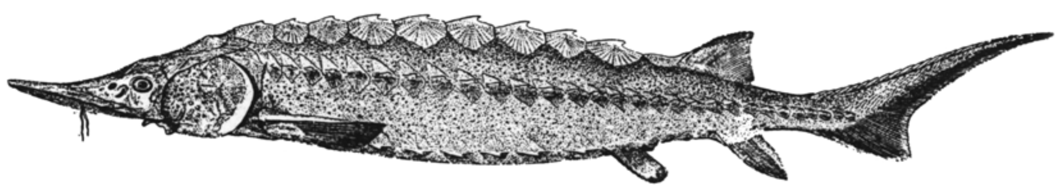
Atlantic States Marine Fisheries Commission

Atlantic Sturgeon Stock Assessment

Peer Review Report



March 1998

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PREFACE

This is a report of the Atlantic States Marine Fisheries Commission pursuant to: U.S. Department of Commerce, National Oceanic and Atmospheric Administration Award No. NA87 FGO 025.

OVERVIEW

The Stock Assessment Peer Review Process, adopted in May 1997 by the Atlantic States Marine Fisheries Commission, was developed to standardize the process of stock assessment reviews and validate the Commission's stock assessments. The purpose of the peer review process is to: 1) ensure that stock assessments for all species managed by the Commission periodically undergo a formal peer review; 2) improve the quality of Commission stock assessments; 3) improve the credibility of the scientific basis for management; and 4) improve public understanding of fisheries stock assessments. The definition of stock assessment adopted for this process includes model development, parameter development, and data review.

The Stock Assessment Peer Review Process report outlines four options for conducting a peer review of Commission managed species. These options are, in order of priority:

1) The Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) conducted by the National Marine Fisheries Service (NMFS), Northeast Fisheries Science Center (NEFSC).

2) A Commission stock assessment review panel composed of 3-4 stock assessment biologists (state, federal, university) will be formed for each review. The Commission review panel will include scientists from outside the range of the species to improve objectivity.

3) A formal review using the structure of existing organizations (i.e. American Fisheries Society (AFS), International Council for Exploration of the Sea (ICES), or the National Academy of Sciences).

4) An internal review of the stock assessment conducted through the Commission's existing structure (i.e. Technical Committee, Stock Assessment Committee).

Twice annually, the Commission's Interstate Fisheries Management Program (ISFMP) Policy Board prioritizes all Commission managed species based on species Management Board advice and other prioritization criteria. The species with highest priority are assigned to a review process to be conducted in a timely manner.

In October 1997, American shad and Atlantic sturgeon were prioritized for an external peer review to be conducted in early 1998. An external review panel was formed of four stock assessment biologists with expertise in anadromous species. Panel members included Dave Perkins, US Geological Service; Roger Rulifson, East Carolina University; Ray Schaffter, California Department of Fish and Game; and Saul Saila, University of Rhode Island (retired). Dr. Saila was unable to attend the review.

Terms of reference were developed for both species and were used to focus discussions during a three day meeting (March 17-19, 1998) to review stock assessments for American shad and Atlantic sturgeon. This Stock Assessment Peer Review Report includes all details of the stock assessment conducted for Atlantic sturgeon, including data inputs, model parameters, assessment results, and management advice. A supplementary Terms of Reference and Advisory Report is also available, which provides the peer review panel comments and advice on each specific term of reference. If you are interested in obtaining copies of the Stock Assessment Peer Review Report for American shad or either of the Terms of Reference and Advisory Reports, please contact Dr. Lisa L. Kline at (202) 289-6400 or lkline@asmfc.org.

The major portion of the Shad Stock Assessment Peer Review Report is the report on stock status of Atlantic sturgeon of Atlantic coast estuaries drafted by Andrew Kahnle, Kathryn Hattala, Kim McKown, Craig Sirey, Mark Collins, Thomas Squiers, Jr., and Thomas Savoy. The Commission would like to extend its appreciation to the many people who reviewed this report, including: William Andrews, Carolyn Belcher, Michael Brennan, Donna Calandrino, Lewis Gillingham, Stephen Grabowski, Joseph Hightower, Michael Hendrix, Walt Keller, Michael Mangold, Ron Michaels, Mary Moser, Robert Sadzinski, Jorgen Skjeveland, Richard Snyder, Glenn Ulrich, and John Young. We would also like to recognize the contributions of various Commission staff members who contributed a great deal of time and effort to the peer review meeting and completion of reports, including Tina Berger, Jeffrey Brust, John Field, Lisa Kline, Vanessa Jones, and Heidi Timer.

These reports were presented to the Commission's Atlantic Sturgeon Technical Committee and Management Board prior to submission to the Peer Review Panel. As of March 1998 the information contained in these reports was current. However, these committees have continued to update the data contained in these reports so as to maintain and improve the management of these species. As such, portions of these reports may have been updated since the peer review and more comprehensive analyses may have been conducted.

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EXECUTIVE SUMMARY

Atlantic sturgeon have been valued as a food fish along the Atlantic coast since pre-colonial times. Colonists harvested Atlantic sturgeon for export from New England rivers as early as the 1600's. Stocks in New England rivers may have collapsed from over harvest, and loss of habitat due to dam construction and water quality problems prior to initiation of consistent landings data in the 1800's. Landings for other Atlantic coastal rivers peaked around the turn of the century at 3.5 million kg. Landings declined precipitously soon after and have remained relatively low through the present.

This document summarizes an assessment of the current status of stocks of Atlantic sturgeon along the US Atlantic coast. Atlantic sturgeon still occur in major river systems and estuaries from Maine through Florida. Remnant spawning stocks are present or suspected throughout their historic range in the US. Immature Atlantic sturgeon begin to emigrate from natal rivers some time after the first year or two of life. Those from rivers north of South Carolina travel widely along the Atlantic coast.

Relative abundance of juvenile Atlantic sturgeon in the Hudson River Estuary has declined since the mid 1970's. Available population estimates for age one Atlantic sturgeon of the Hudson River Estuary were 25,000 for the 1976 year class and 4290 for the 1994 year class. Abundance of juveniles in the lower Delaware River declined in the early 1990's from a high of 5,600 in 1991 to a level so low that it could not be estimated in 1996 and 1997.

The major legal directed harvest of Atlantic sturgeon in the last few years occurred in NY and NJ through 1995. This fishery harvested the Hudson River stock in the nearshore ocean of both states and in the Hudson River Estuary. Harvest from all sources in the two states peaked in 1990 at 121,000 kg.

The target fishing rate (F_{50}) for the Hudson River stock when recovered was estimated to be $F = 0.03$. YPR in numbers at $F = 0.03$ was estimated as 0.19. Rates of fishing mortality (F) during the recent open fishery were estimated at $F = 0.01 - 0.12$ for females. Estimates for males were 0.15 - 0.24. Estimated life time yield from principle year classes harvested in the fishery in 1990 - 1995 was 10,620 animals at $F = 0.03$. Actual harvest in 1990 - 1995 was just above 17,000 animals. Observed mortality rates and reported harvest indicate that the Hudson River stock of Atlantic sturgeon was overharvested during the recent open fishery. Moreover, this harvest may have led to reduced recruitment.

Reduced or degraded habitat is an issue of concern in New England and southeastern rivers. Bycatch does not appear an issue in nearshore fisheries of New England estuaries.

Atlantic sturgeon are a bycatch of commercial fisheries along the entire US Atlantic coast. Most of the bycatch north of South Carolina occurs in gillnet fisheries and in ocean waters. Most of the bycatch in the southeast appears to occur in gillnet fisheries in estuarine and coastal habitats. Highest mortality in commercial bycatch occurs in gillnets. Exploitation rates for Hudson and Delaware River Atlantic sturgeon killed in the bycatch at $F = 0.005 - 0.024$. Bycatch may be a concern since the upper range of this estimate is close to the estimated harvest rate for a recovered fishery on the Hudson River stock. Rate of bycatch induced mortality on other stocks remains unknown.

Given the current depressed abundance of all stocks of Atlantic sturgeon, the demonstrated impacts of the recent commercial fishery on the Hudson River stock, and concerns over current bycatch, we recommend that Atlantic coastal states impose a moratorium on harvest of Atlantic sturgeon. States with significant spawning populations should also explore options for monitoring relative abundance of juveniles. All states should characterize and report bycatch.

We recommend that efforts of the Atlantic Sturgeon SAC to define a recovered stock continue.

TERMS OF REFERENCE

1) Assess current status of Atlantic coastal stocks of Atlantic sturgeon based on commercial landings data, population estimates, and indices of relative abundance.

2) Review estimates of target fishing rate and yield-per-recruit, and evidence for recent overharvest for the Hudson River.

3) Review information on current bycatch of Atlantic sturgeon, including: a) distribution over time, space, and fisheries; b) trends; and c) population level estimates of bycatch induced mortality rates.

4) Review management and research recommendations.

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1.0 INTRODUCTION

Atlantic sturgeon , Acipenser oxyrinchus, have been a valuable natural resource along the US coast since pre-colonial times. Sturgeon remains are commonly found at Native American archaeological sites indicating use of this resource for several centuries (Warner 1972). At the turn of this century, Atlantic sturgeon were among the top three species in weight of fish harvested commercially along the Atlantic coast (US Bureau of Fisheries 1907, US Commission of Fish and Fisheries 1884-1905). Consistent records of commercial harvest were initiated by the Federal government in 1880 (Appendix Table B1). Reported landings peaked in 1890 at three and one-half million kilograms (ASMFC 1990). Landings declined precipitously soon after and have remained relatively low through the present (Figure 1, Appendix B).

During the turn of the century, the Atlantic sturgeon fishery was concentrated in the Delaware River and the Chesapeake systems. Substantive landings also came from the southeastern states of NC, SC and GA (Smith 1985). After the collapse of sturgeon stocks in the mid-Atlantic states, landings for NC, SC and GA dominated the coastal harvest. Landings for these states declined by the 1980's and coastwide harvest shifted to NY and NJ.

The Atlantic States Marine Fisheries Commission (ASMFC) adopted an interstate management plan (FMP) for Atlantic sturgeon in 1990. Among the management recommendations of that plan was the statement that states should adopt a: 1. Minimum size limit of 2.13 m TL and institute a monitoring program; 2. A moratorium on all harvest; or 3. An alternative measure to be submitted to the Plan Review Team for determination of conservation equivalency. Based on plan recommendations and subsequent stock assessments, commercial harvest of Atlantic sturgeon in Atlantic coastal states was severely restricted and ultimately eliminated from almost all Atlantic coastal states. A brief history of current management regulations by state is provided in Appendix Table A1. In spite of these closures some stocks continued to decline. In response, ASMFC began working on an amendment to the plan. The only management recommendation being considered at this time is a coastwide moratorium.

The goal of this document is to present a comprehensive assessment of current status of Atlantic sturgeon stocks along the US Atlantic coast. This material will support recommendations in the plan amendment under development by ASMFC.

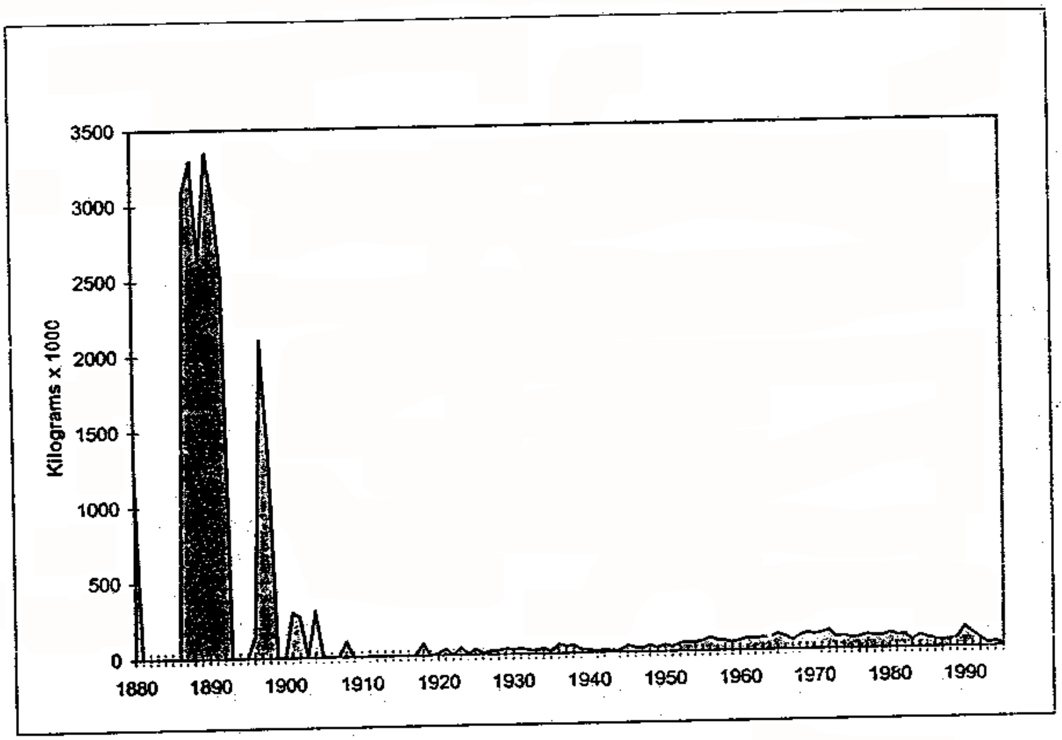


Figure 1. Coast wide commercial landings of Atlantic sturgeon.

2.0 OBJECTIVES

The objectives of this assessment are to:

1. summarize available data on status of major stocks of Atlantic sturgeon along the US Atlantic coast;

2. define acceptable instantaneous rate of fishing for the Hudson River population of Atlantic sturgeon;

3. identify recent mortality rates of Hudson River Atlantic sturgeon; and

4. summarize available data on and evaluate importance of bycatch of Atlantic sturgeon.

3.0 STOCK STATUS OF ATLANTIC COAST STOCKS

3.1 Common Life History

Many documents are available that summarize reproductive and other life history characterisitics (Murawksi and Pacheco 1977; Hoff 1980; ASMFC 1990). What is presented here is a brief overview to set the stage for the remainder of this document. Further details should be researched from the original literature source(s).

Atlantic sturgeon are anandromous fish, found in all Atlantic coastal waters from Florida to Canada.

3.1.1 Reproduction

There is an apparent clinal variation in maturity at age for coastal Atlantic sturgeon stocks. Smith (1985) states that South Carolina fish mature at ages seven through 19 years for females and five to 13 years for males. For the Hudson stock, Dovel and Berggren (1983) state that females mature at ages 20 to 30 and males at ages 11 to 20. For far northern stocks in Canada, age at maturity is older yet at ages 27 to 28 for females and ages 22 to 34 for males (Scott and Crossman 1973).

Timing of the spawning runs is directly related to climatological warming as it occurs on the Atlantic coast. Spawning migration begins in February in FL, GA and SC (Smith 1985); in April in Chesapeake Bay; April - May in the Delaware (Borodin 1925); May in the Hudson (Dovel and Berggren 1983); and in May through July in rivers in New England and Canada (Bigelow and Schroeder 1953). Spawning occurs in fresh or brackish waters of the estuaries (Smith 1985).

3.1.2 Coastal Migration

Most data on Atlantic sturgeon movement comes from fish tagged north of South Carolina. These tagging studies suggest that immature Atlantic sturgeon travel widely once they emigrate from their northern natal rivers. Seasonal movement is north in the late winter and spring and south in the fall and early winter.

Dovel and Berggren (1983) tagged about 4,300 sub-adult Atlantic sturgeon in the Hudson River Estuary in 1975 through 1978. Recaptures occurred from estuaries and the nearshore ocean from Marblehead, MA to Ocracoke, NC. Thirty three percent of the recaptures outside of the Hudson came from the Delaware River and Bay. Thirty-eight percent came from the Chesapeake Bay and tributaries.

Approximately 1,700 sub-adult Atlantic sturgeon from the lower Delaware River were tagged by Delaware Division of Fish and Wildlife from 1991 through 1997 (Shirey et al. 1997). Within this sample of Atlantic sturgeon were individuals that had been 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 near-shore ocean and some estuaries from Maine through North Carolina.

Holland and Yelverton (1973) summarized recaptures of 187 tagged Atlantic sturgeon released off of North Carolina in 1968 through 1971. Most recaptures came from estuaries or near shore ocean in North Carolina. However, one recapture came from Mecocks, New York. Recaptures were less than or equal to 130 cm FL on tagging.

Data on movement of Atlantic sturgeon from southeastern rivers suggest that juvenile Atlantic sturgeon from southeastern rivers do not move as extensively as those from the north. Smith (1985) reported that a juvenile Atlantic sturgeon tagged in the Edisto River, South Carolina was recaptured in Pamlico Sound, North Carolina. Another juvenile tagged in Winyah Bay was recaptured in Chesapeake Bay. Juvenile Atlantic sturgeon tagged in the Altamaha River GA in 1986 through 1992 were recovered as far north as North Carolina (Collins et al. 1996).

A total of 1,038 juvenile Atlantic sturgeon have been tagged in South Carolina rivers, estuaries and coastal waters since 1986 (G. Ulrich, personal communication). Most fish were recaptured within 32 km of their tagging location (Table 3.1.1). Only a few recaptures occurred outside of SC: three from NC, two from GA and one from FL. There are few records of more extensive movements.

Table 3.1.1

Total Juvenile Atlantic Sturgeon Tagged by Year and Location with Recaptures by Area

Year	Location	Number Tagged	Recaptures Within 20 Mi.*		Recaptures Over 20 Mi.				
			Indiv.	Incid.	NC	SC	GA	FL	SUM
1986	Winyah Bay-Inside	5	2①	2					0
1987	Winyah Bay-Ocean	2	1①	1	1				1
1988	Winyah Bay-Ocean	4	0	0					0
1989	S. Edisto River-Mi. 4	2	0	0	1				1
1994	Edisto River-Mi. 18	99	13	14		3		1	4
1994	Ashepoo River-Mi. 1	1	0	0					0
1995	Edisto River-Mi. 18	68	14	14		2②			2
1995	St. Helena Sound	5	0	0			1		1
1996	Edisto River-Mi. 18	508	183③	360	1④	8⑤	1		10
1997	Edisto River-Mi. 18	344	100⑥	123					0
Total	All SC Locations	1038	313	514⑦	3	13	2	1	19

① Recaptured within 2 weeks in commercial shad gill-nets (5 1/2" stretched mesh)
② One fish recaptured both at release site and in St. Helena Sound
③ One fish (Age III) recaptured in commercial shad gill-net the spring after tagging 12 miles upriver from release site
④ Fish also recaptured 3 times at release site
⑤ Three fish recaptured both at release site and outside of Edisto River in South Carolina coastal ocean waters
⑥ Three fish recaptured by research trammel nets within 2 miles of release site
⑦ Many individuals were recaptured multiple times with several having been recaptured on 5 occasions subsequent to tagging
* Indiv. = Individuals recaptured; Incid. = Incidents of recapture

3.2 New England by Thomas S. Squiers Jr. and Tom Savoy

Historical abundance of Atlantic sturgeon throughout New England will likely remain unknown as depletions and extirpations from dam construction, overfishing and/or water quality problems predate the establishment of resource agencies, accurate recording of landings and general concern/knowledge of fishery issues by decades if not centuries. Wood (1634) stated *"This fifh is here in great plenty, an in fome Rivers fo numerous, that it is hazardous for Canoes and the like fmall Veffels to pafs to and again, as in Pechipfcut River to the Eaftward."*. Bigelow and Schroeder (1953) also cite Wood (1634) as a source in stating that sturgeon enter practically every stream of any size emptying into the Gulf of Maine. However, one must consider Woods' writing as the one of the first true advertising sales pitches to entice Europeans to come to America. That aboriginal and native Americans used sturgeon is without question. Warner (1972) states Atlantic sturgeon is the only fish consistently identified in both the archeological and ethnographical records. These fish were evidently highly regarded by native Americans as Josselyn (1692) reported their relative ranking *"...; but in New-England the Indians have in greaeft requeft, the bafs, the sturgeon, the salmon, the lamprey, etc."*. The importance of anadromous fishes to the Indians can also be inferred from retained rights to various fishing places throughout New England in treaties they signed (Judd 1905). Williams (1643) stated that the Indians prized sturgeon so greatly that they would not give any up. Wood (1634) also noted that the Indians had both heavily made nets for catching sturgeon and described a harpoon fishery. Wood's (1634) description of the fisheries suggest that sturgeon were mainly harvested at sea or the mouths of rivers; with the shoals of Cape Cod and the Merrimack River as having the biggest fisheries (Maine to Rhode Island). Coffin (1947) described the nighttime clubbing of sturgeon (with torch from a canoe to draw the fish up) to explain the occasional finding of stone axes in the Housatonic River and nearby in Long Island Sound.

Early use by Europeans may have taken place without much recording of catches except for occasional diary reports. It is likely that fish, fowl and game occasionally supplemented early diets. Decker and Harris (1991) noted that fishing provided food but it was not a commercial enterprise as most families could secure their own fish or trade goods and labor for them. Commercial landing statistics are generally only available from the late 1800s with landings peaking around 1890 and collapsing by 1905. Exceptions occur; Maine had one of the earliest fisheries with export back to England taking place as early as 1628

Atlantic sturgeon supported one of the first commercial fisheries in the State of Maine. The estuarine complex of the Kennebec River probably supported the major fishery for Atlantic sturgeon in the State of Maine. This fishery occurred at head-of-tide on the Androscoggin River in 1628. Total landings for sturgeon at this site in 1628 was stated to be 90 kegs and 90 barrels. This fishery persisted intermittently until 1675 (Wheeler and Wheeler 1878). Atkins (1887) described the Kennebec fishery as being an important intermittent fishery which flourished into the 18th and early part of the 19th century. The last major landings occurred in 1849 when 160 tons of sturgeon were landed (Atkins 1887). Historical accounts of the Atlantic sturgeon in the

Penobscot River are very limited. The fact that there was no mention of a large sturgeon fishery in the Penobscot River in the early 1800's at a time when there was a lot of fishing effort in the estuary for Atlantic salmon and American shad indicates that there may not have been a large run of Atlantic sturgeon on the Penobscot River. Atlantic sturgeon were utilized by native Americans in the Penobscot River drainage. Sturgeon scutes have been identified from two separate archaeological sites on the Penobscot River. The Eddington Bend site is located at head-of-tide and the sample from this site is about 4000 to 3000 years old. The Hirundo Site is located upriver on a smaller tributary, Pushaw Stream. Pushaw Stream enters the Penobscot River just upstream of the historical falls at Milford which means that some Atlantic sturgeon did make it over the falls or that maybe sturgeon were captured at Milford falls and transported to the Hirundo Site. The sample from this site is about 2000 to 1000 years old. Both sites are fire pits so only calcined scute fragments are present and the researchers could not identify to species (Knight 1985, Petersen and Sanger 1986)

Merrimack (or New Hampshire): An early report by William Wood, "New England's Prospect"(1634) gives the following accounting of sturgeon in New England: " The sturgeons be all over the country, but the best catching of them be upon the shoals of Cape Cod and in the River of Merrimacke, where much is taken, some of these being 12, 14, 18 foote long". Atlantic sturgeon migrated as far upstream as Amoskeag Falls (km 113) in Manchester, New Hampshire prior to the construction a dam (km 48) in 1847 at Lawrence, Massachusetts (Murawski and Pacheco, 1977). Jerome et al. (1965) stated that the Merrimack River was a very important fishery during colonial days and that it lasted until the late 1800's. In the early 1600's it was known as one of the two best sturgeon fishing areas in the colonies. Flesh was pickled and sold for 10 shillings a keg in 1656. Jerome et al (1965) notes the pickled sturgeon industry was an important export by 1663. In 1673, a petition was submitted and apparently granted requiring the licensing of individuals to boil and pickle sturgeon with a provision for inspection. They also note the stability of the price from 1656 to 1733 with an increase of only 10 to 12 shillings a keg. In 1882 Massachusetts passed law enacting minimum 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 wiped out.

Information specific to the Thames River is scarce. Sturgeon scutes have been documented at a site along the river and historical reports note use by Indians. Minta (1992) cites Larned (1880) and Anon (1893) as American shad, Atlantic salmon and Atlantic sturgeon being abundant in the system until the 1830's. Whitworth (1996) speculated that populations of both shortnose and Atlantic sturgeon in the Thames were always low because the fall line is near saltwater. He further states that there have probably been no spawning populations in that river since the building of the Greenville dam in 1825 which further restricted what limited habitat was available.

Connecticut: Utilization by early settlers throughout the State (Thames, Connecticut, and Housatonic Rivers) remains unclear. Field (1819) states the Connecticut River used to abound with fish,.... “But as there was a general prejudice against the use of most common and important kinds of these fish, either because they were so generally used by the Indians, or from some other cause which I am unable to assign, little effort was made to take them for more than a century after the county was settled.” Peters (1781) stated simply “The sturgeon is made no use of.” However, in his History of Hadley Mass., Judd (1905) who is often cited for early fish work on the Connecticut River gives an account of the shad fishery in the mid 1700s. He then states simply ‘Sturgeon were taken on the falls with spears.’ In October of 1778, Walt Goodrich and Associated of Glastonbury secured the exclusive fishery of sturgeon in the CT River for five years (Adams and Stiles 1904). Galligan (1960) recorded personal histories recounting the Atlantic sturgeon fishery that took place in the Connecticut River in the mid 1800's to early 1900's.

Limited information is available on the Housatonic River. Similar to the Thames River, Coffin (1947) reports that Atlantic sturgeon were abundant and used by native Americans. He described capture techniques which was a clubbing of sturgeon with stone axes when they were attracted to and bewildered by torches held in canoes. Whitworth (1996) stated that there was a large fishing industry for them (sturgeon) in this basin.

3.2.1 Description of the Estuaries

3.2.1.1 Estuarine Complex of the Kennebec, Androscoggin, and Sheepscot Rivers in Maine

The Kennebec River, at its mouth, drains an area of 24,667 square kilometers. This total encompasses the drainage area of the Androscoggin River and the smaller tributaries of Merrymeeting Bay. Both the Kennebec and Androscoggin Rivers flow into a large freshwater tidal bay called Merrymeeting Bay. This tidal freshwater bay also receives freshwater inflow from several smaller drainages: the Eastern River (130 km^2), the Cathance River (181 km^2), and the Abagadasset River (52 km^2). From the outlet of Merrymeeting Bay upriver to the Edwards Dam (39 kilometers) the river is essentially tidal freshwater. Although salinities of 2 to 3 ppt are commonly found in Merrymeeting Bay during periods of low river discharge, the riverine tidal wetlands are characterized by nonpersistent freshwater emergent plants. The tidal section of the Androscoggin River is approximately 10 kilometers in length.

The Kennebec River estuary below Chops Point (outlet of Merrymeeting Bay) forms a complex with that of the Sheepscot River estuary. Less saline surface water from the Kennebec River flows through the Sasanoa River into Hockomock Bay on an outgoing tide, whereas highly saline water from the Sheepscot River enters Hockomock Bay through Goose Rock passage on the incoming tide as bottom water in the Sasanoa. Water is also exchanged in Montsweag Bay between Hockomock Bay and the Sheepscot River in Wiscasset. Thus, both Hockomock and Montsweag Bays act 8as mixing basins for the Kennebec and Sheepscot Rivers water, with there being an indirect exchange between the two systems. Hockomock Bay is also connected with the Kennebec River through Back River, which is very shallow near Hockomock Bay. The dynamics of water exchanged between the two systems and the exact influence one river system exerts upon the other has not been extensively studied.

The 14 kilometer river segment from Chops Point (outlet of Merrymeeting Bay) downriver to Doubling Point is an area of transition (mid estuary). The salinities in this section vary both seasonally and over a tidal cycle. During spring freshets this section is entirely freshwater but during summer low flows salinities can range from 2 to 3 ppt at Chops Point to 18 ppt at Doubling Point.

The lower estuary from Doubling Point to Popham Beach (18 kilometers) is narrow, deep in areas (over 30 m) and turbulent. This segment is well mixed and there is very little stratification at most stages of tide. Salinities range from 18 ppt at Doubling Point to 31 ppt at Parker Head (5 kilometers from the mouth) during summer low flows.

Mean tidal amplitude ranges from 2.56 m at the mouth to 1.25 m in Augusta near head-of-tide on the Kennebec River and 1.16 m at Brunswick on the Androscoggin River.

3.2.1.2 Penobscot River

The Penobscot River is the largest watershed which lies wholly within Maine (22,257 square kilometers). The watershed is approximately 257 kilometers long and 185 kilometers wide. The estuary is about 51 kilometers in length from head of tide to Searsport. It is narrow from Bangor to Bucksport (about 1.6 kilometer) and widens to a maximum of 13 kilometers. The mean depth of the estuary is 8.84 m with a maximum depth of 30.8 m (Haefner 1967). The mean tide range increases from 3.11 m at Fort Point in Stockton Springs to 4.11 m in Bangor (NOS 1998).

The upstream limit of the salt wedge varies seasonally and over a tidal cycle. During spring freshets tidal freshwater extends to Winterport (km 29). During low flow months the salt wedge (measured as the upstream edge of 1 ppt salinity) extends upstream as far as upstream as Hamden (km 40). Thus there is approximately 14 kilometers of tidal freshwater and 1.6 kilometer of freshwater habitat (up to Veazie Dam -km 56) available for the early life stages of Atlantic sturgeon during the summer months.

The first dam was built on the mainstem of the Penobscot River in 1830 at Old Town followed by the construction of one at Veazie (km 56) just above head-of-tide in 1835. The construction of these dams severely limited the amount of freshwater habitat available. In June and July, the salinity wedge extends to within approximately 16 kilometers of the Veazie dam. There are no records on how far upstream Atlantic sturgeon migrated on the Penobscot River.

The first serious obstacle to migration may have been at Milford, river km 71 (L. Flagg, personal communication). If Atlantic sturgeon could have ascended the falls at Milford, they could have easily migrated to Mattaceunk (km 171).

3.2.1.3 Piscataqua River/Great Bay Estuary System

The Piscataqua River drains 2637 square kilometers in Maine and New Hampshire. Several tributaries empty into a tidal bay, Great Bay, located approximately 10 kilometers upstream from the mouth. There is some limited tidal freshwater habitat located at the head of Great Bay, km 19 to 21, (Larsen and Doggett 1979). Some limited tidal freshwater habitat may also be available in some of the tributaries such as the Salmon Falls River (drainage area of 329 square miles).

