvement projects are underway that will positively affect sturgeon. These include: large-scale nutrient reductions from major Bay tributaries to relieve anoxic conditions in deep waters of the Bay and regenerate important submerged aquatic vegetation; fish passage in tributaries; wetland protection and restoration to aid fisheries productivity; and extensive monitoring. Also, in late 1997, the Baltimore District ACOE contracted the USFWS to examine sturgeon use of dredge spoil disposal areas in the upper Chesapeake Bay. The study will include seasonal capture, tag and release, genetics analysis, and an assessment of sturgeon migrations through the C&D canal.

North Carolina Rivers

Researchers at the University of North Carolina at Wilmington and NC State

University are using sonic telemetry to assess movements of large subadult Atlantic sturgeon in the Cape Fear River and juveniles in Albemarle Sound. A database with GIS maps is being prepared to display all recent North Carolina inshore and offshore sturgeon records and historical use patterns. North Carolina DMF conducts annual anadromous fish gill net surveys in Albemarle Sound and has recorded numerous captures of juvenile sturgeon. Also, whereas many young sturgeon were taken recently in the lower Cape Fear, none were collected above locks and dams on this system.

South Carolina and Georgia Rivers

South Carolina DNR is presently involved in several Atlantic sturgeon research projects. In the Combahee, Edisto, and Savannah Rivers, researchers are using sonic and radio telemetry to assess habitat use. A mark-recapture study of juvenile Atlantic sturgeon is being conducted in the Edisto River in order to estimate population size and trends. As part of an ongoing molecular genetics study conducted in cooperation with New York University Medical Center, juvenile Atlantic sturgeon $\leq$1 nominal year of age are being collected in the Savannah and Ogeechee Rivers to supplement tissue sample reference collections archived from several other systems. Preliminary results from this stock identification research should be available in late 1998. The USFWS Bears Bluff National Fish Hatchery (which has worked with shortnose sturgeon for many years) is planning culture-related research on Atlantic sturgeon. Their preparations include installation of large tanks with a temperature controlled, recirculating water system, and purchase of a large hauling trailer suitable for transporting Atlantic sturgeon broodstock.

Appendix D, Table 4 contains a list of Atlantic sturgeon research projects funded through the Anadromous Fish Conservation Act and the Atlantic Coastal Act. Special Report No. 62 of the ASMFC (1997) contains prioritized research needs in support of interjurisdictional fisheries management. In addition, both the 1996 and 1997 Review of the 1990 ASMFC FMP contain lists of the status of research and monitoring efforts.

RECOMMENDATIONS FOR FURTHER CONSERVATION

Monitoring, research, and other conservation activities that would contribute to and accelerate on-going recovery or enhancement of Atlantic sturgeon are described below. Many of the identified needs are drawn from Public Hearing Draft, Amendment 1 to ASMFC Interstate Fishery Management Plan for Atlantic Sturgeon.

Habitat

- Standardize and obtain baseline data on habitat status for major sturgeon rivers. Data should include assessment of spawning and nursery habitats (e.g., locations, depths, flows, substrates, and estimated carrying capacity or optimal population size).

- Continue and expand efforts to maintain and improve riverine and estuarine habitat, including but not limited to: removal of barriers to fish passage, restoration of adequate flows at appropriate times of year in sturgeon habitat, seasonal restrictions on dredging to prevent impacts to spawning and nursery habitats, and minimization of point and non-point source water pollution.

- Monitor implementation of projects that affect habitat, including habitat improvement projects described above, to ascertain impacts on sturgeon populations. For example, monitor recruitment in the Cooper and Santee Rivers to assess effects of flow rediversion; study impacts of upcoming Savannah River channel deepening project

Stock Assessment and Population Dynamics

- Standardize data collection methods to monitor population status in important sturgeon rivers. Data should include assessment of juvenile production and abundance and age composition of the spawning population. Particular efforts should be made to extend recent population monitoring in the ACE Basin, SC and Altamaha River, GA to evaluate effects of southern harvest closures.

- Continue and expand research on the extent to which Atlantic sturgeon are genetically differentiable among rivers. Tissue samples are needed for adults (>150 cm) and juveniles (age 0-2, <50 cm) taken in inland waters. Additional analyses to respond to this need have been funded by NMFS and the USGS, Biological Resources Division and will be conducted by the latter agency in 1998 and 1999.

- Standardize long-term marking/tagging procedures to provide information on individual tagged Atlantic sturgeon for up to 20 years. Expand tagging of juveniles in major spawning rivers to improve estimated rates of bycatch loss. Periodically assess tagging procedures and improve techniques as indicated.

- Establish criteria in order to evaluate the effectiveness of restoration and supplementation projects using captive-reared stock.

- Expand data used to estimate length at age by sex, maturity at age by sex, and fecundity at age for spawning populations at representative latitudes.

- Characterize the catch and sizes of fish, percent mortality, frequency and extent of sub-lethal injuries, and catch-per-unit effort of Atlantic sturgeon, by location, gear, and season, taken as bycatch in various fisheries. This may include tag/recapture studies of major spawning populations. Evaluate this data to assess population level impacts. If indicated, develop appropriate strategies to avoid and minimize bycatch through gear modifications and seasonal or area fishing restrictions. It is anticipated that this activity will occur as a result of ASMFC requirements in Amendment 1 to the FMP and bycatch restrictions in other ASMFC plans.

Biology/Community Ecology

- Establish environmental tolerance levels (dissolved oxygen, pH, temperature, etc.) for different life stages. The Satilla, Savannah, and Ogeechee Rivers in Georgia may offer good opportunities to study effects of temperature and dissolved oxygen.

- Continue and expand coastal tagging projects to delineate migratory patterns.

- Continue consolidation and evaluation of tagging and tag return information, including associated biological, geographic, and hydrographic data. (This measure is currently being implemented by the USFWS through the Maryland Fisheries Resources Office located in Annapolis, MD.)

- Encourage shortnose sturgeon researchers to include Atlantic sturgeon research, when appropriate, in their projects.

- Evaluate existing groundfish survey data to determine what can be learned about at-sea migratory behavior.

Biological/Captive Propagation

- Continue and refine basic culture experiments to provide information on: (a) efficacy of alternative spawning techniques, (b) egg incubation and fry production techniques, (c) holding and rearing densities, (d) prophylactic treatments, (e) nutritional requirements and feeding techniques, and (f) optimal environmental rearing conditions and systems.

- Conduct research to identify suitable fish sizes, and time of year for stocking cultured fish, in accordance with ASMFC Breeding and Stocking Protocol for Cultured Atlantic Sturgeon. Conduct and monitor pilot-scale stocking programs before conducting large scale efforts over broad geographic areas.

- Determine effects of contaminants on reproduction, development during early life stages, and fish health. Some studies are planned for the Hudson River, NY in 1998. The Winyah Bay Rivers, SC have also been suggested as possible candidates for such studies.

- Develop noninvasive methods to determine sex and maturity of captured sturgeon.

- Standardize collection procedures to obtain biological tissues, and identify a suitable repository to archive all materials.

- Determine the susceptibility of Atlantic sturgeon to sturgeon adenovirus and white sturgeon iridovirus.

- Identify the major viral, bacterial, and parasitic pathogens of Atlantic sturgeon in wild and cultured populations. Effective disease treatments should also be developed.