3.2.1.4 Merrimack River

The Merrimack River basin contains 12,976 square kilometers of drainage area located in central New Hampshire and northeastern Massachusetts. Hoover (1938) states Amoskeag Falls as the historical limit of Atlantic sturgeon based on the record of catch in 1761 in a personal diary. The Essex Dam in Lawrence located at river km 46 is the first upstream barrier blocking the migration of Atlantic sturgeon. Tidal influence extends to river km 35. The salt wedge extends upriver to river km 16 in summer at the lowest river discharges (Kieffer and Kynard 1993). The nontidal section is dominated by sand and gravel and depths less than three meters. Thus there is approximately 19 kilometers of tidal freshwater and 11 kilometers of freshwater habitat available for the early life stages of Atlantic sturgeon during the summer months. A detailed description of the tidal section by river reach can be found in Kieffer and Kynard (1993).

3.2.1.5 Pawcatuck River

The Pawcatuck River basin contains 790.5 square kilometers of drainage area located in Connecticut and Rhode Island and discharges into Little Narragansett Bay. The estuarine portion of the highly stratified estuary is 8 km long. The first dam at Ashaway, Rhode Island was laddered in 1975 with the Potter Hill Fishway.

3.2.1.6 Thames River

The Thames River basin contains 3,790.8 square kilometers of drainage in Connecticut, Massachusetts and Rhode Island. The Thames River (proper) is created by the joining of the Yantic and Shetucket Rivers in Norwich Harbor. The Thames River is actually an estuary with a saline wedge which extends up into the Shetucket River during low flows. High freshwater discharge combined with outgoing tidal stage can displace the salt wedge several kilometers south. The Greenville dam in Norwich located on the Shetucket River was constructed in 1830 and is just above the head of the Thames River.

3.2.1.7 Connecticut River

The Connecticut River is the longest river in New England. It is approximately 660 km long and drops 800 m through four states. The basin contains 29,182 square km of area in Canada, New Hamsphire, Vermont, Massachusetts, and Connecticut. Called the Long (Tidal) River by Indians, the river is effected to the Enfield rapids in tidal amplitude although the maximum extent of the salt wedge is only km 26 (0.1 ppt) (Meade 1966). Generally detectable concentrations of salt are in the lower 10 km and the entire salt wedge and zone of mixing is displaced out into Long Island Sound during the Spring freshet.

The river has been subdivided into a series of several impoundments (Moffit et al. 1983), but the lower most two sections still provide suitable sturgeon habitat as evidenced by surviving stocks of shortnose sturgeon. Some confusion exists over historical range of Atlantic sturgeon in the Connecticut River. Galligan (1960) reported the Enfield dam and rapids area as the northern limit. The Enfield rapids were closed by a series of three wing dams. The first wing was constructed as early as 1829 to divert water into the adjoining canal. The final center section to close off the dam was not finished until 1881 (Turner 1991). It is likely that Atlantic sturgeon could surmount the Enfield rapids area prior to dam construction in all but low flow years. It is likely that Atlantic sturgeon were not able to surmount the falls at South Hadley Massachusetts and this was the northern limit in this system. Judd (1905) reported sturgeon were taken here with no mention of size of fish (or species). However, McCabe (1942) cites Eastman (1912) as "Early in the nineteenth century numberless sturgeon .... passed this town (South Hadley Falls) in their ascent of the Connecticut. They were a large, coarse fish often 8 or 10 feet in length and so tough they were considered unfit for food." The sight has been the northern limit since the first dam was constructed in 1795 (Judd 1905). Adding to the confusion, a total of nine dams have since been built on the site of the South Hadley Falls (Foster 1991) since the first timber structure was completed in 1795.

3.2.1.8 Housatonic River

The Housatonic River basin contains 5,022.5 square kilometers of drainage area in Connecticut, New York and Massachusetts. The Housatonic River is 212 km long and had a large amount of area between saltwater and the fall line at Falls Village until the Derby dam was constructed in 1870. Whitworth (1996) stated that sturgeon were restricted by the falls (Great Falls) at New Milford (km 123), but that most other anadromous fish could surmount these falls and get up to Falls Village. The lower most dam (Derby Dam) at km 23.5 was built in 1870.

3.2.2 Life History and Biology

Sturgeon enter Gulf of Maine Rivers in late spring, slowly migrating upriver beyond tidewater before depositing their eggs in May, June, and July (Bigelow and Schroeder 1953). More recent data from the Kennebec River indicates that Atlantic sturgeon spawn in June and July.

Historically it was thought that Atlantic sturgeon spawned almost wholly above head-of-tide in the Kennebec River. On the Kennebec River it was believed that Atlantic sturgeon spawned mainly between Augusta and Waterville (km 93), a view which was supported by the fact that there was a great decrease in the number of sturgeon after the dam (km 64) at Augusta was built in 1837 (Atkins 1887).

Sturgeon may spend the first several years in the lower tidal reaches of their natal river until they have reached a size of 2-1/2 to 3 feet (Bigelow and Schroeder 1953). Bigelow and Schroeder (1953) further stated that the capture of sturgeon of that size range at various points around the coasts of the Gulf of Maine and southern New England was further proof that they emigrated from the river systems once reaching that size.

Data on age and growth of Atlantic sturgeon in New England are very limited. Data were collected on adult sturgeon sampled in a small commercial fishery which occurred on the Kennebec River in 1980. A total of 18 of the 31 Atlantic sturgeon which were captured in the fishery were measured, sexed, and aged. Fifteen of the eighteen were males ranging in fork length from 145 cm to 193 cm. The ages for the males ranged from 17 to 40 years old. The three females were 170 cm, 208 cm, and 208 cm in fork length and were 25, 34, and 40 years old respectively. Limited age data were collected on Atlantic sturgeon captured from 1977 through 1981 from the Kennebec River (Table 3.2.2).

3.2.3 Current Status

3.2.3.1 Estuarine Complex of the Kennebec, Androscoggin, and Sheepscot Rivers in Maine

It is likely that the estuarine complex of the Kennebec, Androscoggin, and Sheepscot Rivers in Maine is the only system in New England which currently supports a spawning population of Atlantic sturgeon. Adults in spawning condition were captured in 1994, 1996, and 1997. Nine adult Atlantic sturgeon were captured in the Kennebec River from 1977 through 1981. Six of the nine adults were captured in the Kennebec River from Merrymeeting Bay to Gardiner. Five of the six were captured in July. One of the two adults which were caught in South Gardiner on July 21, 1978 was expressing milt. Additional insight into the timing of the spawning season for Atlantic sturgeon was obtained from a small commercial fishery that took place on the Kennebec River in South Gardiner near Rolling Dam in 1980. A total of 31 adult

Atlantic sturgeon were captured from June 15, 1980 through July 26, 1980. Of the total, four were females . Of the five sturgeon captured on July 26, 1980, four were ripe males and one was a ripe female. It was of interest that two adults which were tagged by the Department of Marine Resources on July 21, 1978 in South Gardiner were recaptured in this fishery. On July 13, 1994 the Department of Marine Resources captured seven adult Atlantic sturgeon just below the spillway of the Edwards dam in Augusta. Five of the seven were males expressing milt. The seven sturgeon ranged in total length from 156 cm to 195 cm. In the Kennebec River, 52 subadult Atlantic sturgeon were captured in bottom set multifilament gillnets (90m long and 2.4 m deep with 15.2, 17.8, and 20.3 cm stretch mesh) from 1977 through 1981. The average total length was 86.7 cm with a range from 48 to 114.5 cm (a subadult was classified as being less than 130 cm in the Kennebec River). In addition, eight adult Atlantic sturgeon were caught with an average total length of 148.4 (range of 134.5 to 162.5).

No eggs, larvae, young-of-the-year, or age 1 Atlantic sturgeon have been captured but subadults as small as 36.8 cm TL have been captured. 157 Atlantic sturgeon have been captured in the Kennebec River in scientific sampling programs since 1977 (Table 3.2.1). In 1997, a biweekly trawl survey was conducted by Normandeau Associates in the lower Kennebec River. Thirty-one Atlantic sturgeon subadults and one adult were captured from April through November. This compares to 56 adult shortnose sturgeon caught in the same sampling effort. In addition, on September 23, 1997 eighteen subadult Atlantic sturgeon (including two mortalities) and two adult shortnose sturgeon were captured in the Eastern River, a freshwater tidal tributary to the Kennebec River in an overnight set of two 61 m small mesh gillnets. Five additional subadult Atlantic sturgeon (including one mortality) and no adult shortnose sturgeon were captured in an overnight set of two 200 foot small mesh gillnets in the Cathance River, another small freshwater tidal tributary to the Kennebec River. The presence of adult Atlantic sturgeon in ripe condition near head-of-tide during June and July presents strong evidence that a spawning population still exists in the Kennebec River. The presence of subadults ranging in size from 37 cm TL to over 100 cm in both the tidal freshwater tributaries and in the mid-estuary of the Kennebec River from at least April through November provides additional evidence that a population of Atlantic sturgeon still persists in the estuarine complex of the Kennebec River. It appears that subadult Atlantic sturgeon and adult shortnose sturgeon occupy the same section of the estuary during the spring, summer, and fall. Based on the trawling data collected in 1997 by Normandeau Associates during the Bath Iron Works expansion studies, it appears that subadult Atlantic sturgeon occupy deeper water than shortnose sturgeon although there is overlap.

3.2.3.2 Penobscot River

It is possible that a small population of Atlantic sturgeon occurs in the Penobscot River. No systematic sampling has been done in the Penobscot River to determine the presence or absence of Atlantic sturgeon. The Maine Department of Marine Resources (MDMR) conducted a limited sampling effort in 1994 and 1995 in the upper Penobscot River to assess whether there was a population of shortnose sturgeon present. MDMR made 55 sets of 90 meter experimental gillnets (consisting of three panels of 15.2cm, 17.8 cm, and 20.3 cm stretch mesh, #9 thread size) in the Penobscot River for a total fishing effort of 409 net hours . The majority of the fishing effort in the Penobscot River was near head-of-tide. No shortnose sturgeon or Atlantic sturgeon were captured. Based on the fact that very few sturgeon (25 individuals) were captured in the Merrimack River (Kieffer and Kynard 1993) over a four year period and with a tremendous amount of effort (over 5000 net hours) it is possible that a small population of shortnose sturgeon or Atlantic sturgeon could have escaped capture in the Penobscot River. In addition, the sampling was inadequate to assess the presence of Atlantic sturgeon because the mesh sizes would have been selective for subadult Atlantic sturgeon which are commonly found in the lower estuary of larger river systems and the majority of sampling was in the upper estuary.

3.2.3.3 Other Maine Rivers

The geomorphology of most small coastal rivers in the State of Maine is not sufficient to support Atlantic sturgeon populations. There is very little freshwater habitat in the St. Croix River. The salt wedge intrudes almost to the head-of-tide dam (16 km) during the summer months on the St. Croix River (Larsen and Doggett 1979). The salt wedge extends to the base of impassable falls, Machias Gorge, (10 km) on the Machias River. The salt wedge also extended to the base of an old dam (3 km) on the East Machias (Larsen and Doggett 1979) which has been breached. The amount of Atlantic sturgeon habitat above the breached dam is limited. The Saco River has a fairly large drainage area (4403 square kilometers) but very little freshwater habitat is accessible. During the summer months the salt wedge extends up to falls at head-of-tide (10 km) which are and would have been impassable to sturgeon. In summary, most Maine rivers other than the Penobscot and the estuarine complex of the Kennebec, Androscoggin, and Sheepscot Rivers either have impassable falls or dams at or near head-of-tide with very little tidal freshwater habitat available. It is possible that subadult Atlantic sturgeon utilize the estuaries of these smaller coastal drainages during the summer months but no surveys have been conducted to document their presence or absence.

3.2.3.4 Piscataqua River/Great Bay Estuary System

An occasional Atlantic sturgeon (Hoff 1980) has been captured in the Piscataqua River and two captures of shortnose sturgeon have been documented (New Hampshire Fish & Game 1989). A subadult Atlantic sturgeon (57 cm) was captured by New Hampshire Fish & Game in June 1981 at the mouth of the Oyster River in Great Bay (New Hampshire Fish & Game 1981). A survey was conducted by New Hampshire Fish and Game in the deeper tributaries of the Great Bay Estuary including the Piscataqua, Oyster, and Lamprey Rivers as well as Little and Great bays. Between July 1, 1987 and June 30, 1989 a 30.5 m nets (3 m deep with 14 and 19 cm stretch mesh) was fished for 146 net-days at eleven different sampling locations. No shortnose sturgeon or Atlantic sturgeon were captured. A large female Atlantic sturgeon was captured in a small mesh alewife gillnet at head-of-tide in the Salmon Falls River in South Berwick, Maine on June 18, 1990. This Atlantic sturgeon was 228 cm in total length and weighed 98 kg. This specimen contained 15.9 kg of eggs.

3.2.3.5 Merrimack River

Hoover (1938) reported a 104 kg sturgeon taken at Newburyport on September 14, 1938 while netting for blueback herring. An intensive gillnet survey was conducted in the Merrimack River from 1987 through 1990 to determine annual movements, spawning, summering, and wintering areas of both shortnose and Atlantic sturgeon (Kieffer and Kynard 1993). Thirty-six Atlantic sturgeon were captured. The Atlantic sturgeon were all less than 130 cm in total length, with the exception of one Atlantic sturgeon which was 156 cm in total length. The majority were less than 100 cm TL with the average being 95.0 cm TL (range 70.0-156.0 cm). Twenty-five adult shortnose were captured and successful spawning was documented at Haverhill, Massachusetts (river km 32-31). One dead Atlantic sturgeon (approximately 262 cm TL) was found on June 30, 1990 at the shortnose spawning area. The subadult Atlantic sturgeon were spatially separated from the adult shortnose sturgeon with the subadult Atlantic sturgeon inhabiting the lower reach where salinities exceeded 10 ppt and the shortnose sturgeon occupied reaches with salinities of less than 1 ppt. Nineteen subadult Atlantic sturgeon which received sonic transmitters were tracked. Eleven of these fish left the river within 7 days and all left by September or October of each year. Fish captured in one year were not observed in the river in subsequent years. There is no evidence of a spawning population of Atlantic sturgeon in the Merrimack River and it appears that the estuary is seasonally utilized as a nursery area by subadults from other system (Boyd Kynard, personal communication). Between July, 1988 and June 1990, 36 Atlantic sturgeon were captured in the Merrimack River in bottom set multifilament gillnets (Kieffer and Kynard 1993). These nets were 100 m long x 2 m deep with stretched mesh sizes of 12.8, 15.4, 20.5, and 25.6 cm. The average total length of 32 fish measured was 95.0 cm (range from 70-156 cm). Only one of the 32 Atlantic sturgeon captured in the Merrimack River exceeded 130 cm in total length.

3.2.3.6 Taunton River-Massachusetts/Rhode Island

A gillnet survey was conducted in the Taunton River in 1991 and 1992 to document the use of this system by sturgeon. No shortnose sturgeon were captured but three subadult Atlantic sturgeon were captured (Burkett and Kynard 1993). The authors concluded that a spawning population of Atlantic sturgeon was not likely to be present in the Taunton River and that the three subadult Atlantic sturgeon were likely non-natal fish (Burkett and Kynard 1993).

3.2.3.7 Pawcatuck River

No information is available. Atlantic sturgeon are not believed to be present except for occasional seasonal visits by immature subadults. A 126 lb. 6'4" sturgeon was taken 7 miles up the Pawcatuck River below the Stillmanville Bridge during October 1955. Examination of the ovaries demonstrated only a few small eggs.

3.2.3.8 Thames River

Subadult Atlantic sturgeon have been captured in the estuary (Whitworth 1996) but it is unlikely that a spawning population is present. The salt wedge extends almost to the head-of-tide dam on the river.

3.2.3.9 Connecticut River

Galligan (1960) described the fishery in the Connecticut River as taking place in June through August and utilized both drift gillnets (30.5 to 34 cm stretched mesh, approximately 122 m long and 4.5 to 6.0 m deep) and haul seines. Average size was reported as 90-136 kg for females and 40-61 kg for males. The average roe sturgeon produced 27 kg of caviar (Galligan 1960). Cobb (1895) reported similar mean weights from the Chesapeake area with live weights of female at 350 lbs and males at 65 lbs. He also noted average dressed weights of female at 100 lbs and males at 35 lbs. Scott and Crossman (1973) also state that Atlantic sturgeon dress out to only 40-50% of live weight. They also list a 352 lb female yielding 91 lbs of eggs so that Galligan's 1960 numbers are reasonable. Morton Thompson was somewhat displeased with Galligan's 1960 account and reported to the Hartford Courant that Atlantic sturgeon up to 272 kg were taken by members of his family in the late 1800's. Other reports documenting occasional catches with verification of size are as follows:

> June 12, 1895 While waiting for the Shore Line bridge for the draw to open about 15 years ago had a sturgeon jump into the boat. At the steamboat dock in Essex the fish weighed between 300 and 400 pounds
>
> June 15, 1917 an Atlantic sturgeon 9 feet long yielded 81 pounds of eggs which brought $2.75/lb (Putnam 1991).
>
> June 12, 1925. Report of a 250 pound sturgeon caught in the East Haddam reefs above the East Haddam Bridge by two shad fishermen. Two employees of the U.S. Bureau of Fisheries happened to be in the boat with the fishermen at the time.

An acquaintance related first hand observations (to T. Savoy) of a single fisherman who routinely fished for Atlantic sturgeon in the Haddam area of the Connecticut River in the early 1940s. Interestingly, similar to historical accounts from the turn of the century, this individual would not set his nets until he visually observed a sturgeon “blow”.

A large sturgeon was reported as destroying a shad net on June 8, 1945 with a Portland resident reporting seeing the largest fish he had ever seen in the river at the point near the highway bridge.

The reach below the Haddam bridge produced another large roe fish in 1953.

May 29, 1956 Hartford Courant documents a 9' sturgeon caught the previous Saturday that weighed 450 lbs. Caught by the two shad fishermen in the Brockways reach in the lower river, the fish was loaded into a pickup truck and driven to the Fulton Market in New York.

Six juvenile fish (20-25 lbs class) were reported taken opposite Haddam Meadows in 1959, but it is possible (based on size) that these fish may have been shortnose sturgeon.

As late as the 1980's, the two Connecticut fisheries staff reported occasional visual observations of Atlantic sturgeon below the Enfield Dam during May and June.

From 1988 through 1997 the Connecticut Department of Environmental Protection conducted research efforts to determine the abundance, locations, and seasonal movement patterns of shortnose sturgeon in the Connecticut River. The gillnets that were utilized ranged from 4 to 7 inch stretch measure. This mesh size is appropriate for the capture of subadult Atlantic sturgeon. A total of 99 Atlantic sturgeon were collected in the lower Connecticut River from 1983 through 1997 during these studies (Table 3.2.3). These subadult Atlantic sturgeon ranged in length from 67.0 - 99.0 cm FL (Savoy 1996). These sturgeon were usually found in the lower river (km 10-26) within the area of the salt wedge during the summer months (Savoy and Shake 1993).

Stocks of Atlantic sturgeon native to Connecticut waters are believed to be extinct based on the lack of evidence of spawning adults (Savoy 1996). While directed research efforts have not been carried out, it is believed that seasonal presence of a viable spawning stock of Atlantic sturgeon in the upper Connecticut River would have been observed by fisheries staff given the fairly intensive level of monitoring occurring there. Occasional reports, sightings, and capture of large fish (5-10 ft) are made, but most Atlantic sturgeon captured within the tidal or freshwaters of the State of Connecticut are consistent with the size and seasonal locations of immature Atlantic sturgeon from the Hudson River (Savoy 1996). Yet the occasional presence of large fish is tantalizing and does not allow definitive statements concerning stock status.

3.2.3.10 Housatonic River

Subadult Atlantic sturgeon have been captured in the estuary of the Housatonic River (Whitworth 1996). A spawning population is not believed to be present.

3.2.4 Factors Affecting Abundance

Loss of habitat, overfishing, and water quality were probably the major factors leading to the decline of Atlantic sturgeon. The importance of each factor likely varied from river to river. The impacts due to dam construction and to some extent overfishing in New England occurred prior to the establishment of resource agencies and the recording of landings.

3.2.4.1 Penobscot River

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

The population of Atlantic sturgeon in the Penobscot River, based on recent gillnet surveys, is likely to be at an extremely low level or extirpated. A significant amount of habitat was lost in the early 1800's with the construction of impassable dams at head-of-tide and above. The recent breaching and removal of the head-of-tide Bangor Dam allows Atlantic sturgeon access to the base of Veazie Dam, a gain of 5.0 km. Water quality was very severely degraded until just recently. Dissolved oxygen levels reached 0 ppm in the estuary during the summer months in the late 1960's (Hatch 1971). These low dissolved oxygen levels occurred at the area of transition from fresh to saltwater (salinities 0 to 10 ppt) which is an area important to subadult Atlantic sturgeon in other river systems. Dissolved oxygen levels improved significantly in the late 1970's and 1980's 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. 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) is limited. It is likely that the freshwater tidal zone is as severely impacted from organic debris loading as the mid estuary (Metcalf & Eddy 1994). A coal tar deposit has been discovered in the tidal section of the Penobscot River in Bangor. The impact of this coal deposit on the local benthic and finfish communities is unknown.

Dioxin has been found in fish samples collected in the Penobscot River (Mower 1993).

The suspected sources are the waste water discharges from pulp and paper mills and municipal wastewater treatment plants. The presence of dioxin in finfish is not unique to the Penobscot River in the State of Maine and its impact on finfish has not been assessed.

Overutilization for commercial, recreational, scientific, or educational purposes

3.2.4.2 Estuarine Complex of the Kennebec, Androscoggin, and Sheepscot Rivers in Maine

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

A status review was recently completed by the National Marine Fisheries Service for shortnose sturgeon in the Androscoggin and Kennebec Rivers (NMFS 1996). The findings of this status review are also relevant to Atlantic sturgeon. This status review concluded that the major threats to shortnose sturgeon in this estuarine complex included the direct and indirect modification of habitat due to hydroelectric facilities, the introduction of pollutants (via municipal sewage treatment plants, paper mills and other industrial discharges) and channel dredging. (NMFS 1996).

The Edwards Dam project located on the Kennebec River at head-of-tide has the greatest impact of the two head-of-tide dams (Androscoggin and Kennebec Rivers) by denying Atlantic sturgeon access to their historical habitat. The historical upriver limit of Atlantic sturgeon was at Ticonic Falls in Waterville approximately 27 km upriver of the Edwards Dam. Continuing impacts from this dam include the diversion of flows from the spillway to the powerhouses. The Federal Energy Regulatory Commission staff recommended removal of the Edwards Dam in part because of the benefits of increasing the restoration potential for Atlantic sturgeon by improving the chances for spawning success (FERC 1997). Initially, the FERC staff had recommended minimum flow of 4500 cfs to be released at the spillway during July to enhance Atlantic sturgeon spawning habitat (FERC 1995). The FERC Commission voted to remove the Edwards Dam and the decision is currently under appeal by the dam owner. The Maine Department of Marine Resources captured adult Atlantic sturgeon in spawning condition at the base of Edwards Dam in 1994.

The Brunswick Hydroelectric Dam is located at the head-of-tide on the Androscoggin River. It is unlikely that Atlantic sturgeon ever migrated above this site due the presence of a natural falls. Spawning of shortnose sturgeon has been documented occurring directly the below the dam (Squiers 1993). No studies have been conducted to assess whether Atlantic sturgeon are presently utilizing the Androscoggin River for spawning. The only documented occurrence of Atlantic sturgeon in the Androscoggin River in recent years is an adult Atlantic sturgeon captured

and released approximately 1000 m downstream of the Brunswick Dam in 1975. There are no minimum flow requirements at the Brunswick Hydroelectric Dam. The Brunswick Hydroelectric Dam has very little storage capacity, so the project is not able to modify river flows to any great extent.

Like the Penobscot River, water quality in the Kennebec and Androscoggin Rivers was very severely degraded until just recently. Dissolved oxygen levels reached O ppm in the estuary during the summer months in the late 1960's and early 1970's. These low dissolved oxygen levels occurred from head-of-tide in both rivers to the mid estuary. Fish kills were common in both rivers. 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 severe up 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 river was severely degraded up until the late 1970's. The bottom in the tidal freshwater sections of both the Androscoggin and Kennebec Rivers was covered with wood chips, sawdust and organic debris. This accumulation was quickly flushed from the river systems with the cessation of log drives and the construction of water treatment plants.

Dioxin has been found in fish samples collected in the Kennebec and Androscoggin Rivers (Mower 1995). The suspected sources are the waste water discharges from pulp and paper mills and municipal wastewater treatment plants. The levels of dioxin found in fish has declined significantly since sampling was initiated in 1984. The Androscoggin River has had the highest levels of dioxin levels in fish in the State of Maine followed by the Kennebec River. Levels of tetrachlorodibenzo-p-dioxin (2,3,7, 8 TCDD) which were as high as 10 to 12 ppt in 1984-1986 in fish sampled from the Androscoggin and Kennebec Rivers have dropped to 2 to 3 ppt in 1994 (Maine DEP 1997). The discharge of dioxin into Maine river systems has 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 - all 17 dioxin congeners. No Atlantic sturgeon nor shortnose sturgeon from these two rivers systems have been sampled for contaminants.

The Maine DEP has conducted limited testing for heavy metals, PCBs, and organochlorine pesticides in the tidal waters of the Kennebec River. No Atlantic sturgeon or shortnose sturgeon have been tested. Mercury levels were above levels which were considered safe for human consumption in all Maine rivers and streams tested including the Kennebec River and also exceeded levels reported in the literature as harmful to wildlife (Sowles et al. 1997). PCBs were found at levels higher than EPA’s screening value in both striped bass and bluefish from the Kennebec River in 1995 although at levels much lower than the EPA’s national median level (Sowles et al. 1997).

The US Corps of Engineers (Corps) conducts dredging operations in the lower Kennebec

River to facilitate movement of Navy ships to Bath Iron Works (BIW) in Bath. Maintenance dredging is also conducted by BIW around its docking facilities. Historically, the Kennebec River has also been dredged along Swan Island, at Gardiner, and Hallowell to Augusta. The upriver sites are all located in tidal freshwater habitat. No channel maintenance dredging above Bath has been performed since 1963. There are no federal navigation projects in the Androscoggin River. The state and federal resource agencies have recommended seasonal restrictions for past dredging activities in the Kennebec River. Past recommendations have restricted dredging activities to the time period November 1 to April 1. This time restriction was recommended for the time of year when the least number of anadromous fish species would be present with special emphasis on shortnose sturgeon. One concern that the Maine Department of Marine Resources had in the past was that one of the dredge spoils sites located at Bluff Head downriver of Bath was in a potential overwintering area for shortnose sturgeon. Recent sonic tracking of adult shortnose sturgeon has shown that shortnose sturgeon overwinter upriver in Merrymeeting Bay in the tidal freshwater section and not downriver as had been previously suspected (Squiers and Robillard 1997). There are no data on the overwintering habitat for subadult Atlantic sturgeon. A recent trawl survey in Kennebec River, conducted to assess the impact of proposed expansion of Bath Iron Works, captured subadult Atlantic sturgeon from 4/17/97 (the first date of sampling) to 11/17/97. No subadult Atlantic sturgeon were captured in December 1997, January 1998, or February 1998. It is not known whether the subadult Atlantic sturgeon exhibit a migratory pattern similar to adult shortnose sturgeon or whether they might overwinter in the estuary below Bath or leave the river system.

Overutilization for commercial, recreational, scientific, or educational purposes

No reported bycatch of Atlantic sturgeon has been reported or observed within the estuarine complex of the Kennebec and Androscoggin Rivers. There are no major commercial fisheries occurring in this complex. The use of purse, drag, and stop seines is prohibited. The use of gillnets is prohibited with the exception of gillnets which do not exceed a maximum stretch mesh measure of 3 ½ inches for the taking of menhaden, alewives, blueback herring, sea herring, and mackerel. 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 is no documented record of Atlantic sturgeon being caught incidentally in any recreational fishery although there is the occasional story of recreational anglers foul hooking large Atlantic sturgeon.

A special license is required by the Maine Department of Marine Resources for any entity to conduct scientific studies which would take species in violation of any law or regulation or to use prohibited gear. No licenses have been allowed in the Kennebec River which would allow the lethal take of Atlantic sturgeon. In 1997, Normandeau Associates was granted a license for a finfish sampling program in the lower Kennebec River. Thirty-one Atlantic sturgeon subadults and one adult were captured in a trawl and released alive. In 1997, three mortalities of subadult Atlantic sturgeon occurred in gillnets set by MDMR to collect finfish for a dioxin monitoring study. From 1977 through 1997, a total of 20 mortalities of subadult Atlantic sturgeon occurred in MDMR sampling programs out of a total catch of 117 subadults (Table 3.2.3.1). 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. While the loss of 20 subadult Atlantic sturgeon over 20 years is not a threat to the Atlantic sturgeon population in the Kennebec River, researchers need to be cognizant of the fact that the mortality rate of subadult Atlantic sturgeon in gillnets set overnight can be relatively high.

Coastal Bycatch: The MDMR tagged and released 41 subadult and nine adult Atlantic sturgeon in the Kennebec River from 1977 through 1981 (Table 3.2.3.1). Three of the tagged subadults were recaptured outside the system. One tagged subadult Atlantic sturgeon was recaptured in a fish trap in November 1979 off Newport. R.I. , two years after it was tagged. The second subadult was recaptured twice within two days; it was caught and released from a gill set one mile offshore of the NH/MA border on December 2, 1982 by Normandeau Associates and was caught again in a commercial gillnet near Isles of Shoals, N.H. on December 4, 1982. This fish had been tagged on May 12, 1978. The third subadult was tagged on October 3, 1980 and was recaptured in the same aforementioned commercial gillnet near Isles of Shoals, N.H. on December 2, 1982.

3.2.4.3 Merrimack River

<u>Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range</u>

Presently it appears that there is not a population of Atlantic sturgeon reproducing in the Merrimack River. There is no evidence of a spawning population of Atlantic sturgeon in the Merrimack River and it appears that the estuary is seasonally utilized as a nursery area by subadults from other system (Kynard, personal communication). There is a significant amount of tidal freshwater (19 km) and riverine freshwater habitat (10 km) accessible to Atlantic sturgeon. There are no known water quality limitations which might impact the use of the available habitat (Iwanowicz, personal communication). The bottom substrates appear suitable for Atlantic sturgeon spawning and nursery habitat based on a detailed description by Kieffer and Kynard (1993). There are no major projects proposed such as dredging which impact the habitat. Dredging is limited to the mouth of the river (Iwanowicz, personal communication).

Table 3.2.1 Number of Atlantic sturgeon captured during research and monitoring programs on the Kennebec River, ME, 1977-1997.

	Atlantic sturgeon <120 cm TL				Atlantic sturgeon >120 cm TL			
			Released				Released	
Year	Captured	Tagged	Untagged	Mortalities	Captured	Tagged	Untagged	Mortalities
1977	7	6		1	2	2		
1978	3	2		1	5	5		
1979	25	19		6	1	1		
1980	13	10		3	1	1		
1981	7	4		3	0			
1993	1		1		0			
1994	0				7	6	1	
1995	4		1	3	0			
1996	2		2		10	8	2	
1997	55		52	3	14	10	4	
Totals	117	41	56	20	40	33	7	0

Table 3.2.2 Mean fork length at age, sexes combined for Atlantic sturgeon collected in the Kennebec River, ME, 1977-1982.

		Mean Fork	Range		
Age	Number	Length (cm)	Minimum	Maximum	SD
3	2	57.8	55.5	60.0	3.18
4	6	67.1	56.5	74.0	5.91
5	9	72.4	63.5	92.8	8.58
6	9	87.4	81.2	98.7	6.65
8	2	95.0	93.6	96.3	1.91
10	2	126.0	117.5	134.5	12.02
11	1	124.2			
17	2	157.8	150.5	165.0	10.25
18	1	160.0			
20	2	151.4	145.7	157.0	7.99
22	4	149.5	132.7	168.0	15.31
23	1	170.2			
25	5	172.2	157.5	193.0	13.37
28	1	157.0			
31	1	180.0			
34	1	208.3			
36	1	193.0			
40	3	176.0	144.8	208.0	31.62

Table 3.2.3 Landings (lbs.) Of Atlantic Sturgeon from Long Island Sound (LIS) and Research Catches (Numbers) from Connecticut Waters From 1984 to 1997 (CT DEP unpub.).

Year	Commercial Landings from LIS	DEP Collections	
		LIS	Connecticut River
1983			15[1]
1984		11	
1985		3	
1986		6	
1987		6	
1988		5	24
1989	1445[2]	1	6
1990	1585	8	8
1991	2205	11	31
1992	160[3]	30	5
1993	182	60	2
1994	310	60	2
1995	698	6	2
1996	175	62[4]	2
1997	0[5]	6	2
Total to date		288	99

1. Taken from Buckley
2. Prior to 1989, Atlantic sturgeon did not have a species code for CT Logbook Reports.
3. Increase in minimum total length from 48" to 84".
4. Two from regular CT DEP LIS Trawl Survey, 60 from LIS Atlantic Sturgeon Investigation.
5. Moratorium on Atlantic sturgeon effective 06/24/97

Overutilization for commercial, recreational, scientific, or educational purposes

There are no commercial fisheries in the Merrimack River which might take Atlantic sturgeon as bycatch (Russell Iwanowicz, personal communication).

3.3 Hudson River by A. Kahnle, K. Hattala and K. McKown

Atlantic sturgeon of the Hudson River Estuary have supported some level of subsistence or commercial fishing since colonial times. Reported commercial landings of Atlantic sturgeon are available for New York State from 1880 through 1996. Until about 1980, most of the New York landings came from the Hudson River. Highest annual landings of the time series (231,000 kg) occurred in 1898 (Figure 3.3.1). Landings quickly dropped to 15,000 kg or less per year and remained at low levels through the early 1980's. In 1985, South Carolina closed one of the few active fisheries open in the southern states. Market demand remained high and effort and harvest increased substantially in New York and New Jersey (Figure 3.3.2). The greatest increase in landings was in the nearshore ocean along Long Island and the New Jersey coast.

In 1990, the Atlantic States Marine Fisheries Commission adopted an interstate fishery management plan for Atlantic sturgeon (ASMFC 1990). New York and New Jersey were required to monitor harvest. In addition, New York initiated population modeling to determine acceptable levels of harvest from the Hudson River stock. In 1993 through 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 (Section 3.3.3.5). New York implemented a harvest moratorium in 1996. New Jersey followed with a zero quota in the same year.

3.3.1 Description of the Estuary

The lower portion of the Hudson River is a tidal estuary which extends 246 km north of the Battery in New York City to the Federal Dam at Troy (Figure 3.3.3). The first 40 km of the river is a relatively narrow and deep channel. To the north lie two large, shallow “bays”, the Tappan Zee and Haverstraw Bay (km 40 through km 65) which are up to 5.5 km wide. The river narrows and deepens north through the Highlands followed again by another wide shallow reach at Newburgh Bay (km 90 through 105). A long stretch of deep water extends north from there to Kingston (km 146). From Kingston north to the Federal Dam at Troy (km 246), the river averages about a kilometer wide and gradually becomes more shallow with numerous shoals bordering the channel.

A commercial shipping channel is maintained at 9.75 m depth (at mean low water) for nearly the entire length of the estuary to the Port of Albany (km 233). Tidal range varies by river section from a maximum of 1.5 m at Kingston to a minimum of 0.7 m at Haverstraw Bay (U.S. Department of Commerce 1994). Tidal currents are strong. Mean ebb currents vary with location and range from 0.4 to 1.1 m/sec (U.S. Department of Commerce 1994). The location of the salt

front (measured as the northern edge of salinity at 1 ppt) varies seasonally with freshwater inflow. In dry years, the salt front generally reaches as far north as Newburgh Bay during the summer, but occasionally as far north as Poughkeepsie (km 122).

3.3.2 Life History and Biology

Dovel and Berggren (1983) and Van Eenennaam et al. (1996) provided information on spawning activities of Atlantic sturgeon in the Hudson River Estuary. Based on presence of spent or partially spent females, Dovel and Berggren (1983) reported that spawning occurred above the salt front in deep water from Croton Point (km 56) through Hyde Park (km 135). They suggested that spawning moved north as temperatures increased and the salt front moved upriver. Van Eenennaam et al. (1996) used oocyte development to identify females in spawning condition. They reported that spawning occurred from Hyde Park (km 135) through Catskill (km 181). Dovel and Berggren (1983) observed that mature males entered the river in April when water temperatures reached 6°C. Females appeared several weeks later in May when temperatures reached 13°C. Spawning continued into the summer months. Dovel and Berggren (1983) reported that females returned to the ocean after spawning whereas some males stayed for several months into early fall (October or November).

Early life stages of Atlantic sturgeon have been rarely collected in the Hudson River Estuary. Utility Company sampling programs obtained the greatest number of specimens (Section 3.3.3.1, Figure 3.3.4, CONED 1997). These specimens indicate that the spring/summer nursery area for age zero fish is located from Newburgh Bay (km 90) through Kingston (km 146). This reach overlaps the southern part of the suspected spawning area. Catches of immature sturgeon (age 1+ and older) suggest that juveniles utilize the estuary from the Tappan Zee (km 40) through Kingston. Yearling and older juveniles remain in the river several years before emigrating to the ocean (Dovel and Berggren 1983).

Atlantic sturgeon travel widely once they emigrate from the Hudson Estuary. Dovel and Berggren (1983) tagged sub-adult Atlantic sturgeon in the Hudson River Estuary in 1975 - 1978. Recaptures occurred from estuaries and the near-shore ocean from Marblehead, MA to Ocracoke, NC.

Two studies provide estimates of length at age for Atlantic sturgeon of the Hudson River Estuary (Tables 3.3.1 and 3.3.2). Both used cross sections of fin rays for estimates of age. Dovel and Berggren (1983) reported on data collected from 1976 through 1978. Sturgeon were zero through 29 years old. Sample size ranged from one to 40 fish per age. Largest sample sizes were from ages two through four. Van Eenennaam (personal communication) shared data from Atlantic sturgeon sampled in 1992 - 1994. These fish were five through 40 years old. Sample sizes ranged from one to 31 fish per age. Largest samples were from ages 12 - 18. Van Eenennaam's data were reported by sex and were from fish in the Hudson River and the near-shore ocean of the New York Bight. Mean length at age and maximum age for older fish were different for males and females. Length at age was similar for males and females for younger fish. Data from Dovel and Berggren (1983) were from fish from the Hudson only and were for sexes combined.

We developed Von Bertalanffy growth curves for males and females separately using data from Dovel and Berggren (1983) for ages one through four (sex not identified) and Van Eenennaam's data segregated by sex for ages six and older (Figure 3.3.5). Resulting parameters for males were: $L\infty = 242.4$ cm; $k = 0.082$; and $t_0 = -1.431$. For females they were: $L\infty = 272.6$ cm; $k = 0.076$; and $t_0 = -1.057$. Female estimates presented a problem in that several females harvested in the river were larger than those included in VanEenennaam's study. We estimated growth curve parameters a second time by fixing $L\infty$ equal to 280 cm (length of the largest fish harvested) resulting in a change to $t_0 = -0.861$.

Maturity at age remains poorly documented for Atlantic sturgeon of the Hudson River Estuary. The youngest mature male observed by Dovel and Berggren (1983) was 12 years old. The youngest female was 18 or 19 years old. The youngest mature female observed by Van Eenennaam et al. (1996) was 14 years old. However, if ages are estimated using growth curves for fish harvested in the River (Section 3.3.3.2) , results suggest that females as young as age 10 enter the River. Van Eenennaam et al. (1996) reported that males in the spawning population in 1992 and 1993 were an average of 15 years old (Table 3.3.3). Mean age of females was 20. Dovel and Berggren (1983) reported that most mature males were 1.2 - 2.0 m long and 5.4 - 47.6 kg in weight. Most females were 1.8 - 2.4 m long and 40 - 116 kg. Van Eenennaam et al. (1996) reported that mean total length of males in the spawning population was 182 cm; that of females was 218 cm. Mean weight of males was 37.3 kg; that of females was 72.7 kg.

Information on the reproductive cycle of Atlantic sturgeon of the Hudson River Estuary is incomplete. Van Eenennaam et al. (1996) suggested that males spawn annually once mature, but that the ovarian cycle of females might be greater than a year.

Van Eenennaam et al. (1996) estimated fecundity of female Atlantic sturgeon harvested in the Hudson River fishery in 1992 and 1993. They found that fecundity increased with fish size and age (Table 3.3.4). Fecundity ranged from 0.49 million eggs (ages 15-17) to 1.67 million eggs (ages 24-29). Highest individual fecundity observed was 2.6 million eggs (J. Van Eenennaam, personal communication). We plotted a polynomial curve of fecundity on age for ages 15 to 40 from data provided by Van Eenennaam. We chose the fecundity estimates from the positive ascending portion of the curve (ages 14 to 34) and then assumed that fecundity for younger (<age 14) and older fish (>age 34) was age invariant at the estimated values for ages 14 and 34 (Figure 3.3.6). Our estimates are considered conservative and are subject to further review.

3.3.3 Current Status

Fishery dependent and fishery independent data are available to characterize segments of the Hudson's Atlantic sturgeon population since the early 1970's.

3.3.3.1 Absolute and Relative Abundance of Immature Atlantic Sturgeon

Two population estimates of immature Atlantic sturgeon are available for the Hudson River stock. The first was made by Dovel and Berggren (1983) who sampled and marked immature fish from 1976 through 1978. Estimates varied with data used, but ranged from 14,500 - 36,000 animals (mean of 25,000) for the 1976 year class at age one (Table 3.3.5). In the spring of 1994, the US Fish and Wildlife Service successfully obtained and fertilized Atlantic sturgeon eggs from Hudson stock adults. In October of 1994, NY State Department of Environmental Conservation allowed the stocking, on an experimental basis, of a portion of this progeny (4,929 marked age zero fish) into the Hudson Estuary at Newburgh Bay. The reason for this experimental stocking was to estimate current juvenile abundance. In 1995, Cornell University sample crews found 15 marked and 14 wild Atlantic sturgeon of the 1994 year class (Peterson 1998). A simple Peterson population estimate from these data suggest that there were 9,529 age zero Atlantic sturgeon in the Estuary in 1994. Since 4,929 were stocked, 4,600 were of wild origin. This was a substantial decline from abundance of the 1976 year class. No data are available on the historical variation in abundance of juvenile Atlantic sturgeon in the Hudson Estuary.

Several sample programs provide data on changes in relative abundance among years of immature Atlantic sturgeon in the Hudson River Estuary. None of these programs were designed to sample Atlantic sturgeon. However, all data sets show a similar decrease over time.

1. NYSDEC Surveys

Commercial Fishery Bycatch Monitoring: The commercial gillnet fishery in the Hudson River Estuary exploits the spawning migration of American shad. Young (<1000 mm) Atlantic sturgeon are caught as bycatch. Shad fishing usually begins in early April and continues until May. Most Atlantic sturgeon are caught in fixed gillnets fished from km 40 to km 70 (Piermont to Peekskill). Few are caught in the drifted gillnet fishery for shad that occurs from km 98 to km 182 (Newburgh Bay to Catskill).

We have monitored the commercial fishery annually since 1980. Information is obtained by onboard observers. Data are recorded on numbers of fish caught, gear type and size, fishing time and location. C/f is calculated as the number of fish collected per yd^2 x hrs x 10^{-3} of net fished. Annual c/f data were summarized as total observed catch/total observed effort.

C/f of Atlantic sturgeon in the bycatch was highest in the early 1980's and steadily decreased through the present (Figure 3.3.7, Table 3.3.6).

Bottom Trawl: From 1982 through 1990 and 1993, NYSDEC sampled abundance of juvenile fish in Haverstraw Bay and the Tappan Zee. Bottom trawl collections were made at fixed locations in shoal areas (<9m) of the lower estuary (km 45-64). Sampling occurred during the day on alternate weeks from July through early November. Collections were made with a 7.9 m headrope Carolina wing trawl towed for five minutes against the prevailing current. Catch data were reported as number of fish per haul.

C/f of immature Atlantic sturgeon showed the same trend as that noted in the commercial shad fishery. C/f effort began relatively high in 1982 and declined quickly to zero by 1990 (Figure 3.3.7, Table 3.3.6).

2. Utility Company Surveys.

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 annual reports (CONED 1997). The two surveys regularly catch sturgeon. Hatchery fish, stocked in the fall of 1994 (Absolute abundance section above) have not been collected in either survey.

Long-River Survey (LRS): This measure of relative abundance of juvenile Atlantic sturgeon has been obtained in the Hudson River Estuary since 1974. The LRS samples ichthyoplankton river-wide from the George Washington Bridge (km 19) to Troy (km 246) using a stratified random design (CONED 1997). Ichthyoplankton is sampled from all strata (shoals, bottom and channel). Gears are a one-meter epibenthic sled or a one-meter Tucker trawl. We calculated an annual index for Atlantic sturgeon from epibenthic sled data for the bottom strata from May through July, when most Atlantic sturgeon were collected. C/f is expressed annually as number of fish per haul.

Fall Shoals Survey (FSS): Two relative abundance indices of juvenile Atlantic sturgeon have been obtained annually from this program. For the period 1974 through 1984, the shoals in the entire river (km 19 - km 246) were sampled by epibenthic sled. In 1985, gear was switched to a three-meter beam trawl. We calculated an annual index from data for July through October for both programs as number of fish per haul. This time period bracketed the most consistent presence of Atlantic sturgeon in the data set.

Indices from Utility surveys indicated the same trend as in NYSDEC data. The spring LRS index was relatively high in 1974 and 1975. It declined through the late 1970's, increased slightly through 1984, then declined through the present (Figure 3.3.8, Table 3.3.6). A similar trend was evident in the fall sled data. Highest c/f in the beam trawl index were in 1984 through 1989. Catches decreased dramatically in 1990 and remained relatively low through the present.

Length data are available from the FSS beam trawl sampling for 1989 through the present. Measured fish ranged from 0.1 to nearly 1.0 meter TL. Most were less than 700 mm TL. We used data from Dovel and Berggren (1983) and Van Eenennaam to partition length data into age classes (age 0 = 100-240 mm, age 1 = 240-420 mm, age 2 = 420-580) (Figure 3.3.9). It appears that relative abundance data includes ages zero, one, and two. In some years, one or two year classes dominated the index (the 1988 and 1989 year classes in 1990 and the 1991 year class in 1991). Some age zero fish were also observed in 1996.

Very limited length data were obtained from the LRS spring survey in 1993 to 1995 (J. Young, personal communication) . These data suggest that about the same size and presumably the same age fish were taken in this gear as in the beam trawl.

3. New Jersey Bureau of Marine Fisheries Trawl Survey

The New Jersey Bureau of Marine Fisheries conducts an annual bottom trawl in the state’s near-shore ocean waters. Data are available since 1988. Most Atlantic sturgeon are taken in samples in the northern part of the state in and around Sandy Hook Bay, just below the mouth of the Hudson River. It is suspected that these fish are of Hudson origin. Fish range in size from 69 to 205 mm, most are 75 to 105 mm (Table 3.3.7). Highest catches occur during April (Table 3.3.8). Annual trends indicate that c/f was fairly consistent from 1989 through 1993, declining greatly in 1992 to the present (Table 3.3.8).

3.3.3.2 Characteristics of Atlantic Sturgeon in Commercial Harvest

Data on Atlantic sturgeon in the recent commercial fishery were obtained by direct onboard observation and from various harvest reports. National Marine Fisheries Service (NMFS) reported landings annually through 1992. Landings from 1993 through 1995 in New York and New Jersey were compiled from mandated state catch reports or diaries from selected commercial fishermen. 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.

Commercial harvest in New York was regulated by a 152 cm TL minimum size limit, season and area closures, gear restrictions, and finally by quotas. Harvest in New Jersey was regulated by a 107 cm size limit through 1992 and a 152 cm size limit starting in 1993. New Jersey also added limited entry and eventually a quota in 1993.

The commercial fishery harvested different sturgeon life stages in the River and ocean. The Hudson River fishery targeted mature fish during the spawning run for both caviar and meat. The ocean fishery along Long Island and New Jersey targeted smaller fish. Most were immature coastal migrants but a few were non-spawning mature adults. For both NY and NJ, the number of harvested fish were estimated from the reported weight of the total harvest divided by average weight per fish harvested at a 152 cm size limit in 1994 and 1995. This estimate of number harvested is biased low prior to 1993 because the NJ size limit was 107 cm at that time and smaller, lighter fish were taken.

Ocean catch dominated the total harvest in most years from 1980 to 1995 (Figure 3.3.10, Table 3.3.9). River harvest peaked in 1990 at about 17,700 kg or 590 fish. Ocean harvest also peaked in 1990 at about 103,000 kg or 6,153 fish (Table 3.3.9). Available evidence suggests that most (>90%) of the Atlantic sturgeon harvested in the New York Bight were of Hudson River origin (Waldman et al. 1996).

Hudson River Harvest: Estimated mean total length and live weight for harvested female Atlantic sturgeon were 220.4 cm and 75.6 kg for the period 1991 to 1995 (Table 3.3.10). Males were smaller with means at 183.9 cm TL and 37.2 kg. A wide size range of females (152 to 279 cm TL) were taken. Most were 190 cm to 230 cm TL (Figure 3.3.11, Table 3.3.11). In contrast, most males were 160 cm to 205 cm.

Ocean waters - NY: Estimated mean total length and live weight of sturgeon in the ocean harvest was 164.5 cm and 20.1 kg for the period 1993 to 1995 (Table 3.3.12). Length frequencies show that harvest targeted a smaller size range than was taken in the Hudson Estuary. Most fish in the ocean harvest were 150-160 cm TL (Figure 3.3.12, Table 3.3.12).

Ocean waters - NJ: Length frequencies for fish harvested in New Jersey coastal waters show that in 1992, harvest targeted a wide size range of fish, but most were small between 106 to 152 cm TL (Figure 3.3.13, Table 3.3.13). In February 1993, NJ increased the size limit to 152 cm. Fish harvested in 1993 and 1994 were similar to that taken in New York ocean waters.

3.3.3.3 Mortality Estimates

Total instantaneous mortality (Z) rates were calculated by sex for fish in the spawning stock in 1993-1995 from catch at age data following the method outlined by Crecco and Gibson (1988) . Ages were estimated from length of fish in the River harvest and Von Bertalanffy growth curves (Section 3.3.2).

Sample sizes of age for females were inadequate for annual estimates so data were pooled over the three year harvest. Age estimates generated by the growth curve greater than age 50 are suspect as no fish greater than age 40 has been collected in recent years (Figure 3.3.14).

Estimates of Z were made for two sets of ages to identify major changes in survival with age. When Z was calculated for harvested females of estimated ages 17 through 48, Z = 0.08. However, this Z estimate was driven by one data point at age 48, R^2 = 0.58. When Z was calculated for ages 17-35 or 17-27, Z increased to 0.15 and 0.20. Sample sizes were adequate for annual estimates for males. Estimates were Z = 0.26 for 1993, Z = 0.31 for 1994, and Z = 0.22 for 1995 (Figure 3.3.15).

3.3.3.4 Target Fishing Rate and Potential Yield

We used yield per recruit (YPR) and egg per recruit (EPR) models to estimate a target fishing rate (F) and potential yield in number from recent age one abundance (recruitment) estimates. We assumed Atlantic sturgeon lived 60 years with limited fishing; sturgeon recruited to the fishery at a 1.5 m TL minimum size (females age nine and males age 10); natural mortality (M) was 0.07 (Appendix C, formula 4); and spawning occurred every three years after the age of full maturity. The target fishing rate was defined as that level of F that generated an EPR equal to 50 percent of the EPR at F = 0.0. This rate was F = 0.03 (Table 3.3.14). The YPR (number) at this value was 0.19. Lifetime yield from the 1976 year class (25,000 animals at age one) would be 4,751 fish (Table 3.3.14). The abundance of the 1994 year class was estimated at 4,600 wild fish at age zero. If one advanced this to the next age with a M of .07 we get an estimate of 4,278 fish age one. Life time yield from this year class would be 813 fish. See Appendix C for a more complete description of the methodology.

3.3.3.5 Stock Status

Current Fishing Rates Given that Z = M + F, estimates of Z and assumed values of M can be used to generate estimates of F. We used an age invariant estimate of M=0.07, estimates of F for females in 1993-95 were 0.01, 0.08, and 0.13 depending on ages selected for estimates of Z. Estimates of F for males were 0.19, 0.24, and 0.15 in 1993, 1994, and 1995. Two of three estimates for female and all estimates for males exceeded the target fishing rate of 0.03 (Section 3.3.3.4).

Levels of Harvest Most of the fish in the harvest were 150 -160 cm TL. We estimated that fish in this length range were 10 - 12 years old. That suggests that most of the fish killed in the fishery from 1990 through 1995 were produced in the late 1970's through the mid 1980's. We estimated acceptable levels of harvest from these year classes from the LRS relative abundance index (Table 3.3.6), the recent population estimate, and YPR estimates from our modeling.

Although the LRS index measures relative abundance of several age classes (age zero through 2 or 3), we used it to provide insight on changes in abundance of age one Atlantic sturgeon. The mean LRS index from 1978 through 1985 was 0.94. The index for wild fish in 1995 was 0.41. The 1995 estimate of age one abundance was 4,283. Mean abundance for 1978-1985 can be estimated as (4283*0.94)/0.41 or 9820 animals. Mean life time yield from the 1978-1985 year classes would be 1901 animals per year class or a total 15,208 animals at F = 0.03. During 1990 through 1995 harvest was just above 17,000 animals from these year classes (Table 3.3.9). Had harvest continued, total removal from these year classes would have been much higher.

Recruitment All available data on abundance of juvenile Atlantic sturgeon in the Hudson River Estuary indicate a substantial drop in production of young since the mid 1970's (Section 3.3.3.1). Greatest decline appeared to occur in the mid to late 1970's followed by a secondary drop in the late 1980's. We have no data on abundance of juveniles prior to the 1970's.

Conclusion Data on fishing rate and total harvest indicate that the Hudson River stock of Atlantic sturgeon was over harvested in at least the last six years (1990-1995) of the commercial fishery in New York and New Jersey. Moreover, 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.

3.3.4 Factors Affecting Abundance

Fishing has been an important factor in regulating abundance of Atlantic sturgeon in the Hudson River Estuary for most of this century. Fishing was probably the dominant factor in the dramatic decline in landings and presumably in abundance at the end of the 1800's. Population modeling for the Hudson River stock (Section 3.3.3.4) suggests that mortality caused by fishing cannot be sustained at levels much above 0.04 of the mature stock per year. The short duration and magnitude of harvest during the 1890's indicate harvest well above that level. Fishing may also have been the cause of the recent reduction in production of young in the estuary (Section 3.3.3.5).

Harvest of Atlantic sturgeon from the Hudson River Estuary remained at relatively low levels from the early 1900's through 1980. Continued fishing may have hindered stock recovery through this time period. However, other problems were present. Habitat loss, primarily due to sewage pollution grew in the Hudson Estuary as the human population increased in the valley. Sewage decomposition produced several areas of inadequate dissolved oxygen (oxygen blocks) in the river. Best known was the block present in the Albany pool, located north of the Atlantic sturgeon spawning and nursery habitat. Other blocks occurred at certain times in the southern stretch of river from the Tappan Zee south through New York Harbor (Brosnan and O'Shea 1996). Improved sewage treatment essentially eliminated the problem near Albany by the late 1970's and the problem near New York City by the mid to late 1980's. Dredge and fill operation severely altered the river north of Catskill. However, much of the Atlantic sturgeon spawning and nursery habitat is thought to be relatively intact (Newburgh to Catskill).

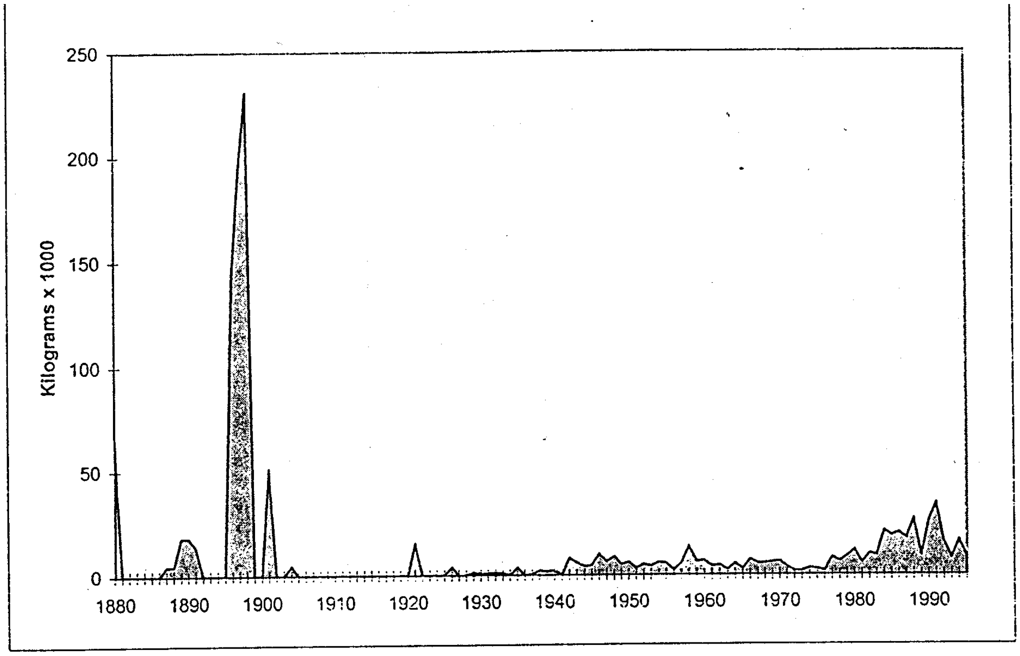


Figure 3.3.1. New York's historical commercial landings of Atlantic sturgeon.

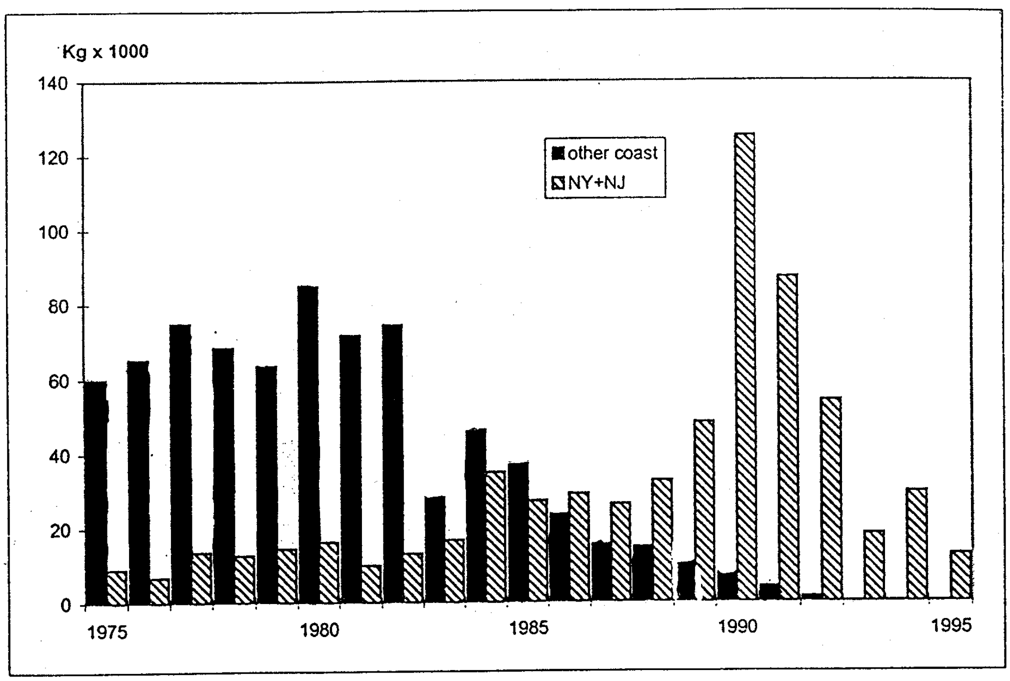


Figure 3.3.2 Coast-wide commercial landings of Atlantic sturgeon, separated for the NY-NJ component, 1975 - 1995

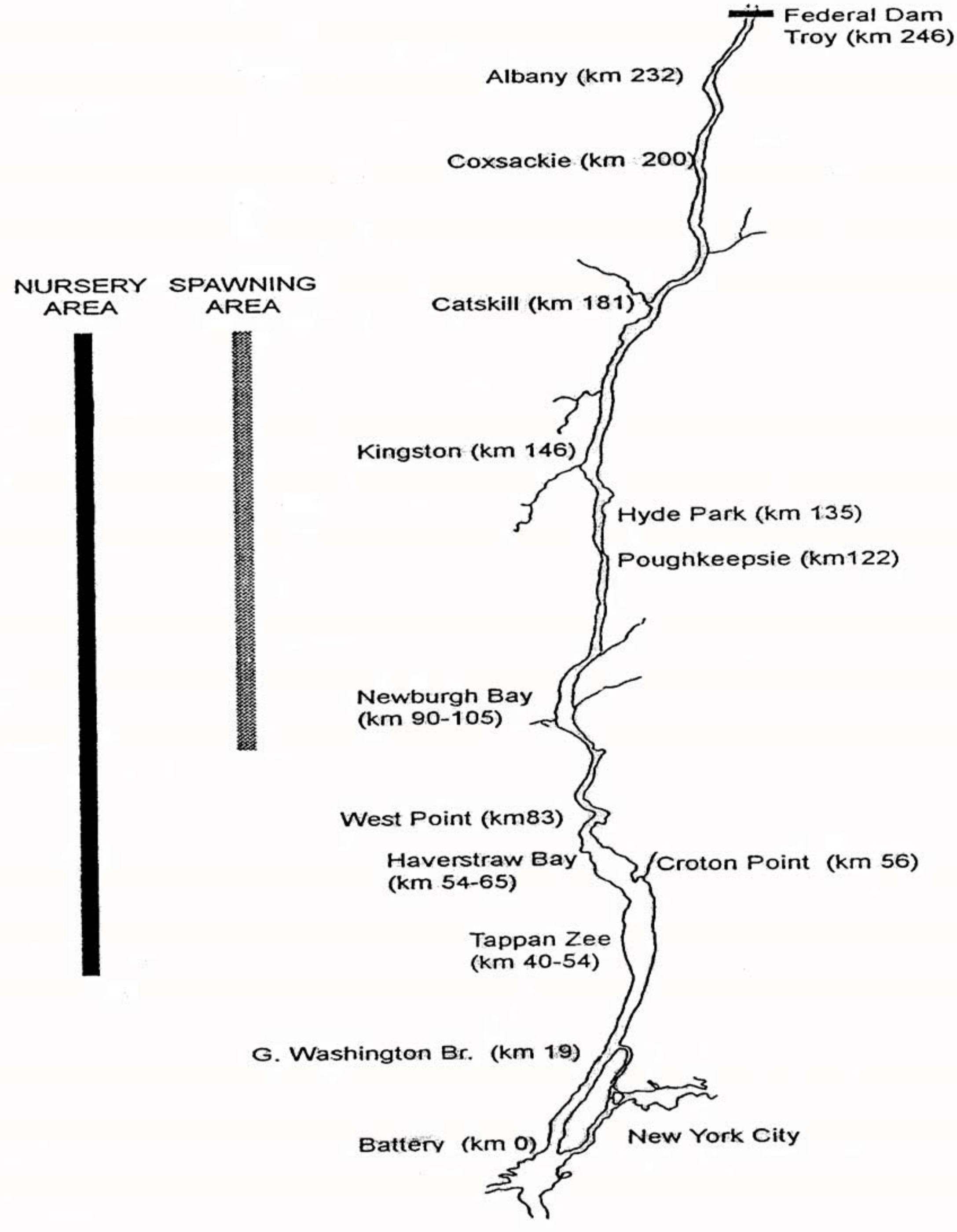


Figure 3.3.3 The Hudson River Estuary.