CURRENT CONSERVATION EFFORTS

State	Year	River	Description	Investigator	Funding Sources	Project Number
ME	1976-81	Kennebec	Distribution and abundance of Atlantic sturgeon in the Kennebec River Estuary	Tom Squiers	Anadromous Fish Conservation Act	AFC-19/20
MA	1987,88	Merrimack	Survey of Atlantic sturgeon population in the Merrimack	Joseph DiCarlo	Anadromous Fish Conservation Act	AFC-15/21
	1991,92	Taunton River and Mount Hope Bay	Study annual movements feeding and spawning habitats and species interactions of sturgeon populations in the Taunton River and Mount Hope Bay		Anadromous Fish Conservation Act	AFC-24
CT	1991, 92, 94,95,96, 97	Connecticut and Thames	Monitor population levels, location, and movements of shortnose and Atlantic sturgeon	Tom Savoy	Anadromous Fish Conservation Act	AFC-20/21/22/23
DE	1992,93, 94,95	Delaware	Marking and recapture study to look at population status and migratory movements.		Anadromous Fish Conservation Act	AFC-6/7/8/12

CURRENT CONSERVATION EFFORTS (cont.)

State	Year	River	Description	Investigator	Funding Sources	Project Number
NJ	1992,93, 95,96	NJ fisheries	Collection of data from commercial and recreational fisheries to determine bycatch, estimate mortality, migrations and stock identification	Bill Andrews	1992/93 Anadromous Fish Conservation Act 1995/96 Atlantic Coastal Act	AFC-13 ACA-13/24
SC	1987,91, 92	shad fishery	Monitor incidental catch of Atlantic sturgeon by commercial shad fishermen through voluntary reporting, and monitor abundance of juvenile Atlantic sturgeon in selected areas	Glenn Ulrich John McCord	Anadromous Fish Conservation Act	AFC-32/44/48
GA	1985,86	Commercial fishery	Determine population structure of the commercial fishery including age date, sex ratios, length frequencies and age at maturity. Conduct biotelemetry study to determine movement and migration patterns	Susan Shipman	Anadromous Fish Conservation Act	AFC-29

Recommendation

Consideration of Canadian Portion of Atlantic Sturgeon Range

While Biodiversity Legal Foundation's May 29, 1997 petition requested listing of the Atlantic sturgeon as threatened or endangered "where it continues to exist in the United States," the Services decided in the 90 day finding to extend their status review to encompass the entire North American range (62 FR 54018). Due to the species' long migration, the Services indicated that a broader scope of review was appropriate to understand the interrelationship of threats and the Atlantic sturgeon's conservation status. Therefore, the status review team considered the issues of (1) whether there is evidence that U.S. and Canadian stocks interbreed and (2) whether activities conducted in Canada currently threaten Atlantic sturgeon of U.S. origin.

As noted in the Distinct Population section of this report, analysis of mitochondrial DNA found highly significant differences between Canadian fish (St. Lawrence and Saint John rivers), and those from the Hudson River and five southeastern rivers. There is no evidence to suggest that U.S. and Canadian stocks are closely related genetically; however, lack of genetic data from Atlantic sturgeon in Maine precludes a definitive statement regarding discreteness of U.S. and Canadian stocks. In assessing potential impacts of directed fishing in Canada on Atlantic sturgeon of U.S. origin, the team considered the absence of an ocean intercept fishery in Canada and the lack of any Canadian tag returns from either Hudson or Delaware River fish, despite an active directed Canadian fishery. There is no documentation of U.S. origin Atlantic sturgeon migrating into Canadian rivers within active directed fisheries; therefore, the team concludes that Canadian fisheries are unlikely to pose a significant threat to fish of U.S. origin. Lacking evidence of Atlantic sturgeon interbreeding between U.S. and Canadian stocks, and because Canadian fisheries are unlikely to threaten U.S. stocks, the status review team believes that the status of Atlantic sturgeon in the U.S. can be assessed without further consideration of the species' status in Canada.

Status of Atlantic Sturgeon in the U.S.

The historic range of the Atlantic sturgeon in the U.S. extended from the Penobscot River, ME to the St. Johns River, FL (although it is unclear whether spawning occurred in these rivers). The current range has contracted slightly, from the Kennebec River, ME (absence from the Penobscot River has not been conclusively determined) to the Satilla River, GA. Historical presence of Atlantic sturgeon has been documented in approximately 34 rivers; but it is not known how many of these rivers supported spawning. Currently, Atlantic sturgeon are present in 32 rivers and spawning populations are documented in 14 rivers, and possibly, in an additional five rivers. Many recent surveys of Atlantic sturgeon, particularly in the southern portion of the range, do not provide comprehensive stock assessment or quantitative trend data, but provide evidence that populations have persisted and continue to reproduce in those systems. Generally, these investigations do not provide estimates of population size but document the presence of gravid females and/or fish $\leq$ age 1 and the number of year classes present in certain areas. Stock assessments, conducted in conjunction with the now-closed New York and New Jersey directed fisheries, provide evidence that populations in the Hudson and Delaware River systems have declined significantly in recent years; however, multiple year classes from juveniles to prespawning adults continue to be present in these systems.

Each of the five ESA listing factors was analyzed for its general impact on U.S. Atlantic sturgeon and on specific river populations. The first factor is the present or threatened destruction, modification, or curtailment of habitat range. Habitat modifications, including dams, dredging, and degradation of water quality were examined. Although loss or degradation of habitat contributed to past declines and may retard the recovery of some populations, overall spawning and nursery habitat conditions are currently better than those under which the species persisted during the first half of the 20th century. Important improvements in habitat quality occurred through elimination of point and non-point pollution sources, seasonal restrictions on dredging operations in spawning and nursery habitats, and (in a few cases) dam removal. Recent increases in shortnose sturgeon populations in many rivers inhabited by Atlantic sturgeon further suggest that riverine habitat is adequate to support increasing populations of the latter species. While the best available evidence indicates that current habitat conditions will not make Atlantic sturgeon likely to become endangered in the foreseeable future, the status review team endorses further habitat improvement measures to accelerate rebuilding of stocks.

The second factor examined was overutilization for commercial, recreational, or educational purposes. Commercial exploitation during the late 18th century led to the decline in Atlantic sturgeon abundance, and is the primary reason for current low abundance. The current moratorium on possession of Atlantic sturgeon in all fifteen coastal states and the District of Columbia removes the threat of over harvesting. Atlantic sturgeon are susceptible to capture in a wide range of gear types that target other species, particularly gill nets and trawls. The best available information indicates that levels of bycatch do not threaten the continued existence of the species, but any mortality has the potential to slow population growth. The status review team strongly endorses ASMFC requirements to monitor gill net and trawl fisheries to further quantify Atlantic sturgeon bycatch. This information will identify or assist strategies to avoid and minimize bycatch through gear modifications and seasonal or area fishing restrictions.

The third factor examined was disease and predation. There is no evidence that either predation or disease are currently threatening the species' continued existence. Furthermore, as an anadromous species, Atlantic sturgeon are provided with a buffer against disease outbreaks that might be more devastating to other fish species in which the entire population remains resident in a single environment. There is potential for introduction of disease through the transfer of non-indigenous sturgeon species or aquaculture of Atlantic sturgeon. The recent ASMFC Plan Amendment advises member states to certify sturgeon aquaculture operations to be disease-free, and requires states to annually report their disease-free certification activities.