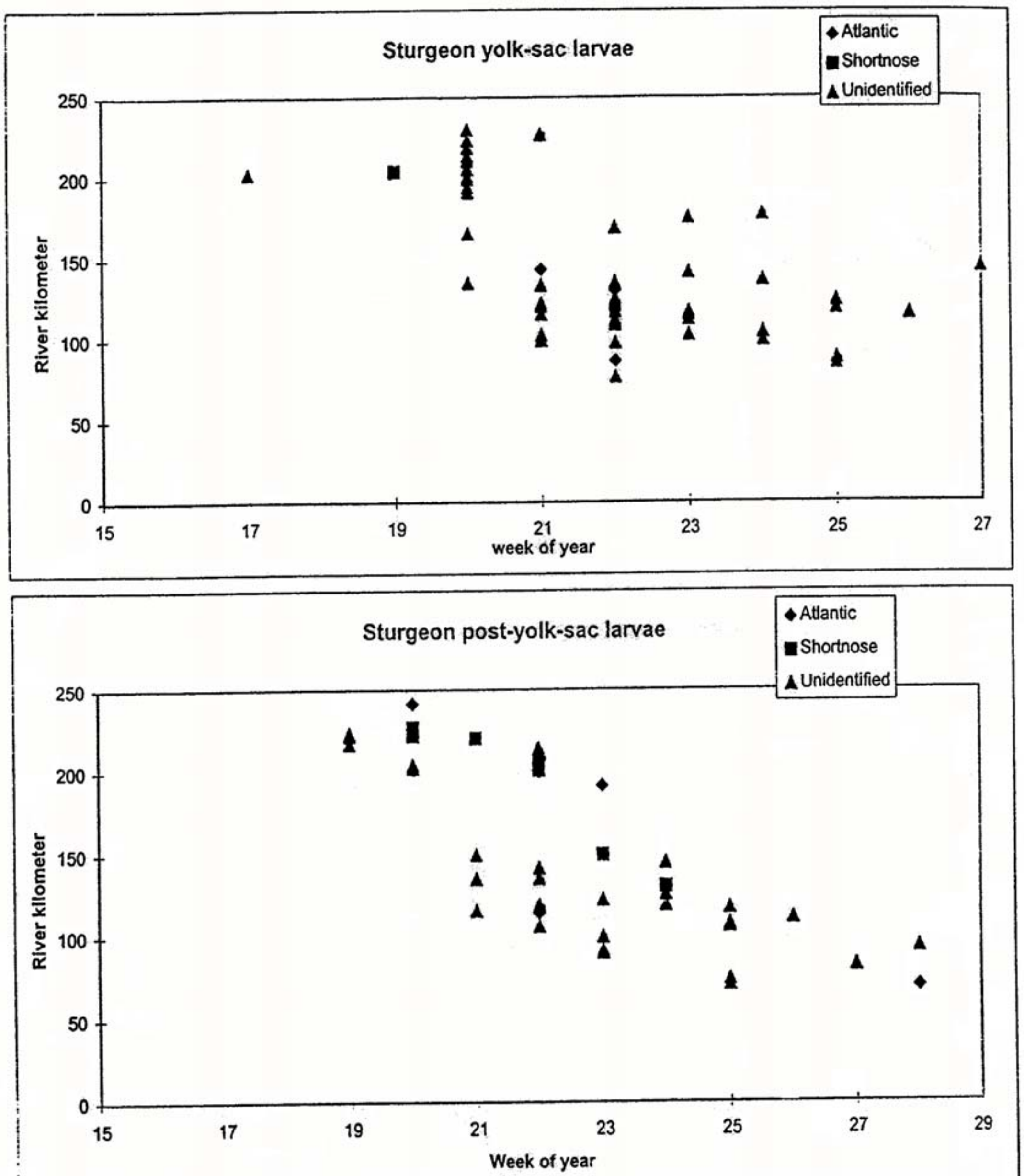


Figure 3.3.4 Sturgeon yolk-sac and post-yolk-sac larvae collected in Utility Company monitoring surveys in the Hudson River Estuary, 1974-1995. Unidentified larvae: above rkm 185 assumed to b shortnose sturgeon, those below Atlantic sturgeon.

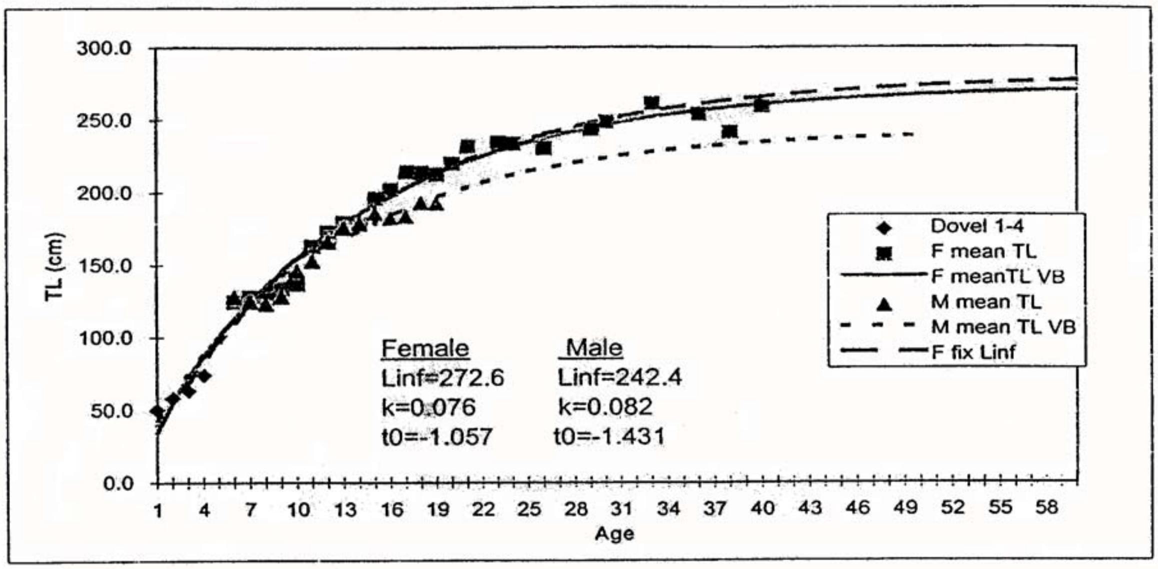


Figure 3.3.5. Mean total length (cm) at age (sexes combined:ages 1-4 and by sex age>age 6), and Von Bertalanffy growth curves for Atlantic sturgeon in the Hudson River Estuary. (Ages 1-4: Dovel and Berggren 1983, Age >6: J. Van Eenennaam, personal communication)

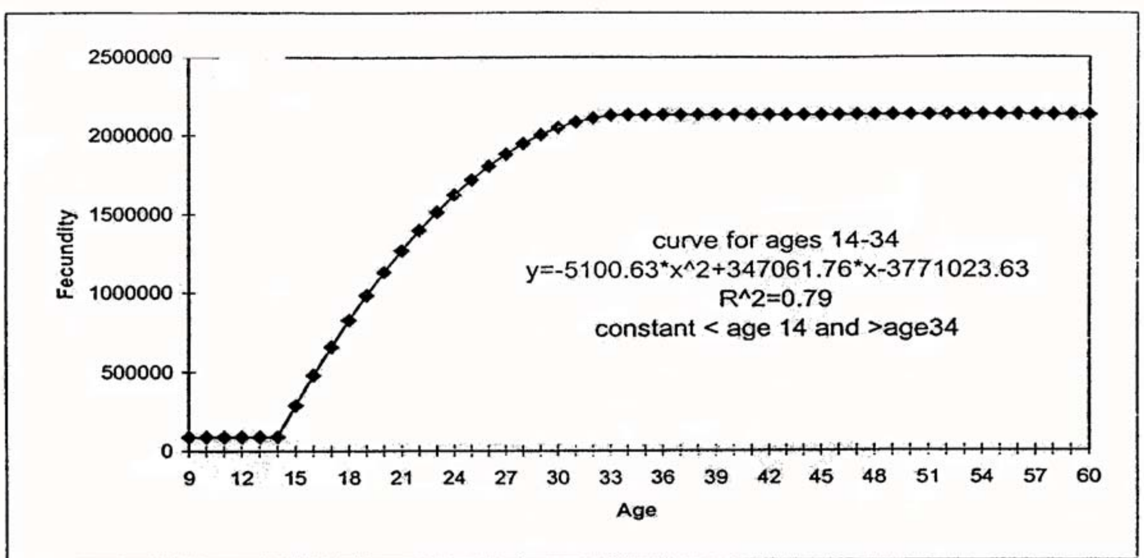
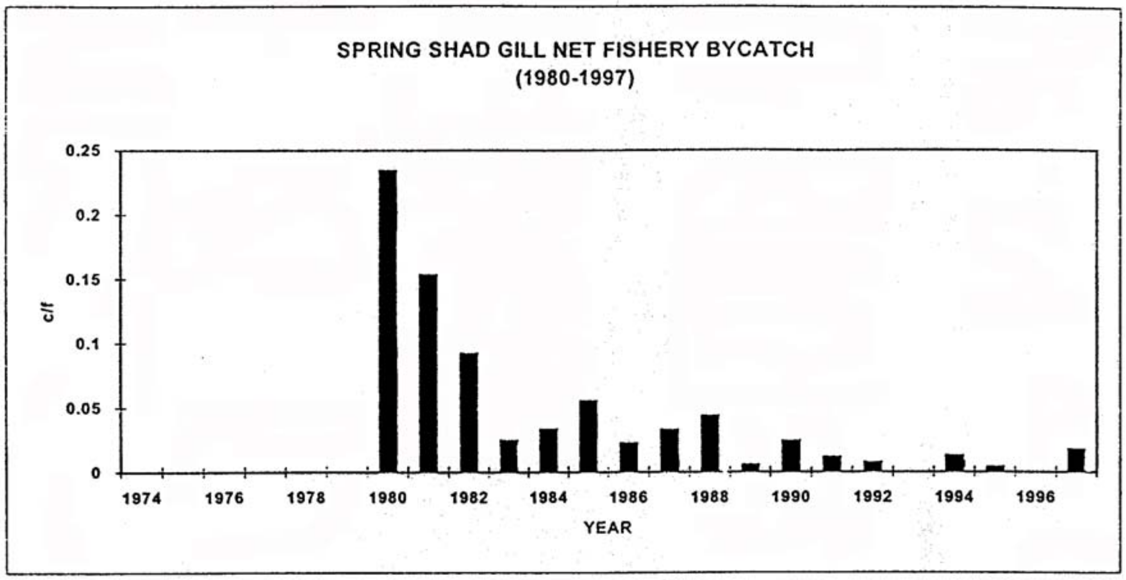


Figure 3.3.6. Fecundity estimates for Hudson River Atlantic sturgeon (VanEenennaam, personal communication)



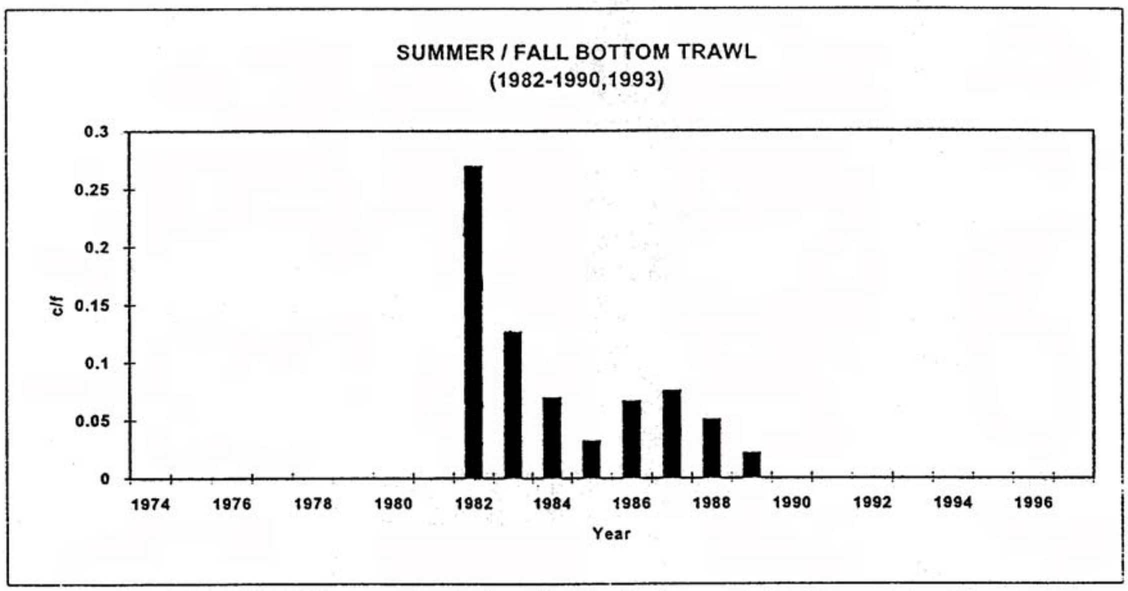


Figure 3.3.7. NYSDEC survey data for juvenile Atlantic sturgeon in the Hudson River Estuary.

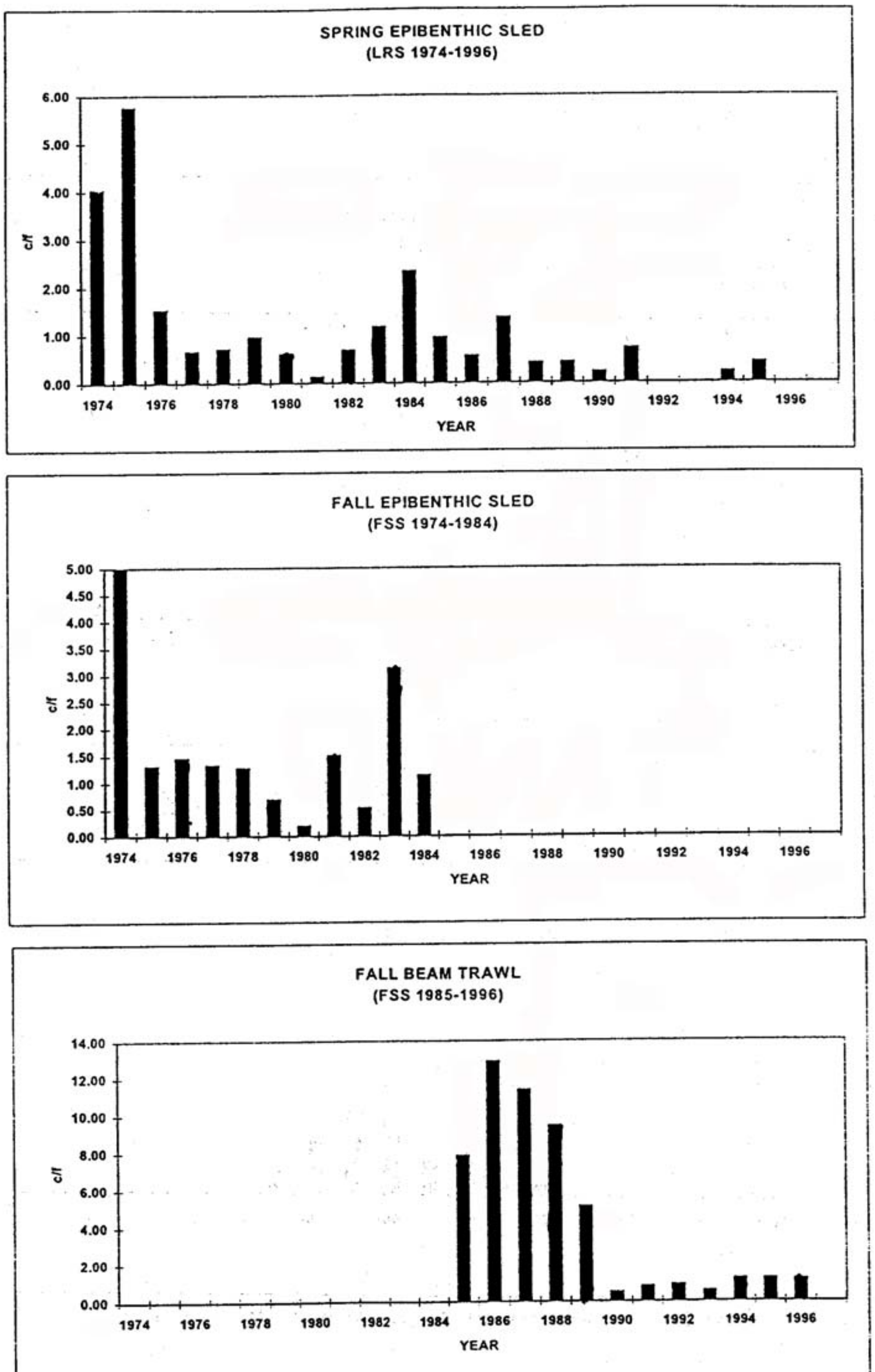


Figure 3.3.8 Utility Company survey data for juvenile Atlantic sturgeon in the Hudson River Estuary.

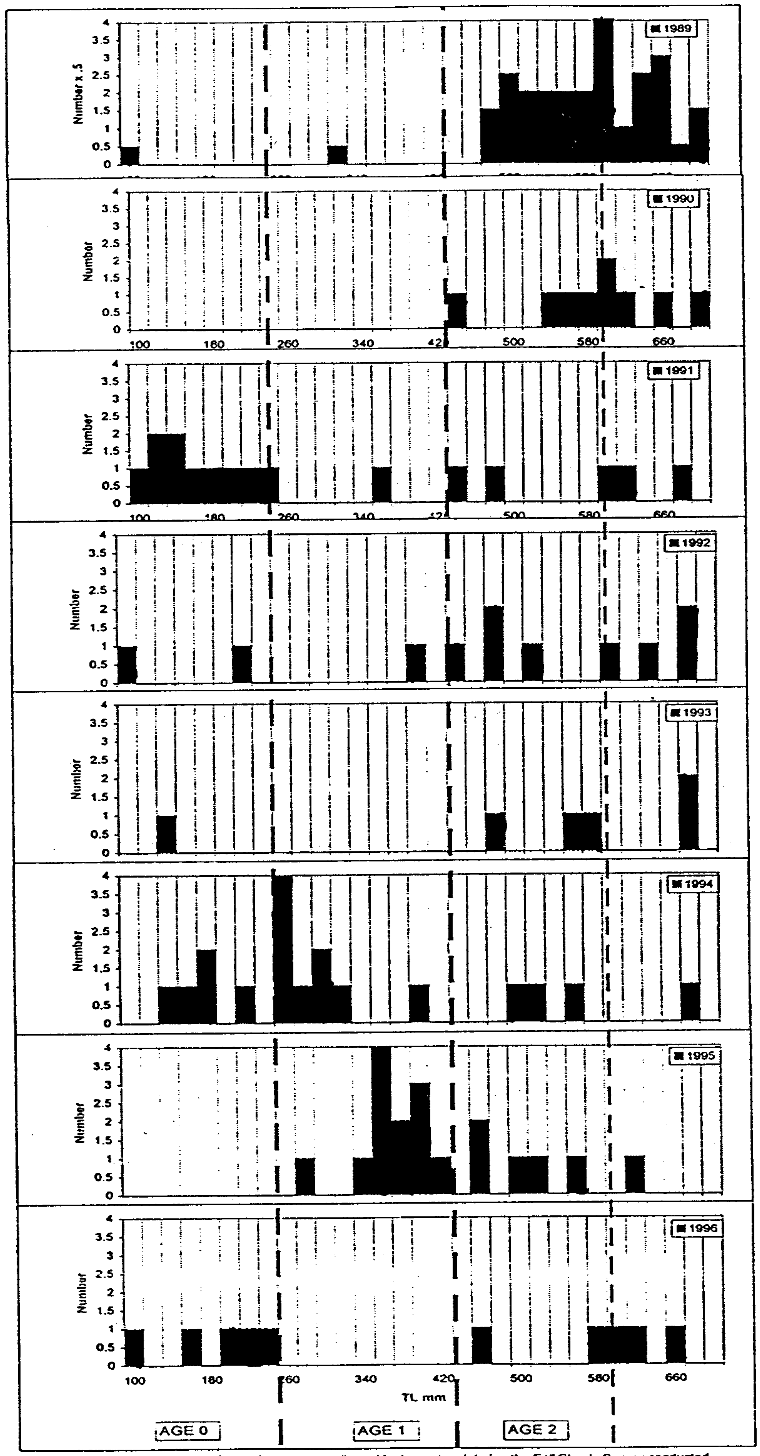


Figure 3.3.9. Length-frequency of Atlantic sturgeon collected by beam trawl during the Fall Shoals Survey conducted by the Hudson River Utility companies, 1989-1995

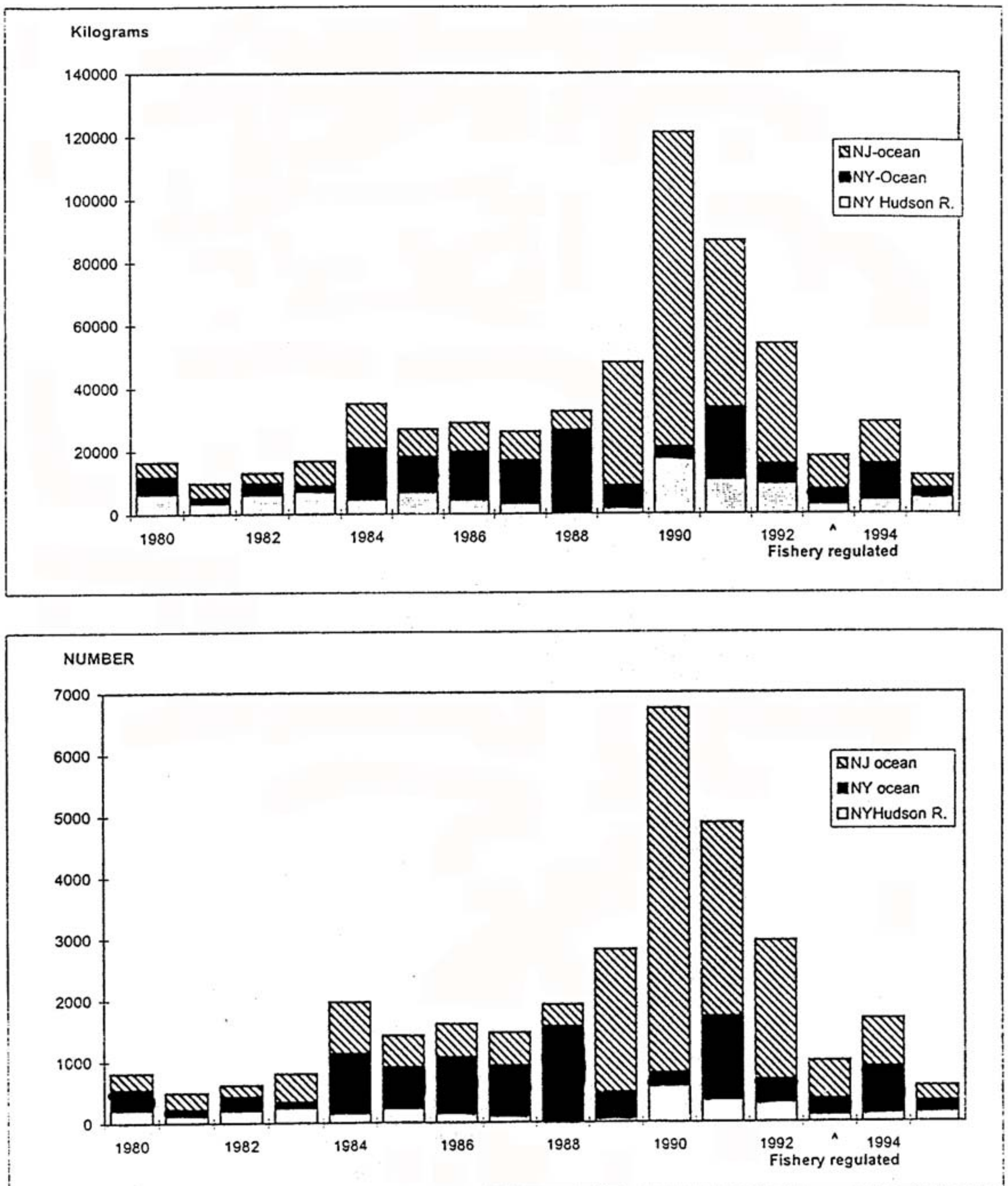


Figure 3.3.10 Total weight and estimated number of Atlantic sturgeon harvested in NY and NJ, 1980-1995.

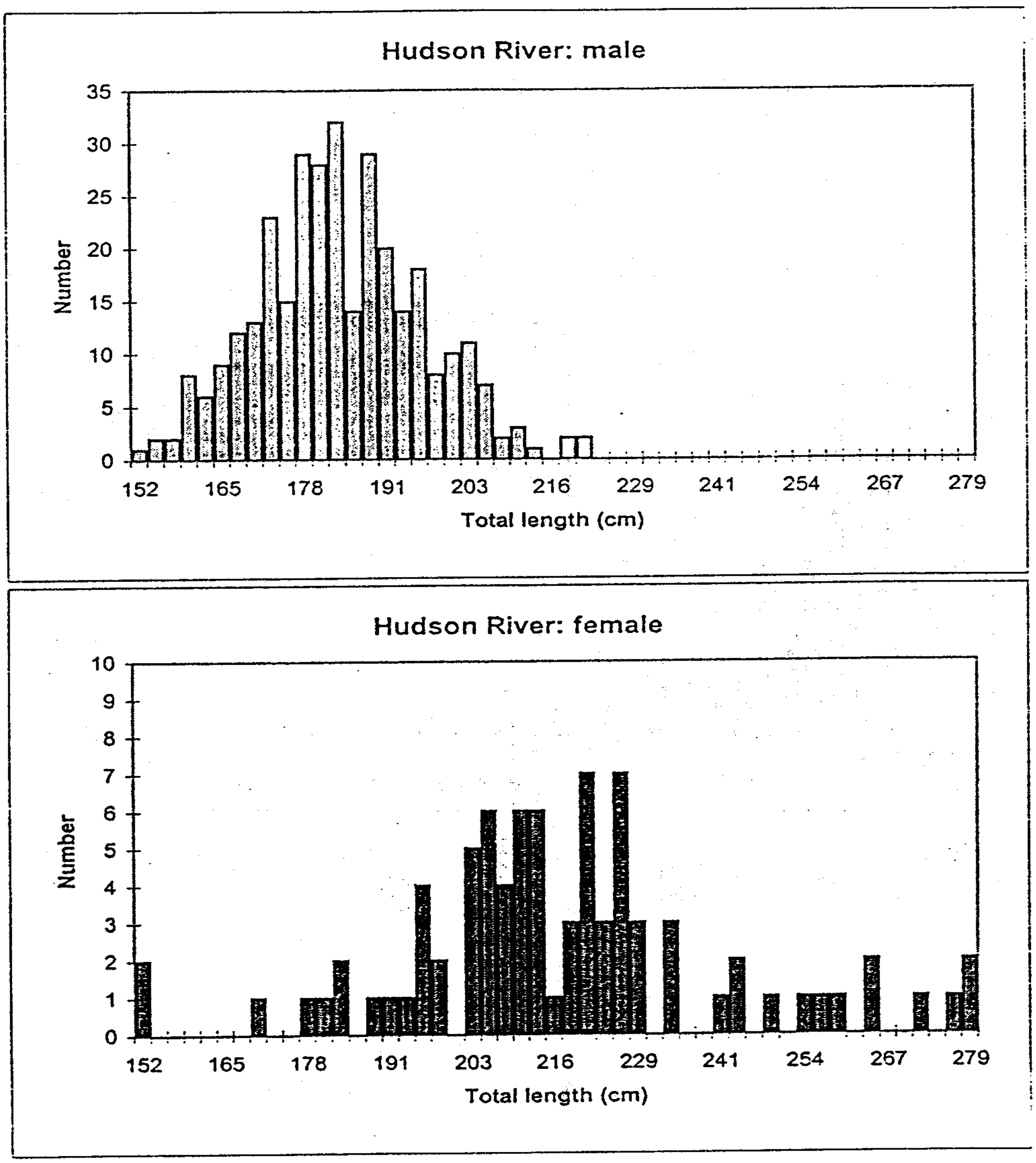


Figure 3.3.11. Length frequency of Atlantic sturgeon harvested in the Hudson River commercial fishery 1993-1995.

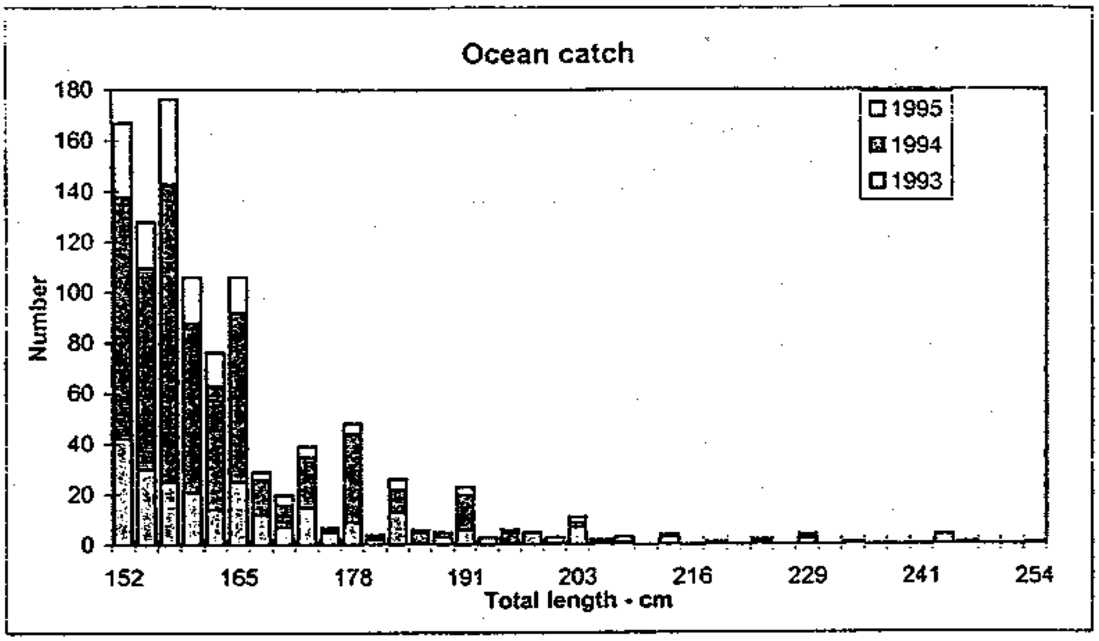


Figure 3.3.12. Length frequency of Atlantic sturgeon harvested in the commercial fishery in New York ocean waters 1993-1995.

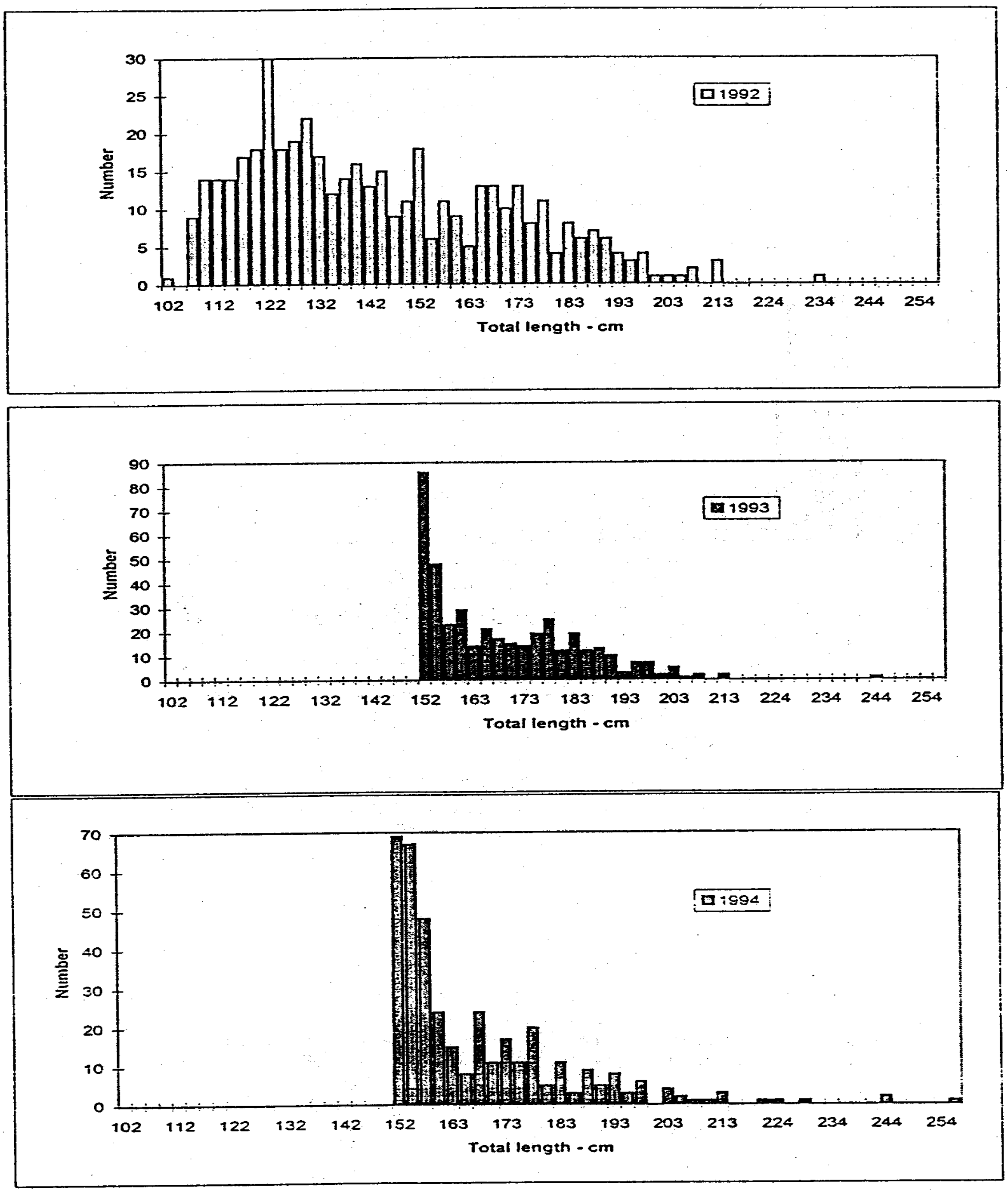


Figure 3.3.13 Length frequency of Atlantic sturgeon harvested in the commercial fishery in New Jersey ocean waters 1992-1994.

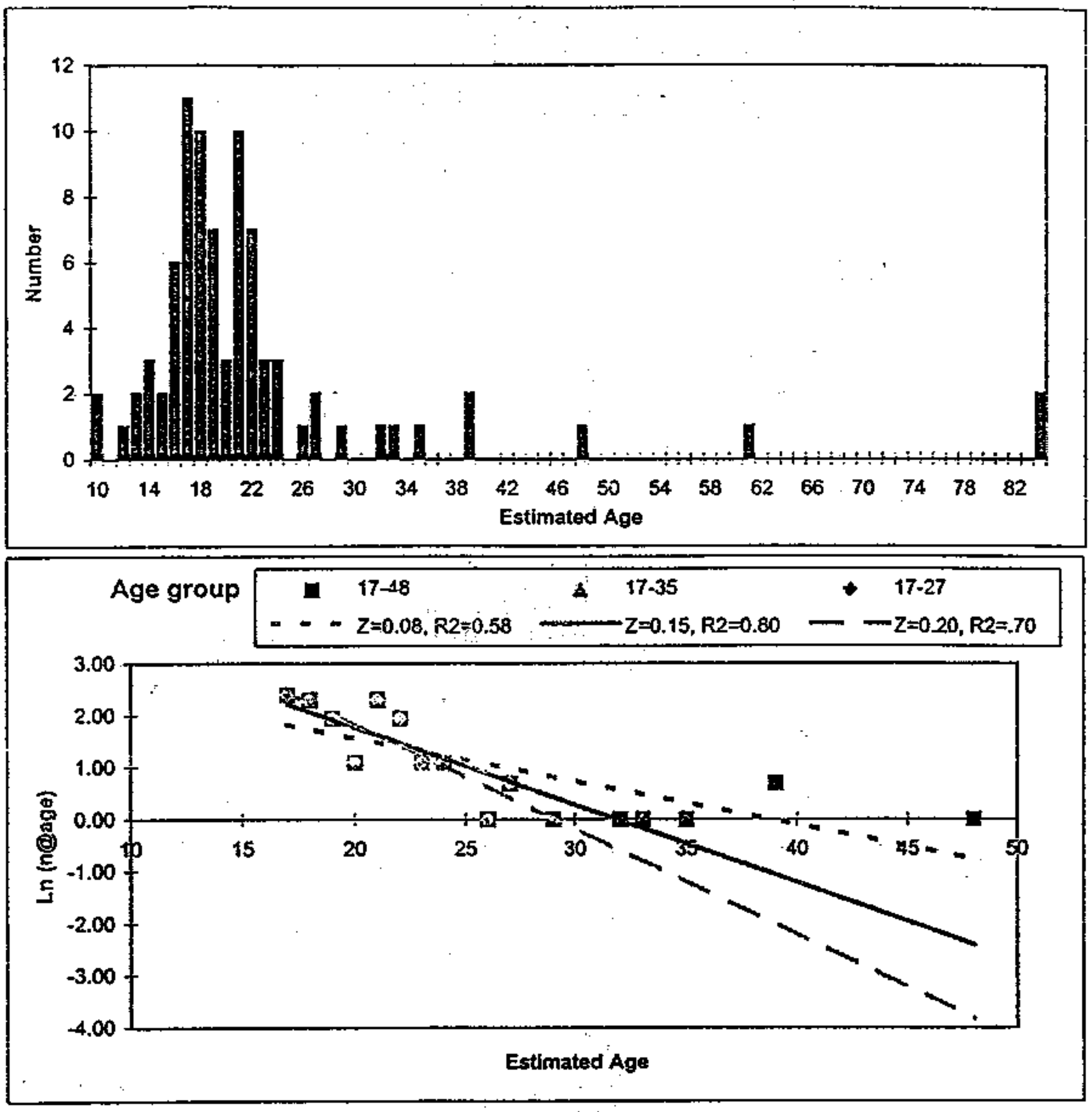


Figure 3.3.14 Estimated age structure and total instantaneous mortality estimates of female Atlantic sturgeon harvested in the commercial fishery in the Hudson River Estuary 1993-1995.

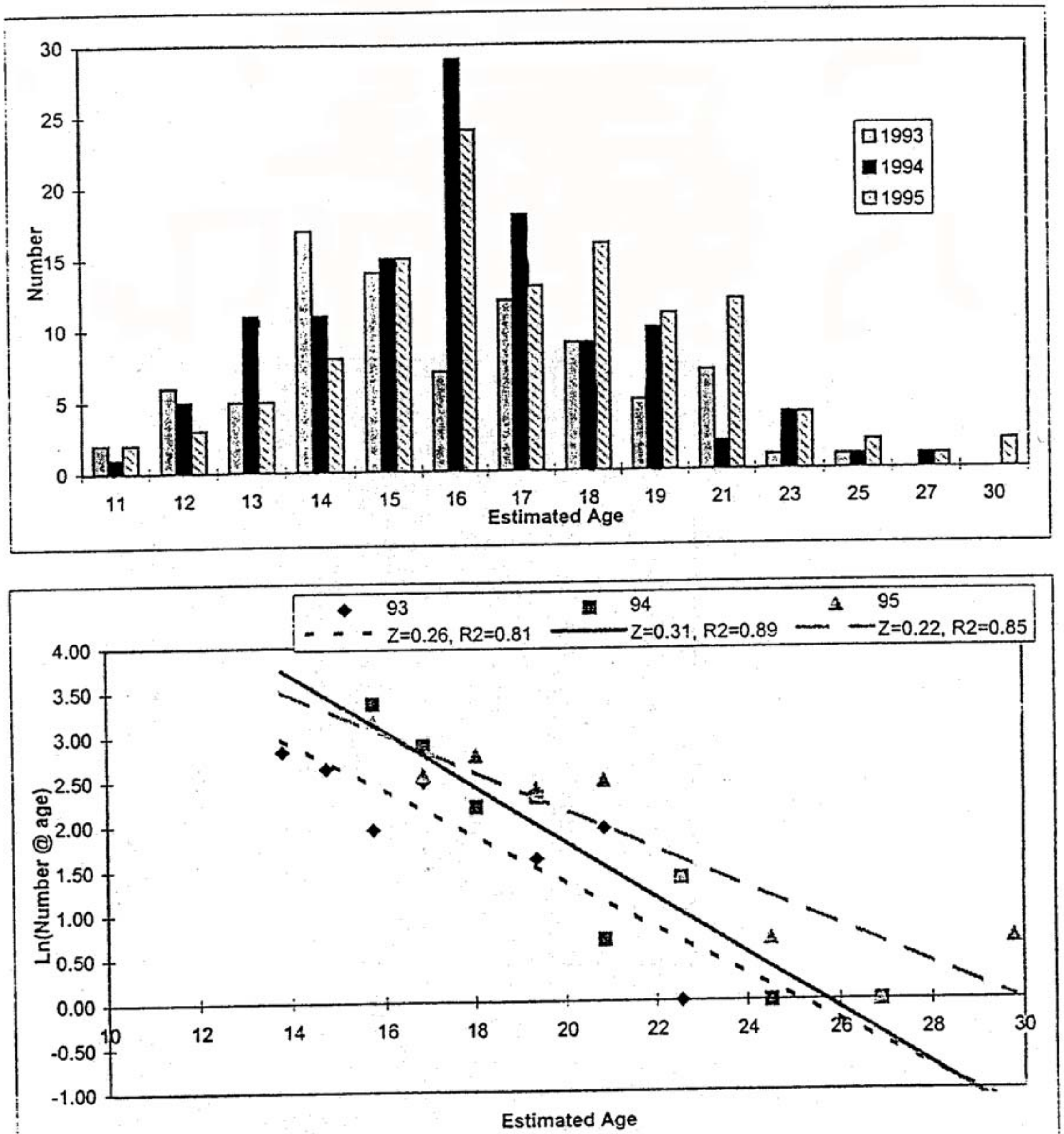


Figure 3.3.15. Estimated age structure and total instantaneous mortality estimates of male Atlantic sturgeon harvested in the commercial fishery in the Hudson River Estuary 1993-1995.

Table 3.3.1. Mean total length (cm) at age, sexes combined, for Atlantic sturgeon collected in the Hudson River Estuary, 1976-1978 (Dovel & Berggren 1983).

	Sexes combined		
Age	N	Mean	SD
1	6	50.2	3.6
2	40	58.2	4.0
3	30	72.0	5.8
4	10	73.9	7.4
5	4	79.9	4.5
12	2	134.3	21.1
13	5	144.8	18.0
14	9	155.5	16.5
15	5	161.9	4.5
16	1	157.5	
17	1	188.0	
18	1	182.9	
19	2	193.1	14.4
20	2	203.0	21.2
21	0		
22	1	208.0	
23	0		
24	0		
25	0		
26	1	228.6	
27	0		
28	2	232.4	5.4
29	1	238.8	

Table 3.3.2 Mean total length (cm) at age, by sex, for Atlantic sturgeon harvested in the Hudson River Estuary, 1992-1994. (J. Van Eenennaam, personal communication).

	Female					Male				
Age	N	Mean	Min	Max	SD	N	Mean	Min	Max	SD
5	1	121.9				0				
6	1	124.5				3	127.8	127.0	129.5	1.5
7	3	127.8	121.9	132.1	5.3	1	124.5			
8	3	127.0	124.5	129.5	2.5	5	122.9	121.9	124.5	1.4
9	3	133.6	121.9	152.0	16.1	6	127.8	121.9	137.2	5.9
10	6	136.8	121.9	163.0	15.2	5	146.0	124.5	165.1	17.1
11	4	163.1	132.1	180.0	21.6	6	152.6	124.5	166.0	14.7
12	6	172.6	144.8	196.0	22.1	13	165.8	132.1	193.0	17.6
13	8	179.5	161.0	201.0	13.5	18	175.5	132.7	205.7	18.2
14	7	178.8	156.0	205.7	16.4	14	178.4	149.9	190.5	10.1
15	4	196.4	188.0	203.0	6.8	27	185.8	165.1	205.7	10.0
16	4	202.2	196.9	213.4	7.6	13	182.4	151.1	205.7	14.8
17	2	214.6	210.8	218.4	5.4	15	183.6	154.9	203.2	12.0
18	8	214.2	201.9	226.1	9.5	2	193.0	190.5	195.6	3.6
19	2	212.7	207.0	218.4	8.1	3	192.6	186.7	198.1	5.7
20	5	220.0	195.6	238.8	18.4	0				
21	3	232.0	218.4	241.3	12.0	0				
22	0					0				
23	2	234.9	233.7	236.2	1.8	0				
24	1	233.7				0				
25	0					0				
26	2	230.5	227.3	233.7	4.5	0				
27	0					0				
28	0					0				
29	1	243.8				0				
30	1	248.9				0				
31	0					0				
32	0					0				
33	1	261.6				0				
34	0					0				
35	0					0				
36	1	254.0				0				
37	0					0				
38	1	241.3				0				
39	0					0				
40	1	259.1				0				

Table 3.3.3. Body size, gonadosomatic index (%), and age of Atlantic sturgeon from the Hudson River Estuary, 1992-1993. From: Van Eenennaam et al. (1996).

	Females			Males		
	n	Mean	SD	n	Mean	SD
Fork Length (cm)	28	194	14.9	66	161.7	14.3
Total Length (cm)	28	217.9	15.8	66	181.5	15.4
Body Weight (kg)	22	72.7	20.3	48	37.3	7.5
Condition Factor (%)	22	0.94	0.11	48	0.83	0.08
Gonadosomatic Index	16	13.84	5.72	42	3.97	1.13
Age in Years	27	20	5	66	15	2

Table 3.3.4. Iteroparity, body size, and reproductive parameters of Hudson River Atlantic sturgeon females in different age groups From: Van Eenennaam et al. (1996).

	Age							
	15-17 (n=4)		18-20 (n=5)		21-23 (n=3)		24-29 (n=3)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Iteroparity (%)	0		0.4		0.67		1	
Fork Length (cm)	184.2	6.4	191.3	8.8	206.2	1.9	213.3	9.2
Body Weight (kg)	55	7.3	71.4	9.1	82.9	14.8	89.7	21.2
Fecundity (million)	0.49	0.1	1	0.26	1.58	0.35	1.67	0.31
Relative fecundity a	8.92	1.78	14.02	2.91	19.02	0.8	18.89	2.83
Oocyte diameter (mm)	2.53	0.12	2.54	0.08	2.67	0.05	2.78	0.12

a Relative Fecundity in thousand/kg

Table 3.3.5. Mark-recapture data for the 1976 year class for Atlantic sturgeon in the Hudson River Estuary from Dovel and Berggren 1983.

Reiteration of Table 2 in Dovel and Berggren 1983.					
		1976 Year class			Age
Period	Date	Caught	Marked	Recap	class
1-2	30 Mar-30 Sep 76				Age0
3	1 Oct-31 Dec 76	25	25	0	
4	4 Mar-30 Jun 77	138	135	0	Age1
5	1 Jul-30 Sep 77	33	27	0	
6	1 Oct-31 Dec 77	90	90	1	
7	28 Mar-30 Jun 78	285	284	2	Age2
8	1 Jul-11 Sep 78	279	273	6	
8&	1 Jul-11 Sep 78	46	46	1	

8&=additonal specimens collected during this period which were used in making population estimate but not in other analyses.

Age	Marking time period	Marks released M	Capture period	Total captured C	Recaptures R	(M*C)/R
1	4 Mar-30 Sep 77 (4-5)	162	1 Oct-31 Dec 77 (6)	90	1	14580
1	4 Mar-31 Dec 77 (4-6)	252	28 Mar-30 Jun 78 (7)	285	2	35910

Table 3.3.6. Relative abundance indices juvenile of Atlantic sturgeon collected in the Hudson River Estuary.

	NYSDEC		Utility Surveys		
	Fixed Gillnet			FSS	
	Fishery Bycatch	Bottom Trawl	LRS Sled	Sled	Beam Trawl
Months>	Apr-May	Jul-Nov	May-Jul	Aug-Oct	Jul -Oct
Year					
1974			4.04	5.00	
1975			5.75	1.31	
1976			1.52	1.46	
1977			0.66	1.33	
1978			0.71	1.28	
1979			0.97	0.69	
1980	0.234		0.60	0.19	
1981	0.153		0.13	1.51	
1982	0.092	0.269	0.68	0.53	
1983	0.024	0.126	1.17	3.13	
1984	0.033	0.069	2.34	1.14	
1985	0.055	0.032	0.95		7.84
1986	0.022	0.066	0.56		12.90
1987	0.033	0.075	1.36		11.36
1988	0.044	0.050	0.41		9.44
1989	0.006	0.021	0.42		5.08
1990	0.024	0.000	0.22		0.48
1991	0.011		0.71		0.81
1992	0.007		0.00		0.89
1993	0.000	0.000	0.00		0.56
1994	0.013		0.21		1.21
1995	0.004		0.41		1.21
1996	0.000		0.00		1.18

Table 3.3.7 Length frequency distribution of Atlantic sturge in bottom trawl surveys of New Jersey coastal during 1988 - 1996.

Total length (cm)	Frequency
69	2
70	1
71	1
72	1
74	1
75	4
80	3
82	3
83	3
84	1
85	2
86	1
87	3
88	4
89	4
90	3
91	1
92	4
93	2
94	5
95	3
96	3
97	2
98	1
99	6
100	6
101	2
102	3
103	1
104	2
105	4
106	2
107	1
108	1
110	3
111	2
112	1
113	1
114	1
115	2
116	1
117	1
119	2
123	1
128	2
131	2
133	1
135	1
165	1
166	1
175	1
196	1
205	1
Total	112

Table 3.3.8 Catch and c/f of Atlantic sturgeon from bottom trawl surveys of New Jersey coastal waters 1988 - 1996.

	January			April			June		
Year	Catch	Samples	c/f	Catch	Samples	c/f	Catch	Samples	c/f
1988	no sample	0	0.000	no sample	0	0.000	no sample	0	0.000
1989	5	28	0.179	16	29	0.552	2	40	0.050
1990	3	30	0.100	9	32	0.281	2	37	0.054
1991	8	30	0.267	4	35	0.114	1	45	0.022
1992	5	31	0.161	16	39	0.410	0	41	0.000
1993	0	30	0.000	1	40	0.025	0	39	0.000
1994	0	30	0.000	0	39	0.000	0	39	0.000
1995	3	30	0.100	1	39	0.026	3	41	0.073
1996	2	31	0.065	0	40	0.000	0	40	0.000
Total	26	240	0.108	47	293	0.160	8	322	0.025

	August			October			Total		
Year	Catch	Samples	c/f	Catch	Samples	c/f	Catch	Samples	c/f
1988	2	34	0.059	0	34	0.000	2	68	0.029
1989	0	34	0.000	9	37	0.243	32	168	0.190
1990	0	37	0.000	1	32	0.031	15	168	0.089
1991	0	38	0.000	3	39	0.077	16	187	0.086
1992	0	39	0.000	4	40	0.100	25	190	0.132
1993	0	39	0.000	9	39	0.231	10	187	0.053
1994	0	39	0.000	0	39	0.000	0	186	0.000
1995	0	39	0.000	0	39	0.000	7	188	0.037
1996	0	39	0.000	1	39	0.026	3	189	0.016
Total	2	338	0.006	27	338	0.080	110*	1531	0.072

* 2 Atlantic sturgeon collected in December 1989, the only year that month was sampled, are not included

Table 3.3.9. Number and kilograms of Atlantic sturgeon harvested in New York and NewJersey waters 1980-1995.

			Ocean waters					
	Hudson River		New York		New Jersey		Total	
Year	kg	n	kg	n	kg	n	kg	n
1980	6451	214	5579	332	4536	270	10115	602
1981	3459	115	1814	108	4536	270	6350	378
1982	6053	201	3856	230	3175	189	7031	419
1983	7404	246	1633	97	7711	459	9344	556
1984	4536	151	16466	980	14062	837	30527	1817
1985	6825	227	11476	683	8618	513	20094	1196
1986	4448	148	15468	921	9072	540	24540	1461
1987	3234	107	13835	824	9072	540	22907	1364
1988	682	23	25991	1547	5897	351	31888	1898
1989	1815	60	7257	432	39010	2322	46266	2754
1990	17713	588	3571	213	99792	5940	103363	6153
1991	10815	359	22951	1366	53071	3159	76022	4525
1992	9541	317	6335	377	38102	2268	44437	2645
1993	2842	104	4948	268	10433	621	15381	889
1994	4246	142	11689	759	13154	783	24844	1542
1995	5158	161	2852	178	4082	243	6935	421

NY:1993-95 number harvested from mandatory reports
NJ: numbers estimated using average weight of NY ocean harvest; 1992 and earlier numbers conservatively LOW given smaller size limit of 107 cm.

Table 3.3.10 Length and weight of Atlantic sturgeon harvested in the Hudson River Estuary, 1991-199

Sex	Year	Dressed length (cm) N	MEAN	SD	MIN	MAX	Dressed weight (k N	MEAN	SD
Male	1991*	2	122.1	7.1	117.1	127.2	2	30.7	3.9
	1992*	26	111.4	9.0	95.2	127.2	26	24.3	4.4
	1993	86	114.2	8.8	91.4	134.6	86	25.9	5.4
	1994	117	113.3	7.8	96.5	137.2	117	27.4	4.9
	1995	118	116.4	8.8	96.9	139.7	118	27.6	5.5
	All	349	114.5	8.6		139.7	349	26.9	5.3
Female	1991*	1	133.9		133.9	133.9	9	27.8	7.3
	1992*	4	180.4	26.8	154.1	214.7	4	37.4	17.6
	1993	15	144.2	21.3	113.7	193.0	15	44.6	5.8
	1994	25	129.5	13.9	93.5	144.8	25	41.7	7.9
	1995	43	138.2	16.1	93.5	175.3	43	44.3	5.0
	All	88	138.6	19.6	93.5	214.7	96	41.8	8.3
All combined	1991*	52	112.4	13.1	93.5	174.3	11	28.3	6.8
	1992*	30	120.6	26.7	95.2	214.7	30	26.0	8.4
	1993	101	118.6	15.6	91.4	193.0	104	28.8	8.5
	1994	142	116.2	11.0	93.5	144.8	142	29.9	7.8
	1995	161	122.2	14.7	93.5	175.3	161	32.0	9.2
	All	486	118.6	15.1	91.4	214.7	448	30.1	8.6

Sex	Year	Total length (cm) N	MEAN	SD	MIN	MAX	Live weight (kg) N	MEAN	SD
Male	1991*	2	195.6	10.8	188.0	203.2	2	43.8	6.7
	1992*	26	179.4	13.6	154.9	203.2	29	34.9	7.2
	1993	86	183.6	13.2	149.3	214.4	86	37.1	7.4
	1994	117	182.3	11.7	157.0	218.3	117	36.2	6.6
	1995	118	186.5	13.2	154.9	222.1	118	38.7	7.8
	All	349	183.9	12.9	149.3	222.1	352	37.2	7.4
Female	1991*	1	213.4		213.4	213.4	1	64.1	
	1992*	4	283.5	40.5	243.8	335.3	10	95.5	82.7
	1993	15	228.9	32.1	182.9	302.6	15	87.1	42.6
	1994	25	206.6	20.8	152.4	228.6	25	62.7	12.4
	1995	43	219.8	24.2	152.4	275.7	43	74.7	25.0
	All	88	220.4	29.6	152.4	335.3	94	75.6	37.0
All combined	1991*	52	182.2	19.2	152.4	274.3	11	23.4	18.4
	1992*	30	193.3	40.3	154.9	335.3	39	50.4	48.8
	1993	101	190.3	23.6	149.3	302.6	101	44.5	24.9
	1994	142	186.6	16.5	152.4	228.6	142	40.9	12.8
	1995	161	195.4	22.4	152.4	275.7	161	48.3	21.5
	All	486	190.2	22.7	149.3	335.3	454	44.7	24.1

*Subsample of total harvest

Table 3.3.11 Length-frequency of Atlantic sturgeon harvested in the Hudson River Estuary, 1993-1995.

	Male				Female			
TL-cm	1993	1994	1995	Total	1993	1994	1995	Total
152	1	0	0	1	0	1	1	2
155	1	0	1	2	0	0	0	0
157	0	1	1	2	0	0	0	0
160	1	4	3	8	0	0	0	0
163	5	1	0	6	0	0	0	0
165	5	1	3	9	0	0	0	0
168	0	10	2	12	0	0	0	0
170	7	3	3	13	0	1	0	1
173	10	8	5	23	0	0	0	0
175	0	11	4	15	0	0	0	0
178	14	4	11	29	0	1	0	1
180	7	10	11	28	0	1	0	1
183	0	19	13	32	1	0	1	2
185	5	4	5	14	0	0	0	0
188	7	14	8	29	0	1	0	1
191	0	9	11	20	0	0	1	1
193	9	0	5	14	0	0	1	1
196	5	8	5	18	1	2	1	4
198	0	2	6	8	0	2	0	2
201	4	0	6	10	0	0	0	0
203	3	2	6	11	1	2	2	5
206	0	3	4	7	1	1	4	6
208	1	1	0	2	0	1	3	4
211	1	1	1	3	2	0	4	6
213	0	0	1	1	0	[illegible]	[illegible]	6
216	0	0	0	0	0	0	1	1
218	0	1	1	2	1	0	2	3
221	0	0	2	2	1	2	4	7
224	0	0	0	0	0	2	1	3
226	0	0	0	0	0	6	1	7
229	0	0	0	0	1	1	1	3
231	0	0	0	0	0	0	0	0
234	0	0	0	0	2	0	1	3
236	0	0	0	0	0	0	0	0
239	0	0	0	0	0	0	0	0
241	0	0	0	0	0	0	1	1
244	0	0	0	0	0	0	2	2
246	0	0	0	0	0	0	0	0
249	0	0	0	0	1	0	0	1
251	0	0	0	0	0	0	0	0
254	0	0	0	0	0	0	1	1
257	0	0	0	0	1	0	0	1
259	0	0	0	0	0	0	1	1
262	0	0	0	0	0	0	0	0
264	0	0	0	0	0	0	2	2
267	0	0	0	0	0	0	0	0
269	0	0	0	0	0	0	0	0
272	0	0	0	0	0	0	1	1
274	0	0	0	0	0	0	0	0
277	0	0	0	0	0	0	1	1
279	0	0	0	0	2	0	0	2
Total	86	117	118	321	15	25	43	83

Table 3.3.12. Length-frequency of Atlantic sturgeon harvested in NY ocean waters, 1993-1995.