The fourth factor examined was the adequacy of regulations protecting Atlantic sturgeon and their habitat. The recently adopted amendment to the ASMFC Interstate Fishery Management Plan for Atlantic Sturgeon formalizes a long-term coastwide prohibition on possession of Atlantic sturgeon and contains other important measures to monitor and reduce threats from bycatch and aquaculture. Its efficacy is dependent on implementation and enforcement by each participating management authority. ASMFC procedures require annual assessment of the Plan, as amended, which will provide for regular evaluation of implementation and effectiveness of recommendations and requirements. Critical components of this annual review, in the opinion of the status review team, will advance progress in obtaining and evaluating bycatch data, stock status, and regulation of any aquaculture facilities to prevent threats to wild stocks.

The role of artificial propagation was examined under the final listing factor, other natural or manmade factors affecting the species' continued existence. Artificial propagation does not threaten the species' continued existence and its potential to facilitate restoration and/or recovery has yet to be fully explored/demonstrated. Specific criteria to be considered for any proposal to use artificial propagation as restoration are identified in the ASMFC document, “Recommendations Concerning the Culture and Stocking of Atlantic Sturgeon (ASMFC 1992)” and are also incorporated into the recent ASMFC Plan Amendment. Stocking measures include important standards to preserve the genetic integrity of spawning stocks. The potential for commercial culture of Atlantic sturgeon was examined and specific measures needed to avoid threats to the wild stocks were identified. These considerations should be addressed before implementing any future commercial venture.

Finally, in addition to the above five factors, the status review team assessed current Atlantic sturgeon conservation efforts. While various agencies and organizations have implemented a number of pro-active measures to benefit this species and its habitat, additional actions could accelerate the rebuilding of populations. A list of recommendations for further conservation is provided in the body of this report. The team believes that the ASMFC Plan Amendment goal to "restore *individual spawning stocks*, including extirpated stocks to the extent feasible, (emphasis added)" represents an ecologically-sound strategy for rebuilding of stocks. The team also notes that the slow maturation rate of Atlantic sturgeon dictates that restoration of this species will be inherently slow under any responsible regulatory or management strategy. This point is reflected in the ASMFC's statement that the fishing moratorium on the Hudson River population "can be expected to remain in place for approximately 41 years...".

Historically, the first two listing factors, habitat impacts and overutilization, resulted in reductions in Atlantic sturgeon abundance. However, spawning populations persisted throughout the 1800's and 1900's despite these threats to the species and its habitat. Atlantic sturgeon are a long-lived species and are resilient to both natural and man-induced variability to their environment. This resilience and tolerance has enabled Atlantic sturgeon to persist during periods of intense commercial fishing effort and habitat degradation. Currently, the commercial fishery is closed, and the vast majority of Atlantic sturgeon habitat is intact and adequately functioning. With the elimination of these former threats, proposed conservation programs should successfully maintain and increase extant Atlantic sturgeon populations.

The status review team determined that the continued existence of Atlantic sturgeon is not threatened by any of the five ESA listing factors alone or in combination. There is no evidence that any of these factors poses a threat to the continued existence of Atlantic sturgeon in the United States. Where isolated potential threats have been identified from habitat perturbations, bycatch, disease introductions, and artificial propagation, preventive and mitigative measures have been implemented or identified. Every effort should be made to acquire information necessary to quantify these potential impacts and to implement appropriate measures to avoid and minimize threats that could slow population growth.

ATLANTIC STURGEON DISTRIBUTION--HISTORIC AND CURRENT STATUS--UNITED STATES

State	System	Historic Presenc e	Current Spawning Presence (sexually mature adults or ≤ age 1)	Current Juvenile-subadult Presence (≥ age 2)	Source / Comments
ME	Androscoggin River	YES	Unknown	YES	Squiers (1998); spawning very likely
ME	Kennebec River	YES	YES	YES	Squiers (1998); adults & juveniles in 1997
ME	Penobscot River	YES	NO?	YES?	Squiers (1998); sampling but no captures
ME	Sheepscot River	YES?	Unknown	YES	Squiers (1998); subadults present, likely a nursery area
NH	Piscataqua River System	Unknown	NO?	YES	Squiers (1998); gravid female captured in 1990; 1981 subadult capture
NH/MA	Merrimack River	YES	NO?	YES	Squiers (1998); maybe a subadult nursery area only
MA	Taunton River	YES?	NO?	YES	Burkett and Kynard (1993); subadults captured 1991+1992
MA/CT	Connecticut River	YES	NO	YES	Savoy (1996 and pers. comm.); adult stock thought extinct
CT	Housatonic River	Unknown	NO	YES	Savoy (pers. comm.); subadults captured
CT	Thames River	NO	NO	YES	Savoy (pers. comm.); subadults only
NY	Hudson River	YES	YES	YES	Kahnle et al. (1998); all life stages occur
NJ/DE/PA	Delaware River	YES	YES	YES	Kahnle et al. (1998); declining but present
PA/MD	Susquehanna River	YES	Unknown	Unknown	Kahnle et al. (1998); dams block access in PA, no recent reports in MD
MD	Nanticoke River	YES	Unknown	NO	H. Speir (MD DNR, 1996), only fish present are from the 1996 stocking of Hudson River fish
MD	Potomac River	YES	Unknown	YES	Kahnle et al. (1998); no recent captures or reports
VA	James River	YES	YES	YES	Spells (1997); age 0 captured 1997
VA	York River	YES	Unknown	YES	Spells (1997); subadults captured 1997
VA	Rappahannock River	YES	Unknown	YES	Spells (1997); subadults captured 1997
NC	Roanoke River	YES	YES	Unknown	Moser (1998); age 0 present-Albemarle Sd.

ATLANTIC STURGEON DISTRIBUTION--HISTORIC AND CURRENT STATUS--UNITED STATES (cont.)

State	System	Historic Presenc e	Current Spawning Presence (sexually mature adults or ≤ age 1)	Current Juvenile-subadult Presence (≥ age 2)	Source / Comments
NC	Tar-Pamlico River	YES	YES	YES	Moser (1998); adults & juveniles present
NC	Neuse River	YES	YES	YES	Hoff (1980); Moser (1998)
NC	Cape Fear River	YES	YES	YES	Moser (1998); all life stages
NC	Brunswick River	YES	Unknown	YES	Moser (1998)
SC	Waccamaw River	YES	YES?	YES	Collins/Smith (1997); 1984 captures
SC	Great PeeDee River	YES	YES?	YES	Collins/Smith (1997); 1991 captures
SC	Black River	Unknown	Unknown	Unknown	Collins/Smith (1997)
SC	Santee River	YES	YES	YES	Collins/Smith (1997); 1997 captures
SC	Cooper River	YES	YES?	YES	Collins/Smith (1997); 1997 captures
SC	Ashley River	YES	NO	YES	Collins/Smith (1997); 1993 juvenile captures
SC	Ashepoo River	YES	YES?	YES	Collins/Smith (1997); 1994 captures
SC	Combahee River	YES	YES	YES	Collins/Smith (1997); 1998 captures
SC	Sampit River	YES	NO	YES	Collins/Smith (1997); 1995 captures
SC	Edisto River	YES	YES	YES	Collins/Smith (1997); 1998 captures
SC	Broad/Coosawatchie R.	YES	Unknown	Unknown	Collins/Smith (1997)
SC/GA	Savannah River	YES	YES	YES	Collins/Smith (1997); 1998 captures
GA	Ogeechee River	YES	YES	YES	Rogers and Weber (1995); 1997 captures
GA	Altamaha River	YES	YES	YES	Rogers and Weber (1995)
GA	Satilla River	YES	YES?	YES	Rogers and Weber (1995)
GA/FL	St. Marys River	YES	NO?	NO?	Rogers and Weber (1995)
FL	St. Johns River	YES	NO?	NO?	FGFWFC 1981 memo (H. Moody to C. Gilbert); 8 subadults

ATLANTIC STURGEON HABITAT AVAILABILITY AND ACCESSIBILITY

State	River	Historically Accessible River Habitat	Location of Any Impediment Blocking Access to Historic Habita (Name & River km)
ME	Androscoggin	40 km	Brunswick Dam (rkm 40)
ME	Kennebec	98 km	Edwards Dam (rkm 71)
ME	Penobscot	71 km	Veazie Dam (rkm 56)
ME	Sheepscot	32 km (shoals)	Head Tide Dam (rkm 35)
ME/NH	Salmon Falls	30 km	Salmon Falls Dam (rkm 25)
NH	Lamprey	Packers Falls (km?)	McCallen Dam (rkm ?)
NH	Oyster	17.6 km	Place? (rkm 16)
NH/MA	Merrimack	113 km	Essex Dam (rkm 46)
MA/CT	Connecticut	140 km(South Hadley Falls)	Holyoke Dam (rkm 140)
CT	Housatonic	123 km	Derby Dam (23.5 rkm)
NY	Hudson	181 km	Federal Dam (246 rkm)
NJ/DE/PA	Delaware	220 km	none
PA/MD	Susquehanna	50 km	Conowingo Dam (rkm 16)
MD/VA	Potomac	Great Falls (km?)	Little Falls Dam (rkm ?)
VA	Rappahannock	160 km	none
VA	York	80 km	none
VA	James	130 km	none
NC	Roanoke	unknown	Roanoke Rapids Dam (rkm 220)
NC	Tar-Pamlico	unknown	Rocky Mt. Dam (rkm 136)
NC	Neuse	378 km (falls)	Milburnie Dam (rkm 353)
NC	Cape Fear	unknown	Locks and Dam #1 (rkm 90)
SC	Great Peedee	unknown	Dam#1

ATLANTIC STURGEON HABITAT AVAILABILITY AND ACCESSIBILITY (cont.)

State	River	Historically Accessible River Habitat	Location of Any Impediment Blocking Access to Historic Habita (Name & River km)
SC	Santee	unknown	Wilson Dam
SC	Ashepoo	unknown	none
SC	Combahee	unknown	none
SC	Edisto	unknown	none

SC/GA	Savannah	320 km	New Savannah Bluff Dam (rkm 299)	93%
GA	Ogeechee	unknown	none	100%
GA	Altamaha	unknown	none	100%
GA	Satilla	unknown	none	100%
GA/FL	St. Marys	unknown	none	100%
FL	St. Johns	unknown	none	?

DREDGING ACTIVITIES WITHIN ATLANTIC STURGEON RIVER SYSTEMS

State	System	Recent/Current Dredging Locations and Restrictions
ME	Kennebec	No channel maintenance dredging above Bath since 1963; seasonal restrictions on dredging in lower river from April 1 to October 31
NH	Merrimack	No current dredging proposals; past dredging limited to river mouth
CT/MA	Connecticut	Dredged from mouth to Hartford every 6-7 years; seasonal restrictions for shad and salmon (spawning sturgeon population presumed extirpated) (W. Neidermyer, USFWS, personal communication)
CT	Thames	Dredging around mouth of river; recent deepening of channel
NY	Hudson	Shipping channel maintained from mouth of river to Albany, but no dredging required from Haverstraw Bay to Catskill
DE/NJ/ PA	Delaware	Bay to Delaware Memorial Bridge: on-board monitor to watch for turtle/shortnose required June 1 - November 30 Del. Mem. Bridge to Betsy Ross Bridge (Philadelphia) no-work windows: hydraulic dredge - 4/15 to 6/21; hopper dredge - 4/15 to 6/21; bucket dredge - 3/15 to 6/1; blasting and overboard disposal - 3/15 to 11/30 (Eric Schrading, USFWS, personal communication). Seasonal restrictions extend to Trenton (Dick St. Pierre, USFWS, personal communication).
MD	Nanticoke	No recent dredging within potential Atlantic sturgeon spawning habitat (J. Gill, USFWS, personal communication)
MD	Potomac	
VA	Rappahannock	
VA	York	
VA	James	
NC	Roanoke	Dredging in Albemarle Sound and major tributaries is minor except for Intercoastal Waterway; no dredging in Roanoke River since 1940's

DREDGING ACTIVITIES WITHIN ATLANTIC STURGEON RIVER SYSTEMS (cont.)

State	System	Recent/Current Dredging Locations and Restrictions
NC	Neuse	Dredging in Intercoastal Waterway in Pamilico Sound, major inlets and tributaries, but seasonal restrictions are in place to protect anadromous species including sturgeon
NC	Tar-Pamlico	
NC	Cape Fear	Extensive dredging on lower river and port facilities at Wilmington and Sunny Point Army Terminal, but restrictions avoid impacts to sensitive locations and seasons, such as potential spawning habitat; proposals for future expansion of navigation channel under consideration would involve blasting
SC	Waccamaw	Winyah Bay is dredged to the port of Georgetown, but rivers (and probable spawning habitat) are unaffected. Offshore restrictions on dredging in the shipping channel during warm months.
SC	Great PeeDee	
SC	Black	
SC	Santee	No dredging
SC	Cooper	Dredging to the base of Pinopolis Dam, no seasonal restrictions
SC	Ashepoo	No dredging
SC	Combahee	
SC	Edisto	
SC/GA	Savannah	Most dredging is in nursery habitat. Channel deepened in 1994, and future expansions planned. Frequent maintenance dredging. Seasonal restriction from 3/16 to 5/31 prevents interference with spawners transitting the area.
GA	Ogeechee	No dredging in last 20 years (D. Harris, USFWS, personal communication)
GA	Altamaha	

GA	Satilla	

CURRENT CONSERVATION EFFORTS

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ME	1976-8 i	Kennebec	Distribution and abundance of Atlantic sturgeon in the Kennebec River Estuary	Tom Squiers	Anadromous Fish Conservation Act	AFC-19/20
MA	1987,88	Merrimack	Survey of Atlantic sturgeon population in the Merrimack	Joseph DiCarlo	Anadromous Fish Conservation Act	AFC-15/21
	1991,92	Taunton River and Mount Hope Bay	Study annual movements feeding and spawning habitats and species interactions of sturgeon populations in the Taunton River and Mount Hope Bay		Anadromous Fish Conservation Act	AFC-24
CT	1991, 92, 94,95,96, 97	Connecticut and Thames	Monitor population levels, location, and movements of shortnose and Atlantic sturgeon	Tom Savoy	Anadromous Fish Conservation Act	AFC-20/21/22/23
DE	1992,93, 94,95	Delaware	Marking and recapture study to look at population status and migratory movements.		Anadromous Fish Conservation Act	AFC-6/7/8/12