TL-cm	1993	1994	1995	Total
152	42	96	29	167
155	30	80	18	128
157	25	118	33	176
160	21	67	18	106
163	14	49	13	76
165	25	67	14	106
168	12	14	3	29
170	7	9	4	20
173	15	20	4	39
175	5	1	1	7
178	9	35	4	48
180	2	1	1	4
183	13	9	4	26
185	1	4	1	6
188	3	2	0	5
191	6	14	3	23
193	3	0	0	3
196	1	4	1	6
198	5	0	0	5
201	1	0	2	3
203	7	2	2	11
206	0	1	1	2
208	0	1	2	3
211	0	0	0	0
213	3	1	0	4
216	0	0	0	0
218	0	1	0	1
221	0	0	0	0
224	1	1	0	2
226	0	0	0	0
229	2	2	0	4
231	0	0	0	0
234	1	0	0	1
236	0	0	0	0
239	0	0	0	0
241	0	0	0	0
244	4	0	0	4
246	0	1	0	1
249	0	0	0	0
251	0	0	0	0
254	0	1	0	1
Total	258	601	158	1017
# landed	268	759	178	1205

Length and weight of Atlantic sturgeon harvested in NY ocean waters, 1993-1995.

Year	N	MEAN	SD	MIN	MAX
Dressed weight (kg)					
1993	262	18.5	9.4	6.4	59.4
1994	726	15.7	6.6	9.1	70.8
1995	177	18.7	7.6	8.6	49.9
All	1165	16.8			
Total length (cm)					
1993	258	168.9	18.7	152.4	243.8
1994	601	162.9	12.5	152.4	254.0
1995	158	163.1	12.6	152.4	208.3
All	1017	164.4			
Live weight (kg)					
1993	262	22.2	11.3	7.6	71.3
1994	726	18.8	7.9	10.9	84.9
1995	177	22.4	9.1	10.3	59.9
All	1165	20.1			

Table 3.3.13 Length-frequency of Atlantic sturgeon harvested in NJ ocean waters, 1992-1994

TL(cm)	1992	1993	1994
102	1		
104	0		
107	9		
109	14		
112	14		
114	14		
117	17		
119	18		
122	30		
124	18		
127	19		
130	22		
132	17		
135	12		
137	14		
140	16		
142	13		
145	15		
147	9		
150	11		
152	18	86	69
155	6	48	67
157	11	23	48
160	9	29	24
163	5	14	15
165	13	21	
168	13	17	24
170	10	15	11
173	13	14	17
175	8	19	11
178	11	25	20
180	4	12	5
183	8	19	11
185	6	12	3
188	7	13	9
191	6	10	5
193	4	3	8
196	3	7	3
198	4	7	6
201	1	2	0
203	1	5	4
206	1	1	2
208	2	2	1
211	0	0	1
213	3	2	3
216	0	0	0
218	0	0	0
221	0	0	1
224	0	0	1
226	0	0	0
229	0	0	1
231	0	0	0
234	1	0	0
236	0	0	0
239	0	0	0
241	0	0	0
244	0	1	2
246	0	0	0
249	0	0	0
251	0	0	0
254	0	0	0
>254	0	0	1
Total	451	407	381

Data from W. Andrews (personal communication) : 1992 voluntary log books, 107 cm size limit, Feb 93 size limit increased to 152 cm with mandatory reports

Table 3.3.14 Model run results of YPR, EPR and BPR for Hudson River Atlantic sturgeon.

	F50 = 1.14					
	MALE:YIELD/REC		FEMALE: YIELD/REC		EGG PER	BIOMASS
F	NO	LBS	NO	LBS	RECRUIT	RECRUIT
0.00	0.00	0.00	0.00	0.00	2.29	139.71
0.01	0.07	8.07	0.07	10.25	1.82	112.22
0.02	0.14	15.86	0.12	17.40	1.45	91.20
0.03	0.21	23.38	0.17	22.45	1.18	74.91
0.04	0.28	30.64	0.20	26.03	0.96	62.13
0.05	0.34	37.65	0.23	28.58	0.79	51.98
0.06	0.40	44.41	0.26	30.39	0.65	43.85
0.07	0.46	50.94	0.28	31.68	0.54	37.26
0.08	0.52	57.24	0.29	32.58	0.45	31.87
0.09	0.58	63.31	0.31	33.20	0.38	27.43
0.10	0.63	69.16	0.32	33.61	0.32	23.74
0.11	0.69	74.81	0.33	33.86	0.28	20.65
0.12	0.74	80.24	0.34	33.99	0.23	18.04
0.13	0.79	85.49	0.35	34.04	0.20	15.84
0.14	0.84	90.53	0.36	34.01	0.17	13.95
0.15	0.88	95.39	0.37	33.93	0.15	12.34
0.16	0.93	100,07	0.37	33.81	0.13	10.95
0.17	0.97	104.58	0.38	33.66	0.11	9.75
0.18	1.01	108.91	0.38	33.49	0.10	8.70
0.19	1.05	113.07	0.39	33.30	0.09	7.79
0.20	1.09	117.08	0.39	33.10	0.07	7.00
0.21	1.13	120.93	0.39	32.89	0.07	6.30
0.22	1.16	124.63	0.40	32.68	0.06	5.68
0.23	1.20	128.18	0.40	32.46	0.05	5.14
0.24	1.23	131.58	0.40	32.23	0.04	4.66
0.25	1.27	134.85	0.40	32.01	0.04	4.23
0.26	1.30	137.99	0.41	31.78	0.04	3.85
0.27	1.33	140.99	0.41	31.56	0.03	3.51
0.28	1.36	143.87	0.41	31.34	0.03	3.20
0.29	1.39	146.63	0.41	31.12	0.02	2.93
0.30	1.41	149.27	0.41	30.90	0.02	2.68

YIELD (no.) OF HUDSON RIVER ATLANTIC STURGEON
AT VARIOUS RECRUITMENT LEVELS AT AGE 1 FOR F=0.03
YPR= 0.19

Separate by sex			Sexes combined	
Recruitment	Male	Female	Recruitment	Total
500	106	84	1000	190
1000	212	168	2000	380
1500	318	253	3000	570
2000	423	337	4000	760
2500	529	421	5000	950
3000	635	505	6000	1140
3500	741	589	7000	1330
4000	847	674	8000	1520
4500	953	758	9000	1710
5000	1059	842	10000	1901
5500	1164	926	11000	2091
6000	1270	1010	12000	2281
6500	1376	1094	13000	2471
7000	1482	1179	14000	2661
7500	1588	1263	15000	2851
8000	1694	1347	16000	3041
8500	1800	1431	17000	3231
9000	1906	1515	18000	3421
9500	2011	1600	19000	3611
10000	2117	1684	20000	3801
10500	2223	1768	21000	3991
11000	2329	1852	22000	4181
11500	2435	1936	23000	4371
12000	2541	2021	24000	4561
12500	2647	2105	25000	4751
13000	2752	2189	26000	4941
13500	2858	2273	27000	5131
14000	2964	2357	28000	5322
14500	3070	2442	29000	5512
15000	3176	2526	30000	5702

3.4 Delaware River by A. Kahnle, C.A Shirey and K. Hattala

The Delaware River supported the largest stock of Atlantic sturgeon of any Atlantic coastal river system. Commercial landings of sturgeon from the Delaware Estuary were reported by the states of DE, PA, and NJ. Landings data are available from 1880 through the present (Figure 3.4.1 and Table 3.4.1). Highest landings for the time series in these states (2,968,000 kg) occurred in 1888 and accounted for over 90 percent of the total Atlantic coastal landings in that year. No other stock or region has supported landings of this magnitude. Landings from DE, PA, and NJ rapidly declined to less than 150,000 kg per year by 1904. From 1920 through 1980, landings seldom exceeded 10,000 kg per year. Reported landings climbed to a peak of almost 100,000 kg in 1990 before declining to zero with fishery closures since 1995. These recent landings were from the directed ocean fishery in NJ rather than any directed in-river fishery or an increase from the Delaware Estuary. Data from Waldman et al. (1996) indicated that 97.2 - 99.1 percent of Atlantic sturgeon in the recent NJ ocean harvest were of Hudson River origin.

3.4.1 Description of the Estuary

The portion of the Delaware River and Bay that is available to Atlantic sturgeon, and is utilized to any extent, runs from the fall line at Trenton, NJ to the mouth of Delaware Bay; a distance of 220 km. The estuary is generally broken into three ecological zones:

1) the tidal river - Trenton to the PA / DE border.
2) the transition zone - PA / DE border to Artificial Island, NJ
3) Delaware Bay - below Artificial Island, NJ to the Capes (Cape Henlopen DE and Cape May NJ)

The tidal river is approximately 85 km in length. This portion of the river is primarily tidal fresh water with a tidal amplitude of 2.5 meters at Trenton. We suspect that this area encompassed the primary spawning and nursery area for Atlantic sturgeon. Land use along the river is characterized by heavy suburban and urban development and heavy industrial use. Channel deepening and other changes to the hydrology of the river such as decreased freshwater flow rates, has had a profound effect on the upper estuary. The tidal height in Trenton has doubled since 1890 with increased salt water intrusion, salinity fluctuation and increased turbidity (Hires et al. 1984. and DiLorenzo et al. 1992).

The transition zone is characterized by strong tidal currents, high turbidity, and the beginning of the salinity gradient. It has a well defined shipping channel which is maintained to over 12.2 m in depth. This 42 km section of the estuary typically has low to moderate salinity, high suspended sediment load and low productivity. The Chesapeake and Delaware Canal and the Christina River enters the river in this area. Land use is mixed, characterized by urban and moderate industrial development, brackish wetlands and significant agricultural areas.

The lowermost zone is approximately 90 km in length and includes all of Delaware Bay.

It is characterized by relatively high salinity (8 to 31 ppt) and low suspended particulate matter. The Bay includes 80 - 95% of the estuary's surface area, water volume and biological productivity. Delaware Bay is generally well-mixed, with little long-term vertical stratification (Biggs 1978). It has a maintained shipping channel which is surrounded by broad shallow flats. The mean depth of the bay is 9.7 meters but 80% is less than 9 meters with a maximum depth of 45 meters. The surrounding land use is predominately agricultural with abundant salt marsh.

The Delaware River has had a history of water quality problems as early as the mid 1800's. Poor water quality was particularly bad in the portion of the river utilized by sturgeon for spawning and nursery habitat. By 1917 the upper tidal river received mostly untreated sewage from a population of over two million people (Marino et al. 1991). Water quality declined even further with increases in industrial pollution. By the 1940's a twenty mile section of the upper tidal river developed a dissolved oxygen sag to near anoxic conditions. Average DO levels were only 8% of saturation during the summer (Tarr and McCurley 1984).

A recent study demonstrated that water quality in the Delaware Estuary has improved dramatically over the past thirty years which coincides with major upgrading of sewage treatment plant facilities (Marino et al. 1991). A statistically significant improvement in dissolved oxygen concentrations was found in both the tidal river and transition zones of the Estuary. In recent years, average summer DO concentrations meet applicable standards, although concentrations still remain somewhat depressed in the lower tidal river.

3.4.2 Life History and Biology

Very little is known about current spawning of Atlantic sturgeon in the Delaware Estuary. Information on potential timing and location of spawning must be inferred from historical observations and anecdotal information.

The spawning migration of Atlantic sturgeon occurred from late April through mid- June at water temperatures of 12.8 to 18.3^0 C (Ryder 1888). Peak spawning activity occurred from 10-22 May at water temperatures of 13-18^0 C. Borodin (1925) reported that running-ripe sturgeon were captured near Delaware City, DE adjacent to Pea Patch Island. In addition, good spawning grounds occurred near Chester, PA over hard stony and gravelly bottom. Sturgeon may have spawned as far north as Bristol, PA and Bordentown, NJ just below Trenton, NJ, since fish were taken in that reach of river by 30.5 cm mesh gillnets and harpoon in the 1830's (PA State Commissioners of Fisheries 1897). Fecundity was reported by Ryder (1888) as 800,000 - 2,400,000 and by Borodin (1925) as 500,000 to 2,500,000 eggs per fish.

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. Historically, juveniles were abundant enough to be considered a nuisance by-catch of the American shad fishery. 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). The US Fish and Wildlife Service collected an approximately one meter long Atlantic sturgeon in the spring of 1996 in the Whitehill Range downstream from Trenton, New Jersey (B. Fletcher and J. Mohler, personal communication).

We have little data on recent growth or size of adults in the Delaware system. However, fish size and weight from the historic fishery was well documented. Cobb (1900) reported mean weights of fish in the 1897 commercial harvest as 71.7 kg in PA, 78.5 kg DE, and 116.7 kg in NJ. Borodin (1925) reported that 80 to 90 percent of the harvest in the early 1900's was made up of females. Horn (1957) reported that fish up to 181.4 kg were taken in 1886. Ryder (1888) indicated that females in the Delaware commercial harvest had a mean length of 2.4 m, with some up to 3.0 m in length. Males were generally 1.8 to 2.1 m long.

Some size and growth information of sub-adult Atlantic sturgeon in the Delaware Estuary has been obtained by Delaware Fish and Wildlife (Shirey 1996) and Lazzari et al. (1986). Length at age was estimated by marks on fin rays for fish taken in the upper Delaware River during 1981 through 1984 (Table 3.4.2a) and the lower river during 1995 (Table 3.4.2b). The age distribution of the fish sampled ranged from one through 11.

The growth rate of tagged sturgeon was determined from the direct measurement of 141 recaptured fish which ranged in size from 605 to 1530 mm (TL) (Shirey 1995). The weighted mean growth rate was 0.35 mm per day (128 mm per year). The data indicated that sturgeon growth in the mid-Atlantic region was relatively constant regardless of season or size, at least during this adolescent life stage.

Annual length frequency distributions of sub-adult fish (Figure 3.4.2, Table 3.4.3) from 1991 through 1997 also suggest the presence of several age classes in the lower Delaware River. 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 origin of sub-adult sturgeon in the Delaware Estuary is not known. Available evidence suggests that the sub-adult sturgeon occurring in the lower river are a mixture of stocks. Waldman et al. (1996) estimated stock composition of these sturgeon by analysis of mitochondrial DNA. They reported that the fish were a mixture of Hudson River and southeastern stocks or of Hudson River and a relict Delaware River stock.

Atlantic sturgeon travel widely once they emigrate from their natal river. Dovel and Berggren (1983) tagged sub-adult Atlantic sturgeon in the Hudson River Estuary in 1975 - 1978. Recaptures occurred from estuaries and the near shore ocean from Marblehead , MA to Ocracoke, NC. Thirty three percent of the recaptures outside of the Hudson came from the Delaware River and Bay. Approximately 1,700 sub-adult Atlantic sturgeon from the lower Delaware River were tagged by DE Fish and Wildlife from 1991 through 1997. Within this sample of Atlantic sturgeon were 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 near shore ocean and some estuaries from Maine through North Carolina. Recaptures from potential spawning areas occurred in the Hudson River-NY Delaware River-DE, York River-VA, and the Pamlico Sound and River-NC.

3.4.3 Current Status

Juvenile and adult Atlantic sturgeon were abundant enough in the Delaware River in the late 1800's to be considered a nuisance to gillnet fishermen and occasionally to boaters (Ryder 1888) (PA State Commissioners of Fisheries 1897). The current abundance of all life stages is most certainly greatly reduced from that time. Bottom trawl collections by DE Division of Fish and Wildlife in Delaware Bay beginning in 1966 rarely encountered Atlantic sturgeon (Table 3.4.4). There are a few isolated areas within the estuary that juvenile sturgeon regularly occur however. Lazzari et al. (1986) frequently took small Atlantic sturgeon from May through December in the upper river below Trenton, NJ. In addition, directed gillnet sampling from 1991 through 1997 consistently took sub-adult Atlantic sturgeon in the mid-estuary throughout the summer months (C. Shirey, DEDFW, personal communication). However, the number of fish taken in the lower river each year declined dramatically through the time period from over 500 to less than 60 (Table 3.4.5). 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 estimate could be made during 1996 and 1997 due to the lack of any recaptures. However, based on the number of fish taken and catch per unit of effort, their 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 undoubtedly low. The recent gillnet program conducted by Delaware Fish and Wildlife did not target adult fish. Some of the larger specimens taken in the program may have been mature males based on the reported size at maturity of Atlantic sturgeon. No mature females were taken although gear selectivity could have prevented efficient capture. The lack of any viable commercial fishery for adult sturgeon within the Estuary also suggests a very low abundance of spawning stock given the current high value for caviar.

A few carcasses of mature fish have been reported routinely from the lower river and upper Bay during the period of the historic spawning season. Fish in spawning condition have not been documented in recent years. However, the collection of Atlantic sturgeon from age 0+ (Delaware Div. of Fish and Wildlife trawl collections) through at least age 11 suggests that some spawning has continued to occur.

3.4.4 Factors Affecting Abundance

The precipitous decline in landings and presumably abundance of Delaware River Atlantic sturgeon could have been caused by a combination of over fishing and poor water quality. Population modeling of Atlantic sturgeon (See section on Hudson River stock) and experience with both white sturgeon (Beamsderfer 1992) and lake sturgeon (Bruch 1993) suggest that mortality caused by fishing cannot be sustained at levels much above 0.05 of the mature stock per year. The short duration and magnitude of harvest during the 1880's indicate harvest well above that level. This likely constituted a fishing-out of the available spawning stock biomass. It is possible that recent directed fisheries coupled with by-catch exceeded this minimal allowable target fishing rate on the remnant Delaware River stock.

Production and survival of early life stages may also have been affected by poor water quality. Borodin (1925) and Horn (1957) both suggested that water pollution was a factor in the decline of Atlantic sturgeon in 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 to 1940. Until recent years, poor water quality has been a significant factor for fishes utilizing the upper tidal portion of the estuary. 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 as late as the early 1970's. Fortunately, water quality has improved markedly and can now support aquatic life throughout most of the estuary throughout the year. Since 1990, dissolved oxygen levels have remained above minimum state standards throughout the entire year (R. Green personal communication).

The continued reports of adult fish, the collection of all age classes of juvenile sturgeon, and DNA studies (Waldman et al. 1996) suggest that a relict population of Atlantic sturgeon has persisted in the Delaware River. Factors which may have kept the stock at low levels include poor water quality in up-river spawning and nursery areas, changes in habitat from development and dredging for channel maintenance, and excessive mortality from directed and by-catch harvest.

Impacts of habitat change on Atlantic sturgeon abundance are unknown. Characteristics of the estuary have changed significantly since the valley was settled. The navigation channel is routinely dredged with some sediment redistributed. Freshwater flow from the upper portion of the watershed is regulated to an extent. Shoreline development has become extensive throughout the middle and upper reaches of the estuary. Atlantic sturgeon apparently used deep water and shoal habitat during the 1800's (Report of the Fish Commissioners 1889, Ryder 1888, and Borodin 1925). We cannot assess how critical habitat for the species has changed relative to that of pre-colonial times. However, other anadromous fish stocks such as striped bass that utilize the main-stem Delaware River for spawning and nursery habitat have recently been restored to harvestable abundance as water quality has improved. This suggests that environmental conditions may now be adequate to support growth of the Atlantic sturgeon population if the remaining population is allowed to reach maturity and spawn.

The importance of harvest and bycatch mortality are not known. Immature fish tagged by Shirey (1996) in the lower Delaware River were taken in a wide range of commercial gears in estuaries and the near shore ocean from Maine through North Carolina (Table 3.4.6). Highest numbers of recaptures occurred in New Jersey reflecting the open directed fishery in coastal waters that occurred in the late 1980's and early 1990's. The New Jersey fishery is now closed and by-catch of under-sized fish has probably declined in this state. Almost 90 percent of the fish in the coastal by-catch were reported as released alive. No landings have been reported in Delaware since the 7-ft. minimum size limit was adopted in 1990. However, given the current low abundance of the Delaware River stock a moratorium on landings throughout the range is the only method which will afford adequate protection through maturity.

By-catch mortality does not appear to be a significant factor with many existing commercial fisheries that encounter Atlantic sturgeon. Data on tagged fish released in the lower river and number of recaptures reportedly killed in the by-catch provide a lower bound on rate of mortality from by-catch. About 1,700 immature Atlantic sturgeon were tagged and released by DE Div. Fish and Wildlife from 1991 through 1996 (Table 3.4.6). Only nine tagged fish were reported killed in the by-catch through the time period. Since under-reporting cannot be discounted, these data provide a lower bound estimate of bycatch mortality rate of 0.005.

Recaptures also provide insight on relative losses to different commercial gears. Poorest survival of captured sturgeon occurred in anchored gillnets (87%). Highest survival (100%) occurred in trawls and pound nets.

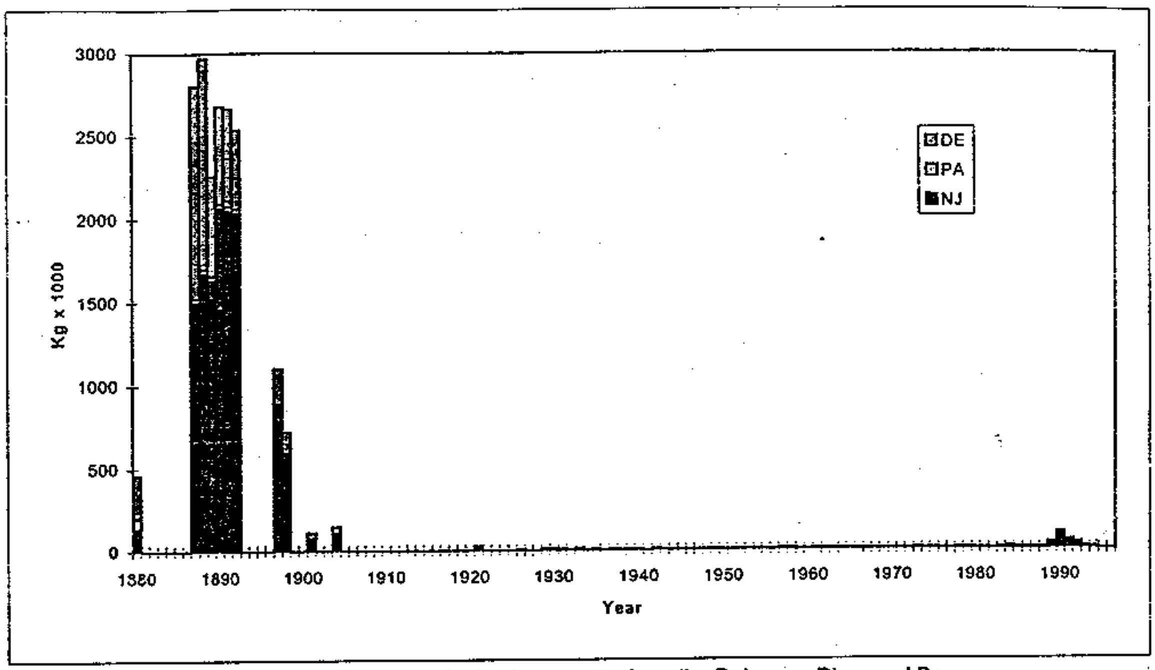


Figure 3.4.1. Reported landings (kg *1000) of Atlantic sturgeon from the Delaware River and Bay.

Table 3.4.2a. Age and fork length (FL) distribution of 22 Atlantic sturgeon captured in the upper Delaware River. From: Lazzari et al. 1986.

FL (mm)	Age in Years 1	2	3	4	5	6	7	Total
200-299	1							1
300-399								0
400-499		3		1				4
500-599			1	3	2			6
600-699					7	1		8
700-799							2	2
800+							1	1
Mean FL		439		516	622		771	

Table 3.4.2b. Length at age of Atlantic sturgeon collected from the Delaware River in 1995. From: Shirey 1996.

Year Class	Age	Number	Mean TL (mm)	Range TL (mm) min	Range TL (mm) max	SD (mm)	Growth Increment
1993	2	2	658	645	670	13	
1992	3	20	704	605	800	51	46
1991	4	14	816	765	865	28	112
1990	5	9	910	860	940	24	94
1989	6	5	970	915	995	29	60
1988	7	4	1063	1005	1135	47	93
1987	8	5	1102	1055	1170	39	39
1986	9	2	1068	1035	1100	33	-34
1985	10	5	1381	1180	1670	170	313
1984	11	1	1445				64

Weighted mean growth increment = 88.6 mm, increments were growth in a given year

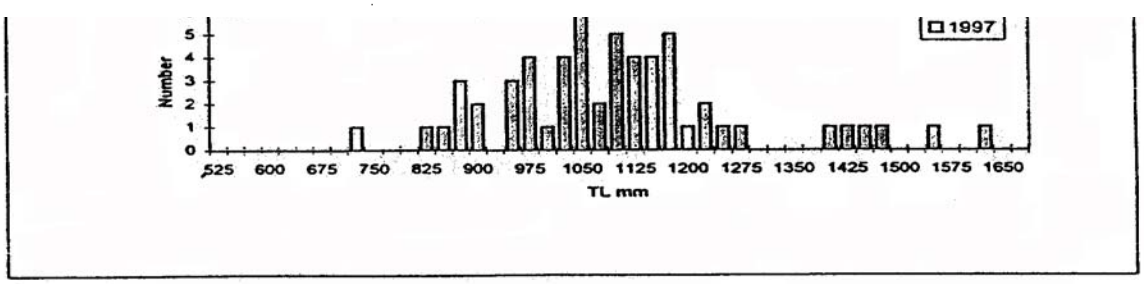


Figure 3.4.2 Length frequency of Atlantic sturgeon collected from the Delaware River, 1991 -1997.

Table 3.4.3. Length frequency (TL in mm) of Atlantic sturgeon collected from the Delaware River, 1991 -1997. From: Shirey 1997.

Interval (mm)	Year of Collection						
	1991	1992	1993	1994	1995	1996	1997
525		1		1	0	0	0
550	1	2	1	1	0	0	0
575		1	2	0	0	0	0
600	1	1		0	1	0	0
625	1	1		0	3	0	0
650	21	5	2	0	2	0	0
675	40	9		3	9	0	0
700	37	15	3	1	7	0	0
725	51	20	2	4	13	0	1
750	38	24	7	5	10	2	0
775	29	16	6	13	9	1	0
800	30	15	10	9	6	0	0
825	39	42	10	5	8	3	1
850	43	43	12	4	5	2	1
875	32	74	13	5	4	5	3
900	31	36	13	10	3	6	2
925	13	48	17	9	4	5	0
950	21	11	21	10	3	2	3
975	24	19	15	8	3	4	4
1000	20	17	23	8	3	2	1
1025	15	15	7	6	1	0	4
1050	15	16	6	13	2	1	6
1075	11	10	11	6	4	1	2
1100	4	12	6	9	1	1	5
1125	8	10	5	16	1	1	4
1150	8	6	7	10	1	3	4
1175	3	3	2	5	2	0	5
1200	1	6	3	8	1	2	1
1225	1	5	3	13	0	0	2
1250	1	3	1	4	0	0	1
1275	1	1	2	7	0	0	1
1300			2	8	2	1	0
1325			2	5	0	0	0
1350	2		2	3	0	0	0
1375	2		2	2	0	0	0
1400			1	3	0	0	1
1425	1		1	6	0	0	1
1450				1	1	0	1
1475		1		0	1	0	1
1500			1	1	0	0	0
1525				1	0	0	0
1550				2	0	0	1
1575	1			1	0	0	0
1600			1		0	0	0
1625					0	0	1
1650					0	0	0
1675					1	0	0
Total	546	488	222	226	111	42	57

Table 3.4.4. Catch of Atlantic sturgeon in the Delaware Bay by 9.1 m bottom trawl. From: Stewart F. Michels, personal communication.

Year	Number of Trawls	Number Sturgeon	Catch per Trawl
1966	56	2	0.036
1967	75	0	0.000
1968	50	0	0.000
1969	53	0	0.000
1970	43	0	0.000
1971	47	0	0.000
1972			
1973			
1974	24	0	0.000
1975			
1976			
1977			
1978			
1979	100	12	0.120
1980	96	2	0.021
1981	102	2	0.020
1982	46	0	0.000
1983	43	0	0.000
1984	50	0	0.000
1985			
1986			
1987			
1988			
1989			
1990	61	3	0.049
1991	72	0	0.000
1992	89	0	0.000
1993	83	0	0.000
1994	71	1	0.014
1995	88	2	0.023
1996	76	3	0.039

Table 3.4.5. Annual sample data on immature Atlantic sturgeon collected in the Delaware River by DE Div of Fish and Wildlife, 1991-1997 (Shirey et al. 1997).

Year	Number Taken	Days Sampled	Net Hours	N/Nethrs.	Population Estimate	Confidence Interval Upper	Lower
1991	565	26	17.5	32.3	5,600	8536	3[illegible]
1992	501	26	29.5	17	3392	4866	2[illegible]
1993	222	24	26.2	8	4154	10385	1[illegible]
1994	220	26	21.6	10.2	3470	8008	1[illegible]
1995	111	18	21.6	5.1	862	2350	[illegible]
1996	43	13	17.5	2.5	NA	NA	
1997	57	17	16.4	3.5	NA	NA	

NA - Population estimates not available for 1996 and 1997 because of no recaptures

Table 3.4.6. Data on fishery, gear, and disposition of Atlantic sturgeon tagged in the Delaware River by DE Div. of Fish and Wildlife, 1991-1996 (Shirey 1998).

State	Target Species	Gear	Disposition: Number Live	Disposition: Number Dead	Disposition: Unknown	Month
ME	Dogfish	Gill net	0	1		Jul
RI	Dogfish	Gill net	2	0		Aug
	Unknown	Unk	1	1		Jun, Oct
	Summer flounder	Trawl	1	0		Oct
MA	Dogfish	Gill net	5	1	1	Jun-Oct
	Summer flounder	Trawl	1	0		Jul
	Atl. Cod	GN/ H&L	2	0		Jul, Dec
CT	Survey	Trawl	1	0		Oct
NY	Sum. flounder/Bluefish	Trawl	8	0		Jun, Jul, Oct, Nov
	Sturgeon	Gill net	1	0		Aug
	Bluefish	Gill net	1	0		Oct
NJ	Sturgeon	Gill net	28	0		Apr, May, Jun, Oct
	Am. shad	Gill net	5	1		Apr, May
	Monkfish	Gill net	3	2		May, Jun, Dec
DE	Am. shad	Gill net	10	0		Mar, Apr
	Weakfish	Gill net	1	1		May, Nov
	Sturgeon	Gill net	6	0		May-Oct
	Survey	Trawl	1	0		Nov
MD	Dogfish	Gill net	1	2		Nov-Dec
	Summer flounder	Trawl	2	0		Sep, Oct
	S.bass/menhaden	Pound	1	0		Nov
	Am. shad	Gill net	1	0		Mar-Apr
VA	River herring	Gill net	1	0		Mar
NC	Weakfish/ bluefish	Gill net	2	0		Feb
	Weakfish/ spot	Gill net	1	0		Sep
	Survey	Trawl	1	0		Jan
	Mixed	Pound	1	0		Nov
Total			88	9	1	

Summary by gear	N-caught	N-live	N-dead	%-dead
Gill net	78	70	8	10.3%
Trawl	15	15	0	
Pound	2	2	0	
Unknown	2	1	1	50.0%

3.5 Chesapeake Bay and Tributaries by A. Kahnle, K. Hattala and C. Shirey

Atlantic sturgeon were once abundant in the Chesapeake Bay and tributaries (Hildebrand and Schroeder 1928). Commercial landings of sturgeon from the Chesapeake system were reported by the states of Maryland and Virginia. Landings data are available from 1880 through the present (Figure 3.5.1 and Table 3.5.1). Highest landings for the time series (416,000 kg) from the Bay states combined occurred in 1890. Landings declined to less than 40,000 kg annually by 1925 and remained below this level through 1993. No landings of Atlantic sturgeon have been reported from Maryland or Virginia since that time. Virginia closed its fishery in 1970. A possession ban was implemented in Virginia in 1992. Maryland closed its fishery in 1996.