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State	Year	River	Description	Investigator	Funding Sources	Project Number
NJ	1992,93, 95,96	NJ fisheries	Collection of data from commercial and recreational fisheries to determine bycatch, estimate mortality, migrations and stock identification	Bill Andrews	1992193 Anadromous Fish Conservation Act 1995/96 Atlantic Coastal Act	AFC-13 ACA-13/24
SC	1987,91, 92	shad fishery	Monitor incidental catch of Atlantic sturgeon by commercial shad fishermen through voiuntary reporting, and monitor abundance of juvenile Atlantic sturgeon in selected areas	Glenn Ulrich John McCord	Anadromous Fish Conservation Act	AFC-32/44/48
GA	1985,86	Commercial fishery	Determine population structure of the commercial fishery including age date, sex ratios, length frequencies and age at maturity. Conduct biotelemetry study to determine movement and migration patterns	Susan Shipman	Anadromous Fish Conservation Act	AFC-29

NMFS REPORTED U.S. ATLANTIC STURGEON LIVE WEIGHT LANDINGS (in kilograms) BY STATE AND YEAR

Year	ME	MA	RI	NJ	NH	MD	VA	NY	CT	DE	NC	SC	GA	FL East Coast	Yearly Totals
1962	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22,226	17,962	816	181	41,186
1963	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19,641	23,859	1,225	0	44,724
1964	33	1,855	543	0	0	0	0	0	0	0	15,331	29,121	862	0	47,745
1965	271	1,488	854	0	0	0	0	0	0	0	34,881	22,498	1,225	0	61,217
1966	201	850	2,022	0	0	0	0	0	0	0	26,717	19,414	590	0	49,794
1967	718	1,070	1,190	0	0	0	0	0	0	0	17,463	15,059	318	0	35,819
1968	258	1,243	299	0	0	0	0	0	0	0	21,273	20,049	227	0	43,348
1969	1,262	765	1,212	0	0	0	0	0	0	0	59,920	18,280	499	0	81,937
1970	2,813	647	1,332	0	0	0	0	0	0	0	54,386	2,858	1,633	0	63,668
1971	388	825	2,037	0	0	0	0	0	0	0	35,516	34,836	1,724	0	75,326
1972	479	1,276	969	0	0	0	0	0	0	0	69,903	30,853	3,498	0	106,977
1973	144	833	525	0	0	0	0	0	0	0	25,334	20,124	1,155	45	48,161
1974	167	1,168	1,261	0	0	0	0	0	0	0	42,374	21,272	858	0	67,099
1975	646	765	459	0	0	0	0	0	0	0	20,021	30,610	917	0	53,418
1976	607	389	551	0	0	0	0	0	0	0	20,770	40,010	630	0	62,956
1977	2,086	1,432	265	0	0	0	0	0	0	0	13,477	52,037	1,310	105	70,711
1978	844	1,884	163	7,362	0	0	0	0	0	0	14,459	42,722	4,926	11	72,372
1979	1,436	599	242	6,943	0	0	0	0	0	0	18,761	35,924	1,471	95	65,472
1980	1,559	1,064	511	5,635	0	0	0	0	0	0	13,613	59,332	6,451	76	88,241
1981	1,499	1,119	277	5,167	95	0	0	0	0	0	14,280	41,718	10,183	121	74,459
1982	1,247	1,103	490	3,386	0	436	1,681	0	0	0	10,599	45,429	12,756	68	77,195
1983	1,042	1,453	743	7,829	112	1,255	933	0	0	0	8,154	8,450	4,561	78	34,610
1984	841	2,358	2,939	13,844	21	1,740	1,898	0	0	0	20,389	11,737	3,307	0	59,073
1985	645	3,212	4,287	8,835	16	1,018	618	0	0	0	12,222	7,002	8,465	0	46,321
1986	729	2,981	3,399	9,175	26	1,643	0	15,537	0	0	9,325	0	4,036	0	46,852
1987	412	3,068	1,926	9,100	345	500	0	13,856	0	0	6,154	0	3,568	0	38,930
1988	213	3,025	2,333	5,911	536	1,083	0	25,944	0	0	3,563	0	3,345	0	45,953
1989	344	248	1,169	38,615	54	1,184	0	8,581	771	0	3,048	0	2,619	0	56,632
1990	116	255	1,003	58,240	64	1,566	0	21,919	728	0	3,065	0	1,876	0	88,832
1991	25	482	1,358	53,189	0	1,828	0	37,807	1,252	0	1,667	0	726	0	98,334
1992	0	52	1,197	38,138	0	614	0	17,784	0	0	0	0	981	0	58,766
1993	29	218	457	16,243	0	1,920	0	10,390	0	1,524	0	0	604	0	31,386
1994	0	27	62	23,300	0	343	0	19,648	0	0	0	0	78	0	43,458
1995	0	201	263	5,795	0	94	0	10,234	317	0	0	0	446	0	17,351
1996	0	0	171	2,421	0	206	0	11	95	0	0	0	106	0	3,010
1997	0	0	24	0	0	75	0	284	0	0	0	0	0	0	382
Totals	**21,056**	**37,955**	**36,531**	**319,127**	**1,270**	**15,507**	**5,129**	**181,995**	**3,163**	**1,524**	**638,533**	**651,153**	**87,990**	**780**	**2,001,713**

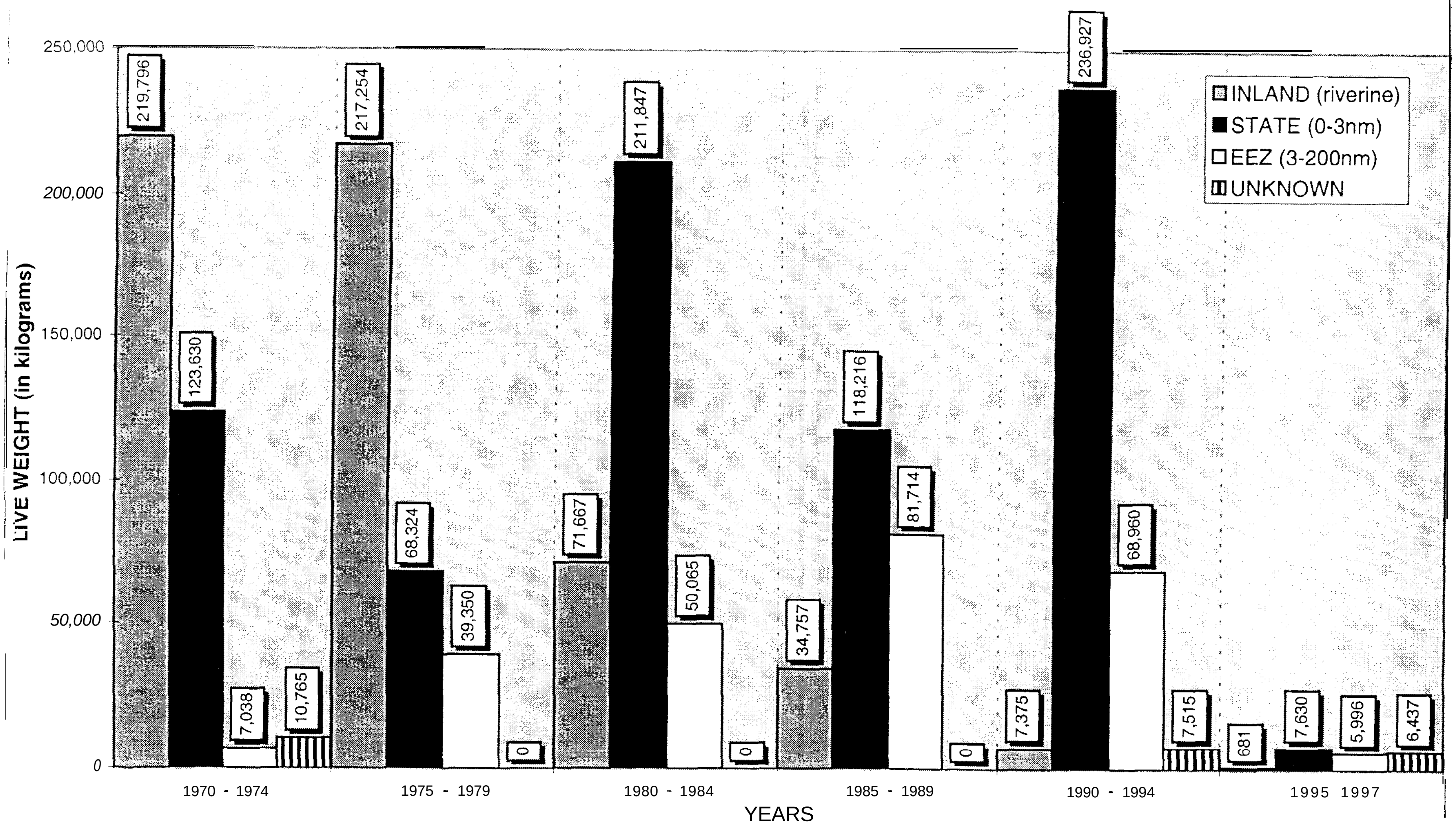
* U.S. includes the following states : Maine, New Hampshire, Massachusetts, Connecticut, Rhode island, New Jersey, New York, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and the Florida east coast.

U.S. ATLANTIC STURGEON LANDED LIVE WEIGHTS (in kilograms) BY AREA AND YEAR

YEAR	INLAND TOTAL	INLAND %	STATE TOTAL	STATE %	EEZ TOTAL	EEZ %	UNKNOWN TOTAL	UNKNOWN %	Yearly Totals
1962	0	0%	0	0%	0	0%	41,186	100%	41,186
1963	0	0%	0	0%	0	0%	44,724	100%	44,724
1964	0	0%	0	0%	0	0%	47,745	100%	47,745
1965	0	0%	0	0%	0	0%	61,217	100%	61,217
1966	0	0%	0	0%	0	0%	49,794	100%	49,794
1967	0	0%	0	0%	0	0%	35,819	100%	35,819
1968	0	0%	0	0%	0	0%	43,348	100%	43,348
1969	0	0%	0	0%	0	0%	81,937	100%	81,937
1970	56,019	88%	2,858	4%	0	0%	4,791	8%	63,668
1971	72,076	96%	0	0%	0	0%	3,250	4%	[illegible]
1972	34,351	32%	69,9031	65%	0	0%	2,723	3%)	106,977
1973	21,279	44%	22,029	46%	4,853 2,1851	10%	0	0%	48,161
1974	36,072	54%	28,841	43%		3%	0	0%	67,095
1975	38,564	72%	10,573	20%	4,281	8%	0	0%	53,418
1976	53,862	86%	6,660	1 1%		4%	0	0%	62,956
1978	50,384	70%	5,234	7%	14,045	8%	0	0%	70,711
1979	14,500	22%	7,942	58%	13,0571	19%	0	0%	72,372
1980	11,850	13%	37,914		10,837	20%	0	0%	65,472
1981	14,476	19%	65,555	74%		12%	0	0%	88,241
1982	19,286	25%	48,937	66%	11,046	15%	0	0%	74,459
			48,540	63%	9,369	12%	0	0%	77,195
1983	7,445	22%	20,078	58%	7,086	20%	0	0%	34,610
1984	18,609	32%	28,738	49%	11,726	20%	0	0%	59,073
1985	17,966	39%	10,988	24%	17,366	37%	0	0%	46,321
1986	5,076	11%	24,640	53%	17.1361	37%	0	0%	46,852
1987	4,492	12%	15,132	39%	19,305	50%	0	0%	38,930
1988	3,729	8%	34,581	75%	7,642	17%	0	0%	45,953
1989	3,493	6%	32,874	58%	20,265	36%	0	0%	56,632
1990	3,226	4%	78,286	88%	7,320	8%	0	0%	88,832
1991	1,014	1%	73,071	74%	24,249	25%	0	0%	98,334
1992	1,019	2%	36,746	63%	21,001	36%	0	0%	58,766
1993	1,895	6%	17,960	57%	11,531	37%	0	0%	31,386
1994	221	1%	30,863	71%	4,859	11%	7,515	17%	43,458
1995	453	3%	7,420	43%	4,938	28%	4,540	26%	17,351
1996	153	5%	159	5%	1,057	35%	1,641	54%	3,010
1997	75	20%	51	13%	0	0%	257	67%	382
Totals	551,530		766,573		253,123		430,487		2,001,718

* U.S. includes the following states: Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, New Jersev. New York, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and the Florida eastcoast.