Vladykov and Greely (1963) reported that historically important sturgeon fisheries occurred in the Susquehanna, Potomac, York, and James Rivers. Some sense for the relative importance of some Bay tributaries can be inferred from limited river specific commercial harvest data. Hildebrand and Schroeder (1928) reported that landings in 1880 were 49,400 kg from the James, 23,400 kg from the York, 8,000 kg from the Rappahannock, and 130,640 kg from the Potomac Rivers.

3.5.1 Description of the Bay and tributaries

3.5.2 Life History and Biology

Very little is known about biology of Atlantic sturgeon in the Chesapeake system. Sturgeon were, at one time, common throughout the bay and tributaries. Presumably spawning occurred in the major tributaries, but we can find little or no verification of which rivers or where. A popular article by Carricata (1997) reports anecdotal evidence from the Pennsylvania Fish Commission that a mature Atlantic sturgeon was killed in the lower Juniata River near Newport sometime around 1900. This fish presumably moved into the river for spawning. As the Juniata joins the Susquehanna River just upriver of Harrisburg, PA, access by sturgeon would have to have been prior to the building of Holtwood Dam on the Susquehanna in 1910.

Information on current distribution of Atlantic sturgeon was obtained by the U.S. Fish and Wildlife Service (Skjeveland, personal communication; Spells 1997). They offered a reward for access to live Atlantic sturgeon caught in the Chesapeake Bay system. The program extended from early 1996 through the present in the Maryland part of the Bay (Skjeveland, personal communication) and from February through November in the Virginia part of the Bay (Spells 1997). To date, data have been obtained on 32 wild fish from Maryland and 190 wild fish from Virginia. Most of the fish in Maryland were from the main Bay or from large embayments. Fish in Virginia were from the James, York, and Rappahannock Rivers (Table 3.5.2). Most were from the James River. Since a greater number of wild Atlantic sturgeon were reported during the shorter Virginia reward program, it appears that Atlantic sturgeon are concentrated in the lower part of Chesapeake Bay and lower Bay tributaries.

The number of Atlantic sturgeon collected in the Chesapeake Bay system varies by season. Most of the sturgeon observed in the U.S. Fish and Wildlife Service reward programs were taken in fall, winter or spring (Table 3.5.3). Few were reported in summer months. It is possible however that the pattern of captures was influenced by the types of commercial fisheries prosecuted in the Bay. Gillnet fisheries are limited to the winter months in the Maryland portion of the Bay (D. Weinrich, personal communication). Although pound net fisheries occur year round, Atlantic sturgeon were primarily caught during the spring. Given sturgeon behavior in other large estuarine systems, such as the Delaware Bay, it may be unlikely to see many sturgeon in shallow waters (less than 4.6 m deep) in the summer where pound nets are set. Data collected during the last few years of the open fishery in the Maryland part of the Bay indicate that most sturgeon were taken in fall and early spring (Speir and O'Connell, 1996). The authors suggested that these fish were a bycatch and season of catch was influenced by the fisheries involved. A few Atlantic sturgeon were collected in the gillnet survey by MDDNR conducted as part of the striped bass assessment (Speir and O'Connell, 1996). Most of these fish were collected in April, May, November, and December.

Limited data are available on size and growth of Atlantic sturgeon in the Chesapeake Bay. The best information on size of fish was provided by the U.S. Fish & Wildlife Service reward program. Fish from the Maryland portion of the Bay were 510 - 1740 mm total length (Table 3.5.3). Fish from the James, York, and the Rappahannock Rivers in Virginia were 260 - 2600 mm TL, 615 - 1150 mm TL, and 506-993 mm TL respectively (Table 3.5.4). Atlantic sturgeon collected in the striped bass gillnet assessment survey were 391 - 1094 mm TL (Figure 3.5.2, Speir and O'Connell, 1996).

Data are not available on length at age for Chesapeake Bay Atlantic sturgeon. However, fin ray samples have been collected by the U.S. Fish and Wildlife Service for future age determinations.

3.5.3 Current Status

Atlantic sturgeon have persisted in Chesapeake Bay through the present. However, abundance is significantly reduced from that in the late 1800's. Extensive fishery dependent and fishery independent sampling conducted throughout the bay and tributaries since the 1950's have produced very few Atlantic sturgeon (Secor 1995; Sadzinski, personal communication). Speir and O'Connell (1996) summarized results of the extensive and intensive fishery surveys conducted by the MDDNR. They reported that no Atlantic sturgeon were collected in 6,454 seine hauls in various Chesapeake Bay tributaries (1958 - 1993) or in 2,900 trawl samples in rivers, bays, and sounds (1980 - 1990). Only one Atlantic sturgeon was collected in 1765 trawl samples by the University of Maryland in the Maryland part of the main Bay (1988 - 1990). No Atlantic sturgeon have been collected in over 20 years of sampling at the Conowingo Dam fish lift at km 16 on the Susquehanna River. Only 35 Atlantic sturgeon were collected in striped bass gillnet surveys since 1981. The greatest number of Atlantic sturgeon collected in the Chesapeak Bay system were observed during the recent U.S. Fish and Wildlife Service reward programs.

Atlantic sturgeon spawning seems to have persisted in some lower bay tributaries. There is evidence that Atlantic sturgeon have spawned in the James and perhaps the York Rivers in recent years. Large, probably mature fish and a sturgeon 260 mm TL (probably age zero) were observed in the James River in the Fish and Wildlife Service reward program. Spells (1997) also reported sightings of two Atlantic sturgeon about 250 mm long in the James River in the winter of 1997. Secor (1995) reported that scientist with the Virginia Institute of Marine Science (VIMS) observed carcases of two large females in the James River and the Eastern shore in the early 1990's. VIMS trawl surveys also captured age zero Atlantic sturgeon in the James and York Rivers in the mid-1970's (Secor 1995). The presence of age zero fish can be inferred as evidence of spawning. It is not known if young Atlantic sturgeon (age one to three) emigrate from Chesapeake tributaries or Bay as quickly as reported by Dovel and Berggren (1983) for the Hudson. The large amount of estuarine habitat offered by the Chesapeake Bay may provide suitable nursery grounds for young fish, but this may be confounded by water quality issues (see 3.5.4 below).

Most of the sturgeon measured in the recent U.S. Fish and Wildlife Service reward program were immature fish. Some of these fish may have come from other Atlantic coastal rivers. Dovel and Berggren (1983) tagged immature Atlantic sturgeon in the Hudson River Estuary in 1975 - 1978. Thirty eight percent of the recaptures from outside the Hudson came from the Chesapeake Bay system. Most of these were from the lower bay and tributaries. Immature Atlantic sturgeon tagged by Shirey (1997) in the lower Delaware River in 1991-1997 were also recaptured from the Chesapeake Bay and the York River. It is clear that immature Atlantic sturgeon in the mid Atlantic region move widely along the coast and into estuaries once they emigrate from their natal rivers.

3.5.4 Factors Affecting Abundance

The dramatic decline in landings and presumably in abundance of Atlantic sturgeon from the Chesapeake in the late 1800's was most likely caused by over fishing. Population modeling of Atlantic sturgeon (see section 3.3.2.4 Hudson River) and experience with the lake sturgeon (Bruch 1993) suggest that mortality caused by fishing cannot be sustained at levels much above 0.05 of the mature stock per year. The short duration and magnitude of harvest during the 1880's indicate rates of fishing mortality well above that level.

Factors keeping the stock at low levels since the turn of the century include poor water quality, changes in habitat from development, dredging, and dam construction, and mortality from directed and bycatch fishing.

Poor water quality has been a problem throughout this century. Secor (1995) suggested that increased nutrient loading and frequency of hypoxia have reduced usable habitat and benthic foods in large parts of the Bay. He inferred that the problem has not improved in recent years. Empirical data on current habitat quality in the Bay comes from experimental release of cultured Atlantic sturgeon by the Maryland DNR. In 1996, the MDNR stocked the Nanticoke River with approximately 3,300 marked age one Atlantic sturgeon, provided by the US Fish and Wildlife Service (Mangold, personal communication). Recaptures of these fish during the reward program provided information on current growth potential of Bay nursery habitat. Recaptured fish appear to be vigorous (J. Skjeveland, personal communication) and are growing very well relative to fish of similar age in the Delaware Estuary (Table 3.4.4). Thus parts of the Bay still sustain growth of immature fish.

Habitat has probably been changing in the Chesapeake Bay system since the area was settled by Europeans in the 1600's. The most obvious and significant change has been construction of dams on Bay tributaries. Access to the Susquehanna was limited with construction of Holtwood Dam (km 39) in 1910 and by Conowingo Dam (km 16) in 1928 (Carricata 1997). Impacts of habitat change from dredging, shoreline development, and changes in tributary flow regime are likely, but remain unquantified. Addition of suspended sediments to the Upper Bay from the Susquehanna River in recent years have been substantial (Gross et al. 1978).

Effects of harvest and bycatch on the current population of Atlantic sturgeon in Chesapeake Bay are unknown. Reported commercial landings of Atlantic sturgeon from Maryland and Virginia have remained relatively low throughout this century. Hildebrand and Schroeder (1928) reported that most sturgeon taken in the early 1900's were a bycatch in pound nets with a few sturgeon taken in gillnets. In the recent past, Maryland allowed take of Atlantic sturgeon with a minimum size of 11.3 kg. Most likely sturgeon were a welcome bycatch of the commercial fishery for other fish rather than focus of a fishery. Commercial harvest of Atlantic sturgeon closed in Virginia in 1970 and in Maryland in 1996. However, the bycatch continues. All of the wild recaptures in the US Fish and Wildlife Service reward program came from the commercial bycatch. Most were from pound nets and gillnets in Maryland (Table 3.5.3) and from 7.6-17.5 cm stretched mesh anchored gillnets (Spells 1997) in Virginia. Size of sturgeon in the Virginia bycatch depended on the target species of the fishery (Spells 1997). Smallest sturgeon were taken in October and November when fishermen used 7.6-8.2 cm stretch mesh nets for Atlantic croaker, weakfish, and white perch.

Rate of mortality in the bycatch is unknown. The US Fish and Wildlife Service reward program was for live captures. Thus few dead sturgeon were reported. It is likely however, that rates of mortality were low. The gillnet fishery where highest mortality would be expected, occurs during cold water months which increases survival. Most captures in warm water months occurred in pound nets which normally have very low rates of mortality.

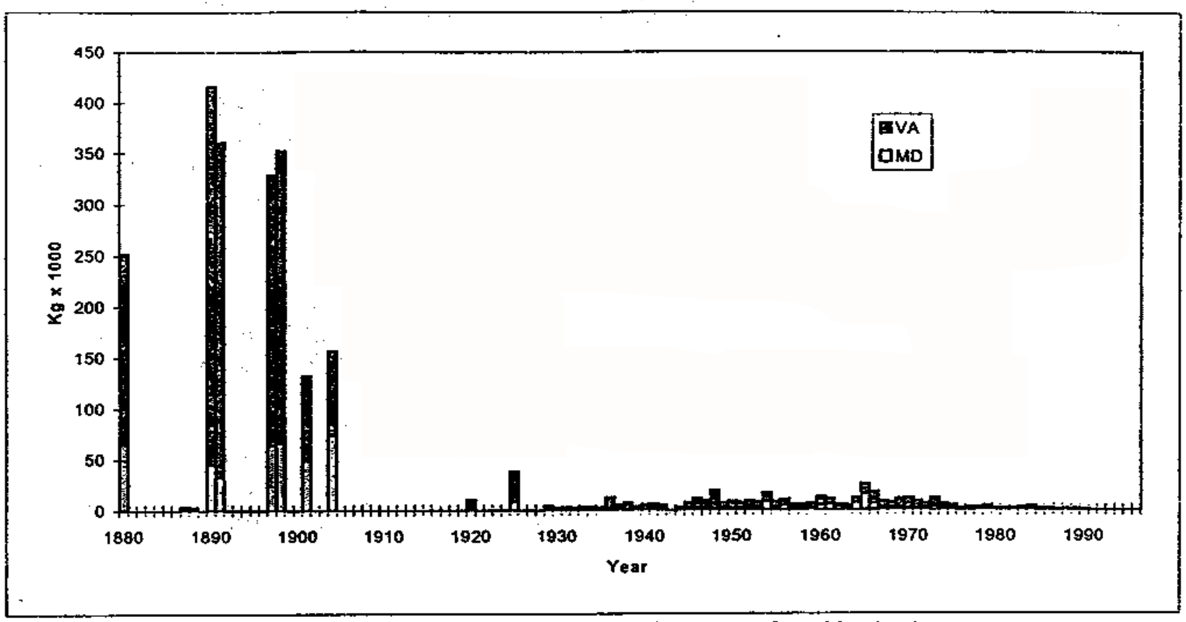
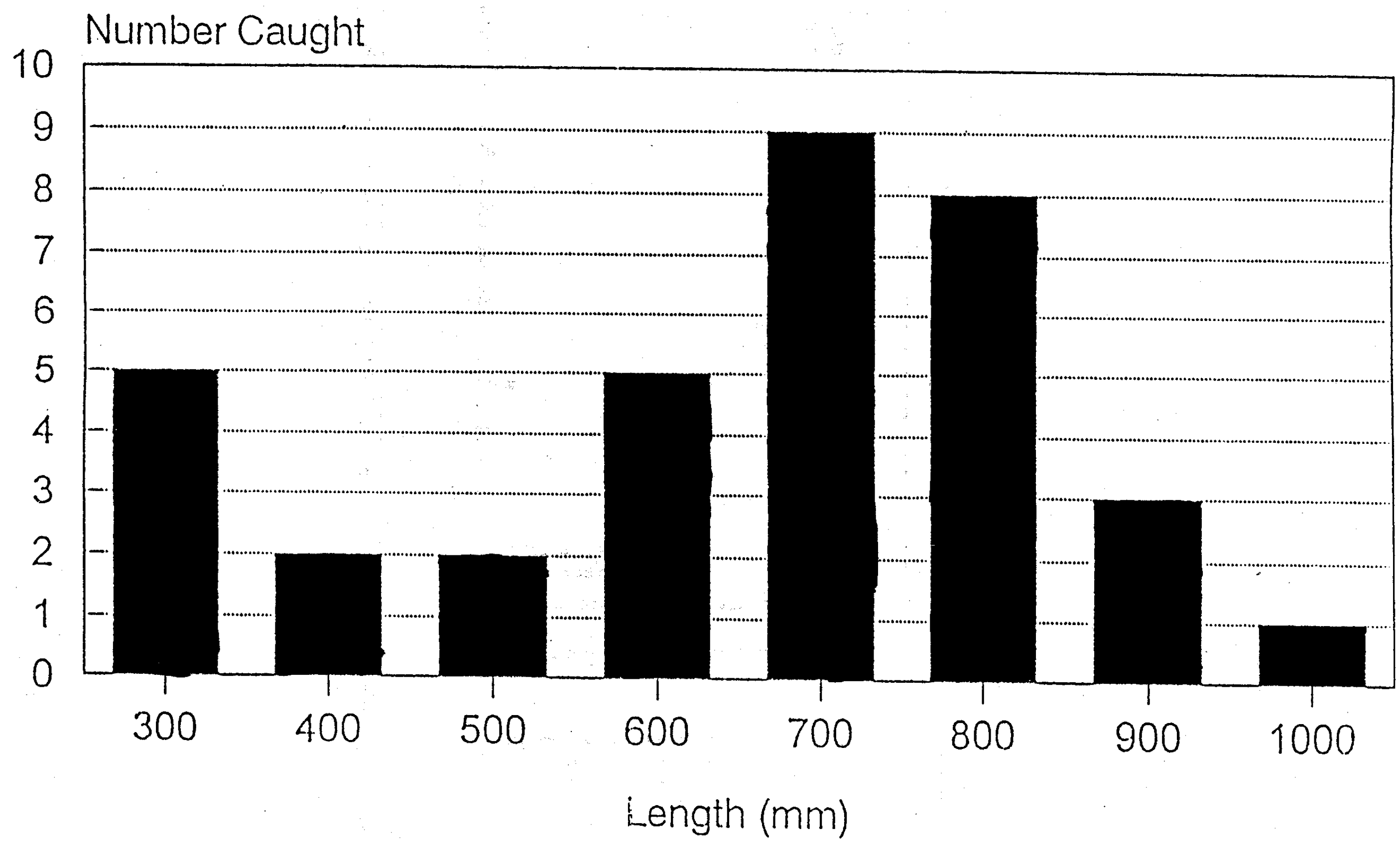


Figure 3.5.1. Reported commercial landings (kgs*1000) of Atlantic sturgeon from Maryland and Virginia

Figure 3.5.2 Atlantic Sturgeon Data Gathered From Striped Bass Stock Assessment Project



From Speir and O'Connel (1976)

Table 3.5.1. Reported commercial landings (kgs*1000) of Atlantic sturgeon from Maryland and Virginia

Year	MD	VA	Total	Year	MD	VA	Total
1880	65.3	186.9	252.2	1940	0.5	5.4	5.9
1881				1941	0.5	5.9	6.4
1882				1942	1.8	3.6	5.4
1883				1943			
1884				1944	0.9	2.3	3.2
1885				1945	2.7	5.0	7.7
1886				1946	1.4	10.4	11.8
1887	3.6		3.6	1947	1.8	8.2	10.0
1888	3.2		3.2	1948	1.8	17.2	19.1
1889				1949	2.3	5.4	7.7
1890	45.4	371.0	416.4	1950	1.4	7.3	8.6
1891	32.7	328.4	361.1	1951	1.8	5.9	7.7
1892				1952	3.2	6.4	9.5
1893				1953	2.7	5.4	8.2
1894				1954	8.6	8.2	16.8
1895				1955	3.2	5.4	8.6
1896				1956	4.5	5.9	10.4
1897	64.0	265.4	329.3	1957	3.2	2.3	5.4
1898	66.2	286.7	352.9	1958	2.7	3.2	5.9
1899				1959	1.4	5.4	6.8
1900				1960	5.0	8.2	13.2
1901	49.0	83.0	132.0	1961	5.9	5.4	11.3
1902				1962	3.6	2.3	5.9
1903				1963	3.2	1.8	5.0
1904	74.4	82.1	156.5	1964	7.3	5.0	12.2
1905				1965	15.9	10.0	25.9
1906				1966	6.4	11.8	18.1
1907				1967	3.2	5.4	8.6
1908				1968	2.3	5.9	8.2
1909				1969	2.7	8.6	11.3
1910				1970	1.8	10.0	11.8
1911				1971	1.4	7.7	9.1
1912				1972	1.8	5.0	6.8
1913				1973	3.6	8.2	11.8
1914				1974	2.3	4.1	6.4
1915				1975	2.3	2.7	5.0
1916				1976	0.9	1.4	2.3
1917				1977	0.9	2.3	3.2
1918				1978	1.8	0.9	2.7
1919				1979	1.4	3.2	4.5
1920	0.5	10.0	10.4	1980	0.5	1.4	1.8
1921				1981	0.5	1.4	1.8
1922				1982	0.5	1.8	2.3
1923				1983	1.4	1.8	3.2
1924				1984	1.8	2.7	4.5
1925	8.6	29.9	38.6	1985	0.9	0.9	1.8
1926				1986	1.8	0.0	1.8
1927				1987	0.5	0.0	0.5
1928				1988	1.4	0.0	1.4
1929	0.5	4.1	4.5	1989	1.4	0.0	1.4
1930		2.3	2.3	1990	0.9	0.0	0.9
1931	0.5	2.7	3.2	1991	0.0	0.0	0.0
1932	0.5	2.3	2.7	1992	0.0	0.0	0.0
1933	0.5	3.6	4.1	1993	0.0	0.0	0.0
1934	0.5	3.6	4.1	1994	0.0	0.0	0.0
1935	0.5	2.7	3.2	1995	0.0	0.0	0.0
1936	0.5	12.2	12.7	1996	0.0	0.0	0.0
1937		5.9	5.9				
1938	0.5	7.3	7.7				
1939	0.5	3.6	4.1				

Table 3.5.2. Atlantic sturgeon reported during the U.S. Fish and Wildlife Service sturgeon reward program from Virginia tributaries of the Chesapeake Bay, February - November 1997 (Spells 1997).

	Tributary			
	James	York	Rapp	Total
Wild	169	6	15	190
% of Total	98.2	66.7	68.2	93.5
Hatchery	3	3	7	13
% of Total	1.7	33.3	31.8	6.4
Total	172	9	22	203

Table 3.5.3. Size (TL-mm) and capture method of wild Atlantic sturgeon reported during the sturgeon reward program in Maryland waters of Chesapeake Bay (J. Skjeveland, personal communication).

	Number by Capture Gear			
Year	Gill Net	Pound Net	Trawl	Crab Pot
1996	4	9	0	1
1997	10	13	1	0
1998	7	0	0	0
Total	21	22	1	1

	Gill Net			
Season	N	Mean	Min	Max
spring	0			
summer	0			
fall	0			
winter	21	902.3	700	1160
Total	21	902.3		
	Pound Net			
spring	18	940.7	510	1740
summer	0			
fall	1	930.0	930	930
winter	3	1124.7	895	1526
Total	22	965.3		
	Trawl			
spring	0			
summer	1	950		
fall	0			
winter	0			
Total	1	950		
	Crab Pot			
spring	1	1030		
summer	0			
fall	0			
winter	0			
Total	1	1030		

Table 3.5.4. Atlantic sturgeon reported during the U.S. Fish and Wildlife sturgeon reward program from the James, York, and Rappahannock Rivers , February - November 1997 (Spells 1997).

	James River					
	Number		Avg. TL (mm)		Range TL (mm)	
Month	Wild	Hatch	Wild	Hatch	Wild	Hatch
Feb	2	0	945		835-1055	
Mar	10		805	575	440-1030	510-640
Apr	14	1	811	815	260-1390	815
May	18	0	817		510-1700	
June	2	0	648		420-931	
July	1	0	875			
Aug	2	0				
Sep	4	0	470		445-495	
Oct	90	0	510		402-2600	
Nov	30	0	504		442-940	
	Rappahannock River					
	Number		Avg. TL (mm)		Range TL (mm)	
Month	Wild	Hatch	Wild	Hatch	Wild	Hatch
Feb	0	0				
Mar	1	1		595		
Apr	14	5	716	647	506-993	508-744
May	4	0	630		506-708	
June	1	1		630		
July	0	0				
Aug	0	0				
Sep	0	0				
Oct	1	0	1004			
Nov	0	0				
	York River					
	Number		Avg. TL (mm)		Range TL (mm)	
Month	Wild	Hatch	Wild	Hatch	Wild	Hatch
Feb	1	0	625			
Mar	2	1	1150	630		
Apr	3	2	675	683	675	680-687
May	1	1	759			
June	0	0				
July	0	0				
Aug	0	0				
Sep	1	0	615			
Oct	0	0				
Nov	0	0				

3.6 North Carolina by A. Kahnle and K. Hattala

Atlantic sturgeon were, at one time, abundant in most coastal rivers and estuaries in North Carolina. Statewide records of commercial harvest are available from 1880 through the present (Figure 3.6.1, Appendix Table B1). Highest landings of the time series (198,000 kg) occurred in 1880 followed by several slightly smaller peaks through the remainder of the late 1800's. Landings declined precipitously soon after and remained at relatively low levels through 1960. Landings then climbed to 70,000 kg in 1972 before declining again. The fishery was closed in 1991.

The largest fisheries for Atlantic sturgeon in 1880 occurred in the Cape Fear River (118,000 kg, Goode 1887) and the Roanoke River - Albemarle Sound complex. Harvest in the Cape Fear River was a directed fishery for flesh and it occurred from spring through fall (Goode 1887). Zarzecki and Hightower (1997) provided an extensive review of existing records and literature documenting the historical fisheries in the Roanoke River and Albemarle Sound. They indicate that the primary fishery occurred in Albemarle Sound and that Atlantic sturgeon were caught as bycatch in the haul seine fishery targeting American shad. It wasn't until the demand for caviar grew that a directed fishery developed in the late 1880's. With the development of directed fisheries in both the Sound and the river, by the early 1900's, harvest soon declined.

3.6.1 Description of the Estuaries

3.6.1.1 Roanoke River, Albemarle Sound

Zarzecki and Hightower (1997) indicated that Atlantic sturgeon utilized the Roanoke River to a greater extent than the Chowan River. Atlantic sturgeon moved as far inland as the fall line near Weldon NC, between river km 206 and 242. The falls above Weldon may have been impassable except in high water years. However, Zarzecki and Hightower (1997) state that sturgeon may have been able to move above the falls. Catches at "fish traps or slides" built in this section of the river indicate that sturgeon, as well as other species, were seldom allowed to escape downriver. A canal system was followed by hydropower facilities that have been in operation at Weldon since about 1905.

3.6.1.2 Cape Fear River

Moser and Ross (1995) described the Cape Fear River Estuary as a system driven by tidal currents (up to the first dam at km 96) with high turbidity and vertical salinity stratification. Sediments are soft mud to sand. Salinity in the lower 20 km ranges from 9 to 25 ppt, varying seasonally with freshwater river discharge. The Cape Fear River is dredged annually to maintain a depth of 4 m, but up to 12 m in the Wilmington harbor. The river in general averages 4 m (dredged depth) with occasional deep holes of > 10 m. Areas of the Brunswick River, which parallels the main stem Cape Fear for about 10 km, have not been dredged since the 1940's.

3.6.2 Life History and Biology

Very little is known about biology of the Atlantic sturgeon in North Carolina. Potential timing of spawning in the Roanoke River must be inferred from historical observations and anecdotal information in Zarzecki and Hightower (1997). Atlantic sturgeon appeared in the catch as early as March, but most were caught during April into the first two weeks of May. Goode (1887) indicated that the spring fishery in the Cape Fear River for export to New York City occurred from mid March through April.

Growth of Atlantic sturgeon in North Carolina is poorly documented. Goode (1887) reported that mean dressed weight of Atlantic sturgeon in the Cape Fear River fishery was 27.2 kg. Hoff (1980) reported that at the turn of the century Atlantic sturgeon up to 225 kg in weight and 3.7 m long were common.

3.6.3 Current Status

Hoff (1980) reviewed several studies conducted in North Carolina. The studies indicated that Atlantic sturgeon were present in low levels in most coastal rivers of North Carolina through the 1970's. Juvenile Atlantic sturgeon as small as 400 mm were collected in the Neuse and Pamlico Rivers. He indicated that remnant spawning populations remained in the Cape Fear and Northeast Cape Fear Rivers.

Information on current distribution of Atlantic sturgeon was obtained by Moser and Ross (1995) and most currently by Moser et al. (In press 1998). In 1990 through 1992, Moser and Ross (1995) conducted a gillnet study in the tidal Cape Fear system to examine habitat use and movement of Atlantic and shortnose sturgeons. Juvenile Atlantic sturgeon were relatively common and ranged from 340 to 1230 mm TL. Most were 600 to 800 mm TL, attributed to size selectivity of the sampling gear (gillnets). Highest CPUEs occurred in June through September in the Brunswick River, an area near the edge of the salt wedge. Movements indicate that Atlantic sturgeon sought out depths greater than 10 m year-round and in summer moved infrequently, seeking out deep freshwater thermal refugia.

Moser et al. (In press 1998) conducted a more recent study on distribution of sturgeons in several North Carolina systems. They classified sturgeon into three size groups: young-of-the-year (YOY) < 440 mm FL, juvenile 440 mm FL to 1430 mm FL, and adult fish >1430 mm FL. Spawning seems to have persisted in two systems. YOY fish are present in Albemarle Sound and the Cape Fear River (Figures 3.6.2 and 3.6.3). Some juveniles were found within Albemarle Sound and the Cape Fear River. Most juveniles are in ocean waters bordering Albemarle Sound and Pamlico Sound (Figure 3.6.4). Adults were found within the Pamlico and Cape Fear Rivers and in ocean waters off Albemarle and Pamlico Sounds.

3.6.4 Factors Affecting Abundance

Factors contributing to the decline in abundance of Atlantic sturgeon in North Carolina were similar to those implicated in earlier sections for other systems along the coast. The drop at the turn of the century was most likely caused by over-fishing. The short duration and magnitude of harvest during the late 1800's indicate rates of fishing mortality well above the level recommended by population modeling (see section 3.3.2.4 Hudson River). Many of the early authors such as Goode (1887) and Smith (1907) as cited in Hoff (1980) implicated over-fishing as the factor responsible for stock decline. Factors keeping the stock at low levels since the turn of the century include poor water quality, changes in habitat from development, dredging, dam construction, and mortality from directed and bycatch fishing.