U.S. EAST COAST ATLANTIC STURGEON LANDINGS BY AREA

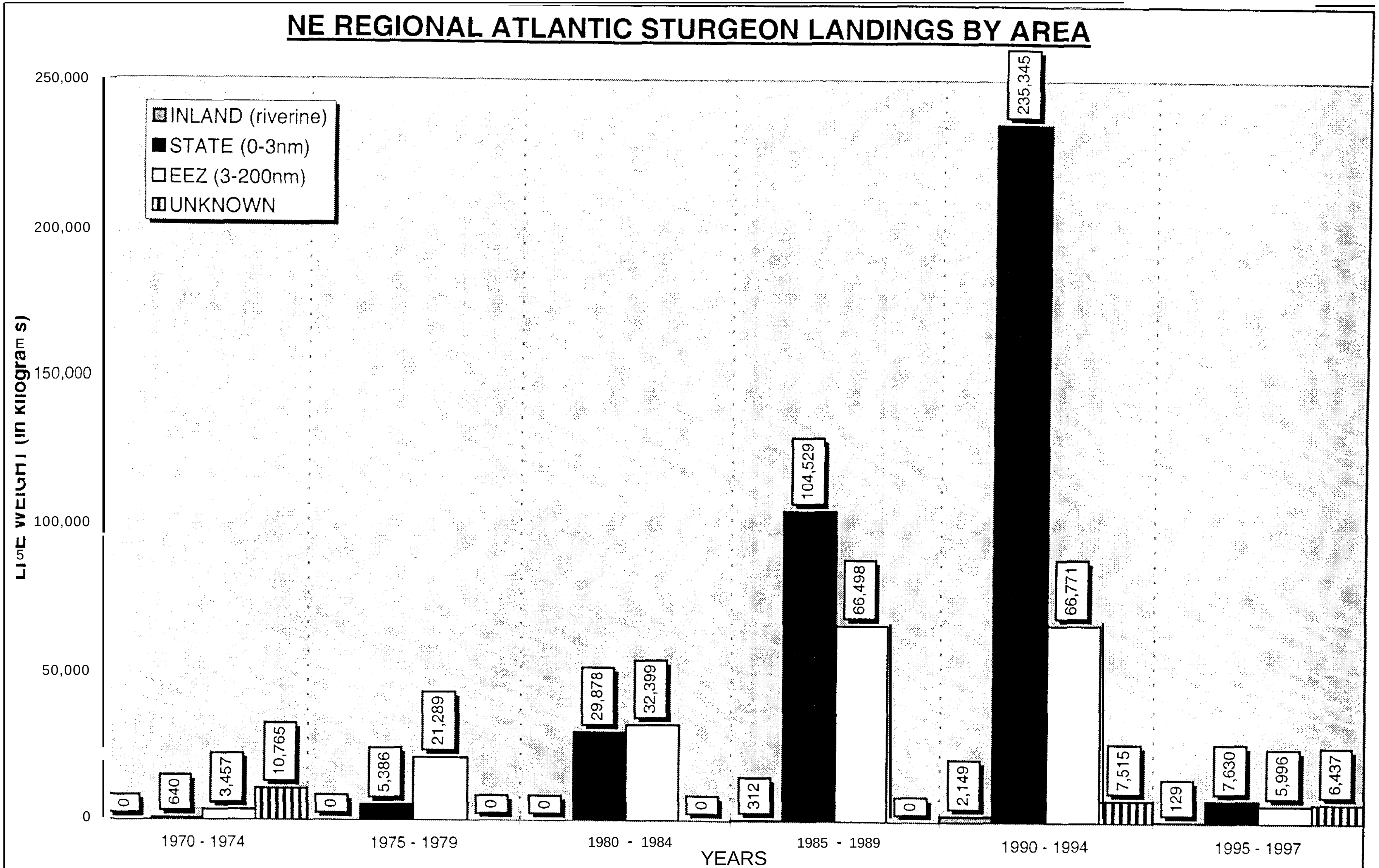


'U.S. EAST COAST includes the following states: Maine, New Hampshire. Massachusetts; Connecticut, Rhode Island, New Jersey, New York, Delaware, Maryland, Virginia, North Caroiina, South Caroiina, Georgia, and the Florida east coast.

NE ATLANTIC STURGEON LANDED LIVE WEIGHTS (in kilograms) BY AREA AND YEAR

YEAR	INLAND TOTAL	INLAND %	STATE TOTAL	STATE %	EEZ TOTAL	EEZ %	UNKNOWN TOTAL	UNKNOWN %	Yearly Totals
1962	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1963	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1964	0	0%	0	0%	0	0%	2,431	100%	2,431
1965	0	0%	0	0%	0	0%	2,613	100%	2,613
1966	0	0%	0	0%	0	0%	3,074	100%	3,074
1967	0	0%	0	0%	0	0%	2,979	100%	2,979
1968	0	0%	0	0%	0	0%	1,799	100%	1,799
1969	0	0%	0	0%	0	0%	3,239	100%	3,239
1970	0	0%	0	0%	0	0%	4,791	100%	4,791
1971	0	0%	0	0%	0	0%	3,250	100%	3,250
1972	0	0%	0	0%	0	0%	2,723	100%	2,723
1973	0	0%	147	10%	1,355	90%	0	0%	1,502
1974	0	0%	494	19%	2,101	81%	0	0%	2,595
1975	0	0%	456	24%	1,414	76%	0	0%	1,870
1976	0	0%	558	36%	989	64%	0	0%	1,547
1977	0	0%	767	20%	3,015	80%	0	0%	3,783
1978	0	0%	2,286	22%	7,968	78%	0	0%	10,254
1979	0	0%	1,318	14%	7,902	86%	0	0%	9,221
1980	0	0%	2,325	27%	6,445	73%	0	0%	8,770
1981	0	0%	2,058	25%	6,099	75%	0	0%	8,157
1982	0	0%	2,695	32%	5,648	68%	0	0%	8,343
1983	0	0%	7,581	57%	5,785	43%	0	0%	13,366
1984	0	0%	15,220	64%	8,421	36%	0	0%	23,641
1985	0	0%	6,033	32%	12,599	68%	0	0%	18,632
1986	0	0%	20,570	61%	12,921	39%	0	0%	33,491
1987	0	0%	13,607	47%	15,600	53%	0	0%	29,207
1988	0	0%	32,459	83%	6,586	17%	0	0%	39,045
1989	312	1%	31,861	63%	18,793	37%	0	0%	50,966
1990	619	1%	76,905	92%	6,368	8%	0	0%	83,891
1991	0	0%	72,928	76%	23,013	24%	0	0%	95,941
1992	73	0%	36,711	64%	21,001	36%	0	0%	57,785
1993	1,291	4%	17,960	58%	11,531	37%	0	0%	30,782
1994	166	0%	30,841	71%	4,859	11%	7,515	17%	43,380
1995	7	0%	7,420	44%	4,938	29%	4,540	27%	16,905
1996	47	2%	159	5%	1,057	36%	1,641	56%	2,904
1997	75	20%	51	13%	0	0%	257	67%	382
Totals	2,590		383,408		196,409		40,851		623,257

* NE Region includes the following states: Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, New Jersey, New York, Delaware, Maryland, and Virginia.



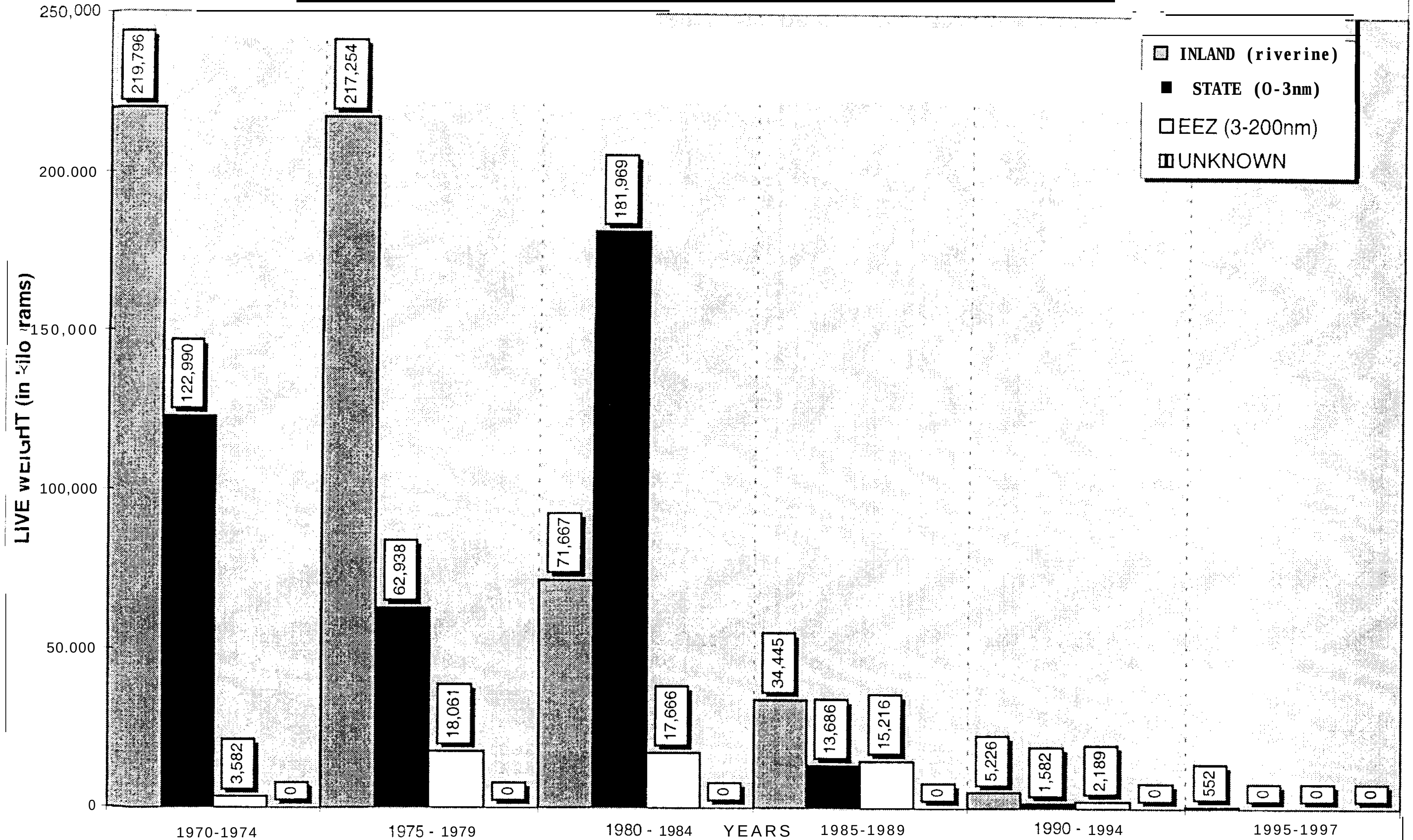
*NE REGION includes the following states: Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, New Jersey, New York, Delaware, Maryland, and Virginia.

SE ATLANTIC STURGEON LANDED LIVE WEIGHTS (in kilograms) BY AREA AND YEAR

YEAR	INLAND TOTAL	INLAND %	STATE TOTAL	STATE %	EEZ TOTAL	EEZ %	UNKNOWN TOTAL	UNKNOWN %	Yearly Totals
1962	0	0%	0	0%	0	0%	41,186	100%	41,186
1963	0	0%	0	0%	0	0%	44,724	100%	44,724
1964	0	0%	0	0%	0	0%	45,314	100%	45,314
1965	0	0%	0	0%	0	0%	58,604	100%	58,604
1966	0	0%	0	0%	0	0%	46,720	100%	46,720
1967	0	0%	0	0%	0	0%	32,840	100%	32,840
1968	0	0%	0	0%	0	0%	41,549	100%	41,549
1969	0	0%	0	0%	0	0%	78,098	100%	78,898
1970	56,019	95%	2,858	5%	0	0%	0	0%	58.876
1971	72,076	100%	0	0%	0	0%	0	0%	72,076
1972	34,351	33%	69,903	67%	0	0%	0	0%	104,253
1973	21,279	46%	21,882	47%	3,498	7%	0	0%	46,659
1974	36,072	56%	28,347	44%	84	0%	0	0%	64,504
1975	38,564	75%	10,117	20%	2,867	6%	0	0%	51,548
1976	53,862	88%	6,102	10%	1,445	2%	0	0%	61,409
1977	59,944	90%	4,467	7%	2,517	4%	0	0%	66,928
1978	50,384	81%	5,656	9%	6,078	10%	0	0%	62,118
1979	14,500	26%	36,596	65%	5,154	9%	0	0%	56,251
1980	11,850	15%	63,230	80%	4,392	6%	0	0%	79,472
1981	14,476	22%	46,879	71%	4,947	7%	0	0%	66,302
1982	19,286	28%	45,845	67%	3,721	5%	0	0%	68,852
1983	7,445	35%	12,497	59%	1,301	6%	0	0%	21,244
1984	18,609	53%	13,518	38%	3,305	9%	0	0%	35,432
1985	17,966	65%	4,955	18%	4,768	17%	0	0%	27,689
1986	5,076	38%	4,070	30%	4,216	32%	0	0%	13,361
1987	4,492	46%	1,525	16%	3,705	38%	0	0%	9,722
1988	3,729	54%	2,123	31%	1,056	15%	0	0%	6,908
1989	3,181	56%	1,013	18%	1,472	26%	0	0%	5,666
1990	2,607	53%	1,381	28%	953	19%	0	0%	4,941
1991	1,014	42%	143	6%	1,237	52%	0	0%	2,394
1992	946	96%	35	4%	0	0%	0	0%	981
1993	604	100%	0	0%	0	0%	0	0%	604
1994	56	71%	23	29%	0	0%	0	0%	78
1995	446	100%	0	0%	0	0%	0	0%	446
1996	106	100%	0	0%	0	0%	0	0%	106
1997	0	0%	0	0%	0	0%	0	0%	0
Totals	548,941		383,165		56,714		389,636		1,378,456

* SE Region includes the following states: North Carolina, South Carolina, Georgia, and the Florida east coast.

SE REGIONAL ATLANTIC STURGEON LANDINGS BY AREA



*SE REGION includes the following states: North Carolina, South Carolina, Georgia, and the Florida east coast.

NMFS REPORTED U.S. ATLANTIC STURGEON LIVE WEIGHT LANDINGS (in kilograms) BY GEAR AND YEAR

Year	Gill Nets	Gill Nets %	Trawls	Trawls %	All Others	All Others %	Yearly Totals
1962	3,674	9%	0	0%	37,512	91%	41,186
1963	4,536	10%	0	0%	40,188	90%	44,724
1964	38,930	82%	2,834	6%	5,980	13%	47,745
1965	46,491	76%	3,670	6%	11,055	18%	61,217
1966	24,345	49%	23,772	48%	1,676	3%	49,794
1967	25,452	71%	9,640	27%	728	2%	35,819
1968	38,511	89%	4,031	9%	806	2%	43,348
1969	55,254	67%	25,910	32%	774	1%	81,937
1970	29,318	46%	33,261	52%	1,089	2%	63,668
1971	54,673	73%	17,114	23%	3,538	5%	75,326
1972	83,139	78%	19,949	19%	3,888	4%	106,977
1973	30,704	64%	15,916	33%	1,541	3%	48,161
1974	35,924	54%	27,579	41%	3,596	5%	67,099
1975	38,419	72%	14,285	27%	714	1%	53,418
1976	52,910	84%	8,666	14%	1,380	2%	62,956
1977	62,220	88%	8,054	11%	437	1%	70,711
1978	51,578	71%	18,669	26%	2,124	3%	72,372
1979	43,439	66%	19,960	30%	2,072	3%	65,472
1980	72,513	82%	14,662	17%	1,066	1%	88,241
1981	58,513	79%	14,944	20%	1,003	1%	74,459
1982	64,972	84%	11,191	14%	1,033	1%	77,195
1983	17,426	50%	16,197	47%	987	3%	34,610
1984	34,157	58%	24,001	41%	915	2%	59,073
1985	22,325	48%	23,483	51%	513	1%	46,321
1986	16,528	35%	29,030	62%	1,294	3%	46,852
1987	13,921	36%	22,746	58%	2,263	6%	38,930
1988	24,937	54%	19,729	43%	1,286	3%	45,953
1989	45,407	80%	10,451	18%	773	1%	56,632
1990	74,996	84%	10,088	11%	3,748	4%	88,832
1991	77,717	79%	17,880	18%	2,737	3%	98,334
1992	49,408	84%	8,876	15%	483	1%	58,766
1993	27,981	89%	2,942	9%	463	1%	31,386
1994	38,568	89%	4,087	9%	803	2%	43,458
1995	14,833	85%	1,966	11%	552	3%	17,351
1996	2,738	91%	11	0%	261	9%	3,010
1997	66	17%	0	0%	316	83%	382
Totals:	**1,376,521**		**485,597**		**139,595**		**2,001,713**
Ave %:		**66%**		**24%**		**10%**	

* U.S. includes the following states : Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, New Jersey, New York, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and the Florida east coast.

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