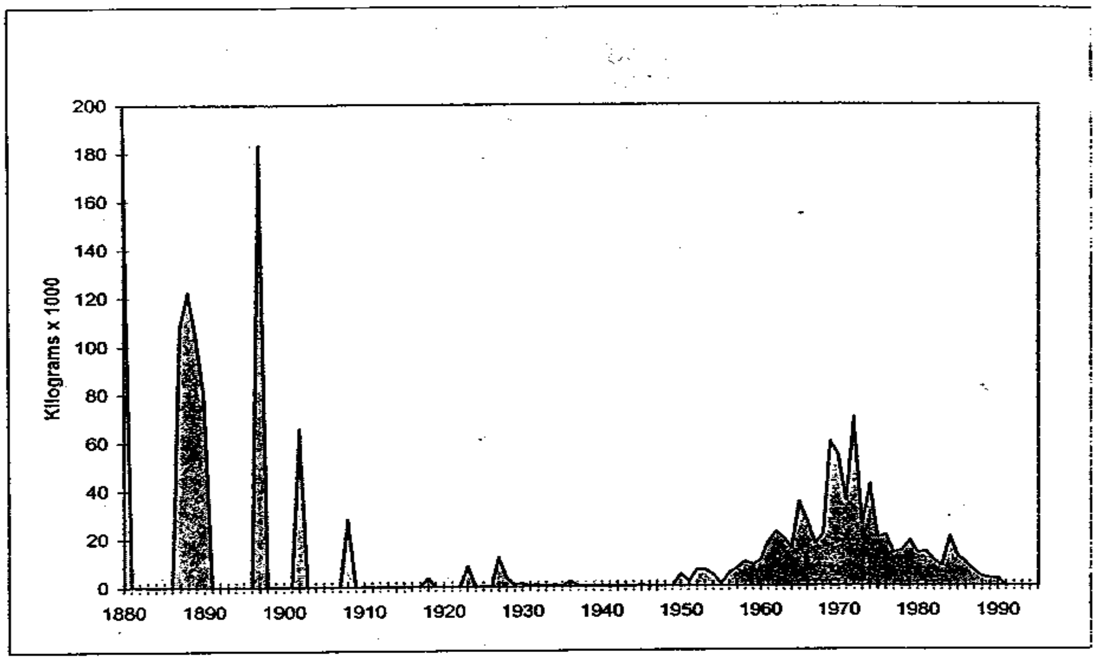
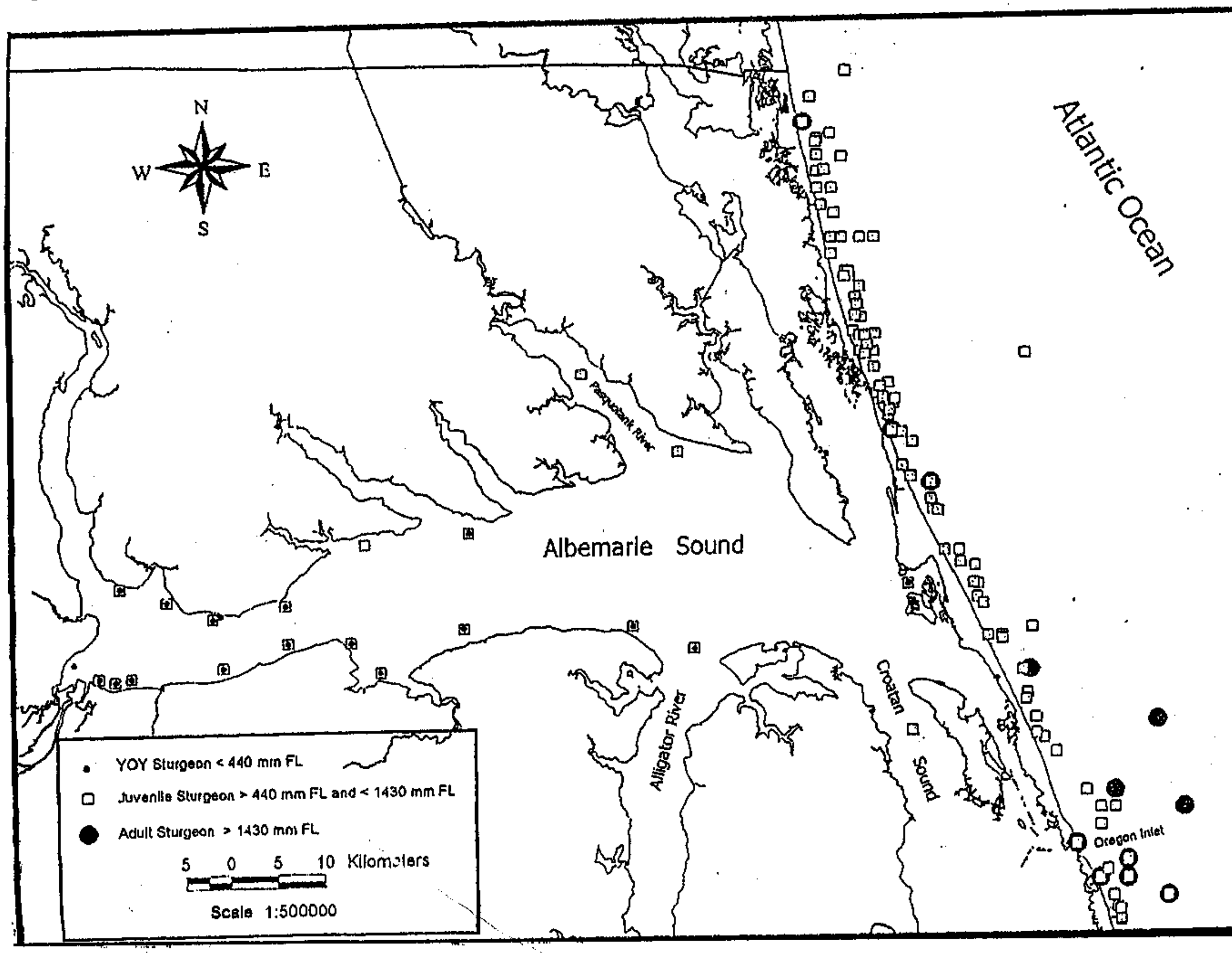


Figure 3.6.1 North Carolina's historical commercial landings of Atlantic sturgeon.

Figure 3.6.2 Presence of YOY, juvenile and Adult sturgeon in waters of Albemarle Sound and bordering ocean waters.



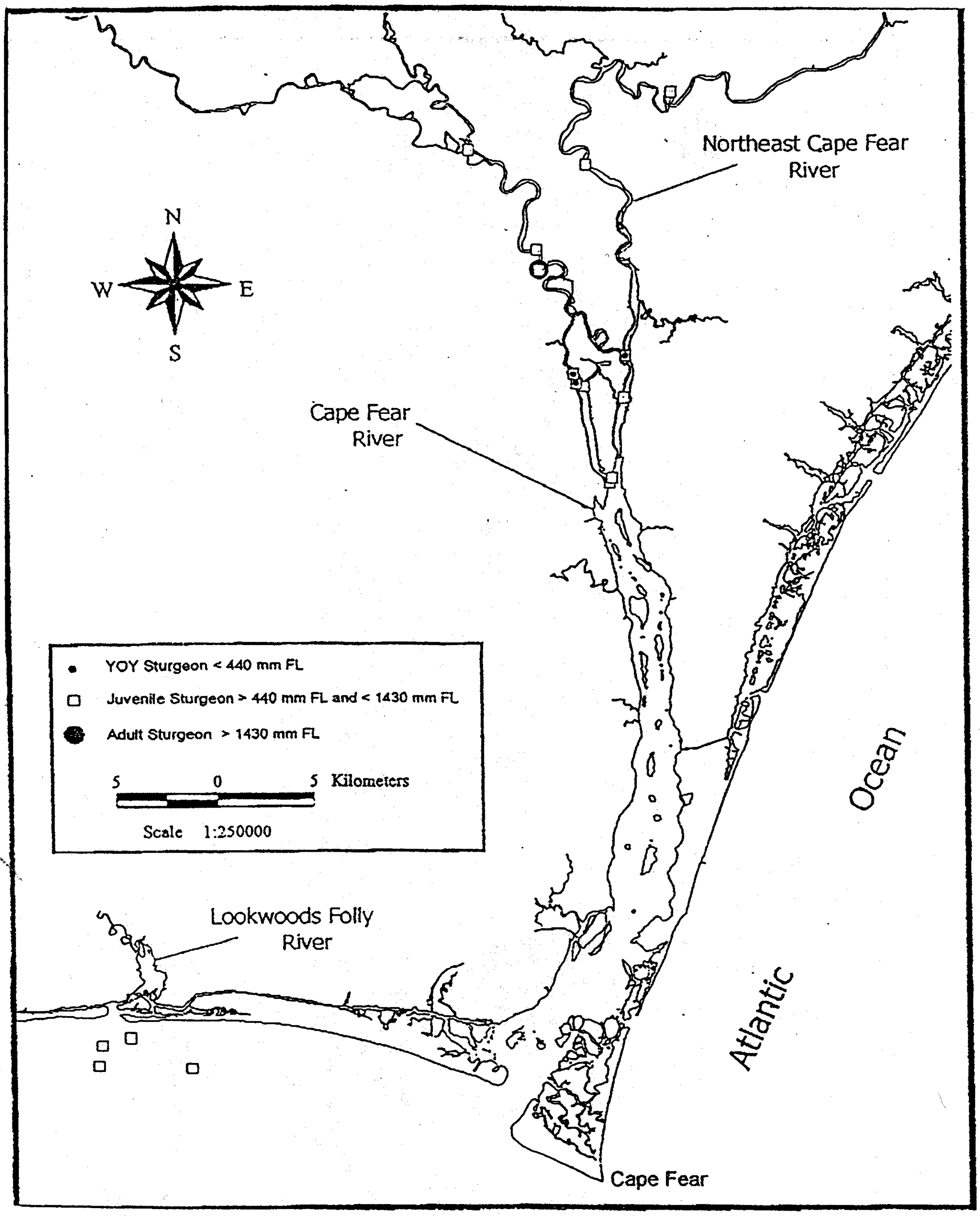
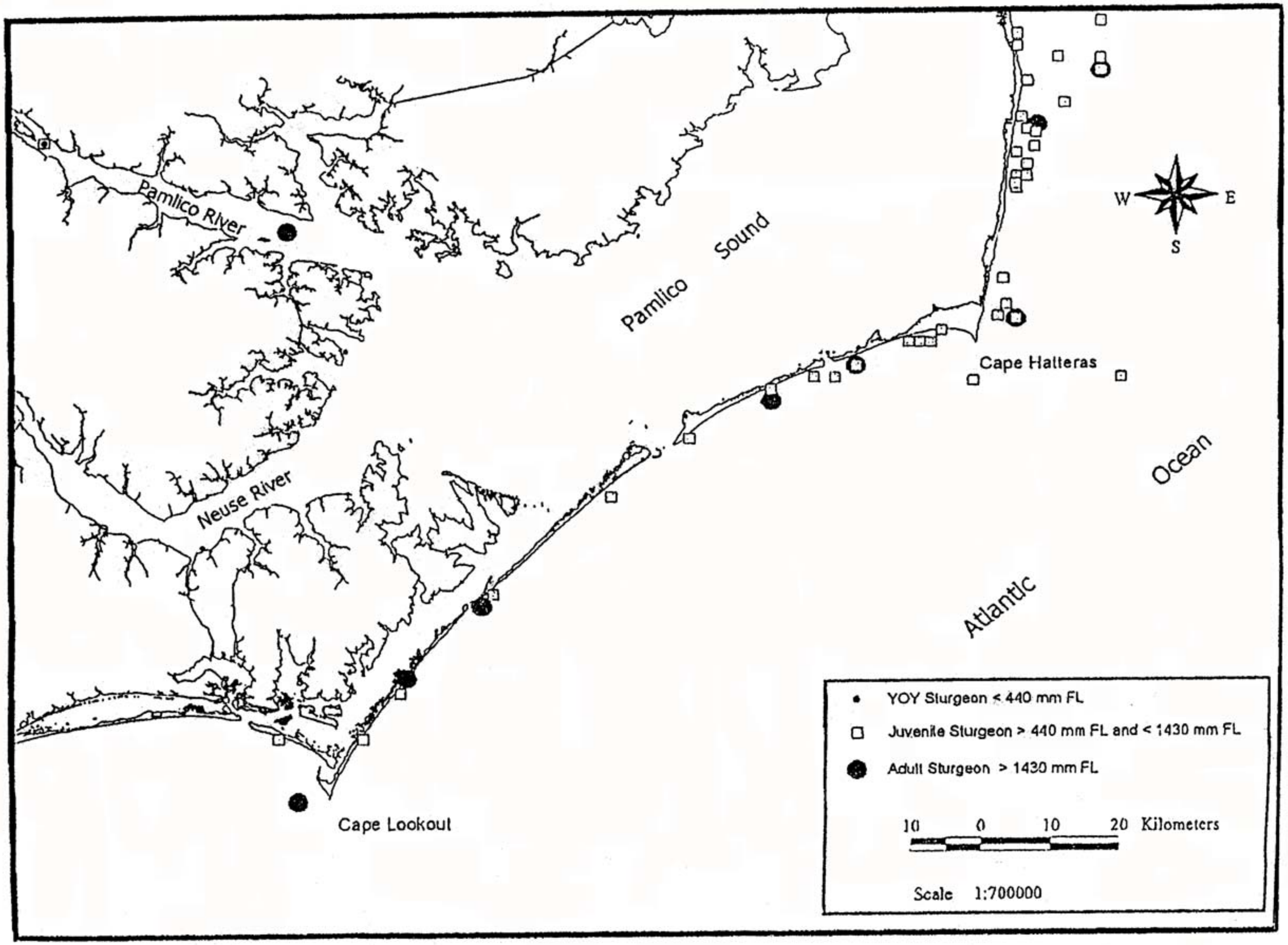


Figure 3.6.3 Presence of YOY, juvenile and Adult sturgeon in waters of Cape Fear River and bordering ocean waters IN Moser et al. (In press 1998)

Figure 3.6.4 Presence of YOY, juvenile and Adult sturgeon in waters of Pamlico Sound and bordering ocean waters IN Moser et al. (In press 1998)



3.7 Southeast States by Mark R. Collins

3.7.1 Current status

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

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 the 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. Capture of age 1 juveniles from the lower Waccamaw suggests that a reproducing population of Atlantic sturgeon persists in that river (Collins and Smith 1997). However, it is possible that the fish were actually from the nearby PeeDee. The Black River may also support populations, but the Sampit probably does not due to its small size. 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. The Sampit arm of upper Winyah Bay is industrialized (e.g., paper mill, steel mill), which has reduced water quality. Certain areas are high in various toxins (e.g., Dioxin). The bay is fished by American shad (*Alosa sapidissima*) gillnet fishermen, resulting in an estimated annual bycatch of 83-171 juvenile Atlantic sturgeon of which about 16% die immediately and another 20% are injured to some degree (Collins et al. 1996). The rivers are also fished by shad fishermen, but neither effort nor average numbers of Atlantic sturgeon encountered are known. Poaching of adult Atlantic sturgeon has been reported from the Winyah Bay area in recent years; carcasses of large fish have been found with the gonads (presumably ovaries) removed.

3.7.1.2 Santee River, SC

This river, once one of the largest of the region, was impounded during the 1940's to create the Santee-Cooper Lakes (Lakes Marion and Moultrie), and most water was diverted into the Cooper River. Anadromous fish runs were extremely strong prior to construction of the Wilson Dam, but numbers of anadromous fish in general have dwindled since then. Although a fish lift operates at the dam during spring, observations of sturgeons in the lift are extremely rare, and there is no record of an adult Atlantic sturgeon being lifted. However, three Atlantic sturgeon approximately 150 CMTL were found dead in the lake above the dam during 1995-1997. It is doubtful that there is a reproducing population in the lake system (Santee-Cooper Lake System), although there may be a damlocked shortnose sturgeon population in the system. Capture of age 1 juveniles in the river suggests that an Atlantic sturgeon population persists there (Collins and Smith 1997). In 1985 most water from the Santee-Cooper Lakes was rediverted to the Santee River; this 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, etc. are unknown. The mouth of this river is just south of Winyah Bay and is fished by the same groups of shad fishermen, so mortality and injury rates are likely to be very similar. Upriver bycatch levels are unknown.

3.7.1.3 Cooper River, SC

Although historically a small river, the flow was increased dramatically after impoundment by diversion of the Santee River when the Santee Cooper Lakes were created; this diversion was reversed in 1985. It is believed that there is a population of Atlantic sturgeon in the Cooper River, but this has not been verified (Collins and Smith 1997). There is definitely a population of shortnose sturgeon, which spawns at the base of the Pinopolis Dam (D. Cooke, SCDNR, unpub. data). The Cooper River flows into Charleston Harbor, a major port which is dredged regularly. Although water quality is generally good, sediments in some areas are still contaminated due to previous industrial operations and military facilities. The river channel is maintained by dredging all the way to the dam, which has a lock to pass boats into the Santee-Cooper Lakes. The lock is primarily used during summer by recreational boaters. Telemetry studies with shortnose sturgeon suggest that sturgeons do not pass through the lock even when they are congregated at the base of the dam, probably because passage would require swimming upward along a vertical wall approximately 50 ft high (D. Cooke, SCDNR, unpub. data). The Navy base in the lower Cooper River was recently closed, drastically reducing ship traffic in the river. However, some military and private ship-related operations persist on the river (e.g., drydock repair facilities). The Cooper River is closed to the shad gillnet fishery, so bycatch is not a concern. A project funded for 1997-98 by NMFS (S-K Program) will attempt to telemeter adult Atlantic sturgeon in order to document critical habitats and verify spawning in the Cooper River.

3.7.1.4 Ashley River, SC

This river also flows into Charleston Harbor. There is no documented evidence that a population of Atlantic sturgeon exists, or ever existed, in the Ashley River.

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

These rivers, and St. Helena Sound into which they flow, are among the least developed in the region, and water quality is generally very good. There was a directed commercial fishery for Atlantic sturgeon in this system prior to the fishery closure. The area near the confluence of the rivers has been designated the ACE Basin National Estuarine Research Reserve. A commercial sturgeon fishery operated in the lower portions of both the Combahee and Edisto Rivers. It is not known which river(s) support(s) a population of Atlantic sturgeon, but capture of age 0 and age 1 juveniles in the lower Edisto suggest a population in that river (Collins and Smith 1997). The ACE Basin rivers are being sampled for adult Atlantic sturgeon as part of the study described for the Cooper River.

3.7.1.6 Port Royal Sound Rivers, SC (Broad, Coosawatchie)

Although a few commercial sturgeon fishermen apparently operated in this area, the landing of only one Atlantic sturgeon has been recorded (Smith et al. 1984). There is no other evidence for the previous or present existence of a population of Atlantic sturgeon in this system. However, there has been little or no directed scientific sampling for Atlantic sturgeon.

3.7.1.7 Savannah River, SC/GA

This river on the border of South Carolina and Georgia supports a reproducing population of Atlantic sturgeon (Collins and Smith 1997). The lowest dam, at the city of Augusta, probably isolates fish from some spawning habitat, and discharge fluctuations (primarily from reservoirs above Augusta) may impact spawning success, etc. The lower river at the city of Savannah, GA is heavily industrialized and 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. Dredging is frequent, and port expansion and extensive channel deepening are planned to begin in 1998. Reduced DO levels and upriver movement of the salt wedge may result. The status of the population of Atlantic sturgeon is not known. The bycatch of the commercial shad gillnet fishery during 1989-91 included more of the endangered shortnose sturgeon than juvenile Atlantic sturgeon, which is considered unusual (unpub. data). It has been recommended that the Army Corps of Engineers and the Georgia Ports Authority immediately begin a 5-year study of sturgeons in the river to determine whether planned actions (i.e., channel deepening) affect the populations. NMFS (S-K Program) has funded a stock ID (molecular genetics) study of Atlantic sturgeon in the, and the Savannah River is presently being sampled for age 0-1 juveniles as a part of that study. Life history information is also being collected on all sturgeons captured.

3.7.1.8 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. Based simply on abundance of young juveniles, this river appears to support one of the healthiest Atlantic sturgeon populations in the Southeast. The ecology of juveniles was studied rather extensively (e.g., Rogers et al. 1994). Although the drainage basin is dominated in areal extent by silviculture and agriculture, two paper mills and over two dozen other industries or municipalities discharge effluent into the river. Nitrogen and phosphorus concentrations are increasing; eutrophication, and possible loss of thermal refugia are concerns (see Ogeechee River), as is bycatch of juveniles in the shad fishery.

3.7.1.9 Ogeechee River, GA

Although a population of Atlantic sturgeon apparently persists in this river, results of recent sampling efforts (including 1997 efforts to collect age 1 juveniles as part of the genetics study described for the Savannah River) suggest that the population is highly stressed. Scarcity of young juveniles in general, and apparent absence of age 1 fish in some years, are indicative of spawning or recruitment failure. Rogers et al. (1994) hypothesized that reduced DO levels from nonpoint source pollution and loss of thermal refugia from lowering of the aquifer have compromised the function of the nursery habitat during hot, dry summers. Bycatch in the shad fishery is a concern.

3.7.1.10 Satilla River, GA

Recent sampling suggests that the shortnose sturgeon population may have been extirpated and the Atlantic sturgeon population is highly stressed (see possible causes under Ogeechee River) (Rogers and Weber 1995). Bycatch in the shad fishery is not presently a concern in this river because the greatly diminished shad population has virtually eliminated the fishery.

3.7.1.11 St. Mary's River, GA/FL

This river once supported a commercial sturgeon fishery. Recent standardized sampling through the appropriate salinity regime resulted in no catches of sturgeons of either species, suggesting that both populations have been extirpated from this river (Rogers and Weber 1995). The cause is thought to be reduced DO levels during summer in the nursery habitat, probably due to eutrophication from nonpoint source pollution.

3.7.1.12 St. John's River, FL

Indications are that populations of both species have been extirpated from this river (if indeed a population of Atlantic sturgeon was truly present, which has not been documented). It is theorized that the primary cause was dam construction (Rodman Reservoir on the Oklawaha River tributary) which blocked access to spawning habitat. This dam is scheduled for removal in the near future. Agencies in Florida have expressed interest in re-establishing a shortnose sturgeon population by stocking cultured fish. It is possible that the same interest would apply to Atlantic if broodfish were available as they are for shortnose sturgeon.

3.7.1.13 Rivers Farther South

Although Atlantic sturgeon have been recorded from locations to the south of the St. Johns River, including the St. Augustine (unpub. data) and the St. Lucie River (ASMFC 1990), apparently there is no evidence for the previous or current existence of Atlantic sturgeon populations in these rivers.

3.7.2 Summary of Research Needs

The status and trends are known for few Atlantic sturgeon populations in the Southeast. Spawning persists in seven rivers, habitat is threatened in nine systems. Most rivers have very low adult populations. Impacts of bycatch have been studied in only six systems, and not at all in most upriver shad fisheries. Populations have probably been extirpated from two systems.

Further study of the life history (i.e., age-growth relationships and reproductive biology) of Atlantic sturgeon in the Southeast is needed. Spawning areas and primary nursery habitats (age 0 to 6 months) should be identified, and baseline data on juvenile abundance for all extant populations should be acquired.

Stock ID studies should be extended to include other river systems, as well as the presumably multi-stock aggregations that occur during the winter in coastal waters. The hypothesis concerning the existence and importance of thermal refugia should be tested (see Ogeechee River). Certain rivers are subject to specific concerns that should be addressed (e.g., channel deepening in the Savannah River).

4.0 BYCATCH OF ATLANTIC STURGEON IN COASTAL FISHERIES

by Andrew Kahnle, Kathryn Hattala and Craig Shirey

Atlantic sturgeon are a bycatch of commercial fisheries along the entire US Atlantic coast. Bycatch has been reported from many different fisheries and from rivers, estuaries, the near-shore ocean and the Exclusive Economic Zone (EEZ) (Table 4.1). Reported commercial landings from 1990 - 1997 provide some idea of potential magnitude of recent bycatch in the gillnet and trawl fisheries (Table 4.2). Most harvest in New York and New Jersey through 1995 was from a directed sturgeon fishery. However, landings in other states and in New York and New Jersey in the last two years were essentially incidental catches. Landings of Atlantic sturgeon were much higher in the gillnet fisheries than in the trawl fisheries (Table 4.3). With the harvest moratorium in most coastal states, landings of Atlantic sturgeon have been almost eliminated. Turtle excluder device (TED) and bycatch reduction device (BRD) requirements have lessened the bycatch potential in southeast trawl fisheries.

Relative importance of commercial bycatch from rivers and estuaries, territorial ocean waters, and the EEZ can be inferred from tagging and recapture data reported by DE Div of Fish and Wildlife tagging studies (Shirey et al.1997). Subadult Atlantic sturgeon were tagged in the lower Delaware River in 1991 - 1997. Recaptures came from commercial fisheries from North Carolina through Maine. Most (61 %) came from ocean waters within 4.8 km of shore. Twenty percent of the recaptures came from rivers and estuaries, 18 percent from the EEZ, and one percent were captured at unknown locations.

Insight on relative bycatch in various commercial gears can be obtained from tagging studies in Delaware and the southeastern states. Most recaptures of Atlantic sturgeon tagged by Shirey (1998) occurred in gillnets (78%) and trawl (15%) (Table 3.4.6). Juvenile Atlantic sturgeon were also tagged in several South Carolina rivers and bays in 1986 - 1997 (Glenn Ulrich, personal communication). Nineteen fish were recaptured more than 32 km from the tagging area (Table 4.4). Most of these recaptures (17) came from shrimp trawls. Atlantic sturgeon were tagged in the Altamaha River, Georgia in 1986 - 1992 Collins et al. (1996). Most recaptures (52 %) came from gillnet fisheries for American shad in Georgia (Table 4.5). However, 41 percent came from shrimp and whelk trawl fisheries in Georgia. One trawl recapture came from North Carolina.

4.1 Ocean Fisheries

Although widespread, bycatch of Atlantic sturgeon appears to be a relatively rare event in ocean fisheries north of South Carolina. NMFS observer data for these fisheries in 1990 - 1997 were examined to identify fisheries of potential concern, catch rates, and trends in the bycatch of Atlantic sturgeon (Table 4.6). Trips which targeted Atlantic sturgeon were removed from these data. It appears that the gillnet fisheries for monkfish, mixed groundfish, dogfish and the trawl fisheries for summer flounder produced the most consistent and highest weight per trip of Atlantic sturgeon. However, mean annual catch rates were generally less than 20 kg of Atlantic sturgeon per trip. If these strugeon were the same mean weight (40 kg) as those observed when directed ocean harvest was legal in New York, then Atlantic sturgeon were encountered by commercial fisheries once every two trips in ocean waters north of South Carolina. Overall catch per trip data for the gillnet fisheries suggest an increase in bycatch rate through 1995 with a decline in 1996 and 1997. Exceptions to this trend were increases in the monkfish and mixed groundfish fisheries. Bycatch in the various dogfish gillnet fisheries has generally declined over the time period. There were no clear trends in the trawl bycatch. However, the 1996 bycatch in the summer flounder fishery was the highest value observed in the trawl fisheries.

Other studies in the Northeast ocean fisheries also report low incidence of Atlantic sturgeon in the commercial bycatch. Observers on sink gillnet vessels from Rhode Island to Mainein 1990-1994 reported bycatch rates of less than 0.5 kg per day (Kennelly 1996a). Catches were even lower in the trawl fisheries. Observed mean bycatch in trawl fisheries from Maryland through Maine in 1990-1994 were less than 0.05 kg per day (Kennelly 1996b). McKiernan and King (1996) reported no Atlantic sturgeon in catches in 36 sea days of monitoring trawlers north of Cape Cod in July through November 1996. Observations in the fall and winter of 1997 in the near-shore fisheries (both territorial seas and EEZ) from Maryland through Massachusetts found no Atlantic sturgeon in eight sea days of observation on trawlers and nine Atlantic sturgeon in 21 sea days on gillnet vessels (Manomet 1998). All observed Atlantic sturgeon were taken in the monkfish fisheries off western Long Island, NY and New Jersey.

Atlantic sturgeon are caught as bycatch in gillnets and trawls in the Maryland ocean fishery (R. Sadzinski, personal communication). Most sturgeon are taken in March through June when fisheries target American shad, dogfish or monkfish. The size range for these sturgeon is 122 cm to 183 cm TL. Mean length is about 137 cm TL, although specimens up to approximately 305 cm TL have occasionally been reported. Based on empirical data, mortality of Atlantic sturgeon caught by these fisheries appears to be very low if the fish are caught in trawls. It is higher for sturgeon caught in gillnets. The higher mortaltiy is due to the duration the gillnet is set (one to two days). The number of Atlantic sturgeon caught depends on the proximity of the gear to the bottom. The closer the set to the bottom, the higher the number of sturgeon caught.

In the northeast ocean fisheries, there is a seasonal trend to the bycatch of Atlantic sturgeon. Most of the bycatch in the studies cited above occurred in the fall, winter, and spring. The NMFS observer data from 1990 through the present (Table 4.7) indicate a shift to late winter and early spring in the gillnet data. There was no trend apparent in the trawl data. Recaptures of Atlantic sturgeon tagged in the Delaware River (Shirey 1998) indicated most bycatch in the near-shore ocean waters was in June through October.

4.2 Rivers and Estuaries

Catches in the commercial gillnet fishery for American shad in the Hudson River estuary have been monitored by the NY State Department of Environmental Conservation since 1980 (Section 3.3.3.1). This fishery occurs from early April through May. Most Atlantic sturgeon are caught in fixed gillnets fished from river km 40 to km 70. A few are caught in the drifted gillnet fishery from km 98 to km 182. Highest annual c/f of Atlantic sturgeon in the bycatch of the fixed gear was 0.23 Atlantic sturgeon per 1000-yd^2 -hr in 1980. C/f decreased steadily since then through the present (Figure 3.3.7, Table 3.3.6).

Bycatch information of Atlantic sturgeon from Delaware Bay and coastal Delmarva has been gathered through the tag recapture information of sturgeon tagged in the Delaware River from 1991 through 1997 (Shirey 1998). In addition, the more active fishermen were given a log sheet to record incidental records of all sturgeon encountered during the 1997 fishing season (C. Shirey, personal communication)

Atlantic sturgeon bycatch in Delaware Bay typically occurs from March into May associated with the fixed gillnet fisheries for a variety of species: primarily American shad, striped bass, weakfish and white perch. These fisheries employ several different mesh sizes depending on the target species. However, most sturgeon are taken in nets set for shad and striped bass. Sturgeon range in size from approximately 61 cm TL to 152 cm TL with the majority between 95 and 102 cm. Bycatch mortality, as reported by the fishermen is low. Only one of the 10 tagged sturgeon was reported as dead from Delaware Bay fishermen. A lower bound estimate of bycatch mortality from these fisheries would therefore be 0.10. Water temperature during this period are typically low and would tend to increase survival. The disposition was not recorded for non-tagged sturgeon on the voluntary log sheets (n=43). Although this information is important, including it on the form would probably have decreased fishermen participation. On-board observers are required to more accurately describe bycatch mortality rates of these fisheries.

Seven tag returns were reported as bycatch in fisheries from coastal areas off the Delmarva Peninsula. Most were taken close to shore (within 4.8 km) but some take did occur in the EEZ. Tag returns from this area were reported from Septemeber through March. Trawlers, targeting mixed groundfish during the fall and gillnet fishermen using fixed gear for dogfish, American shad and weakfish reported tagged sturgeon. The reported bycatch mortality was estimated to be 0.29.

Information on bycatch in the Chesapeake Bay system is available from the reward programs conducted by the U.S. Fish & Wildlife Service for access to live Atlantic sturgeon (Section 3.5). All of the wild captures in this program came from the commercial bycatch. Most captures in Maryland were from pound nets and gillnets (Table 3.5.3). Most in Virginia waters came from 7.6-17.5 cm stretched mesh anchored gillnets (Spells 1997) in Virginia. Size of sturgeon in the Virginia bycatch depended on the target species of the fishery (Spells 1997). Smallest sturgeon were taken in October and November when fishermen used 7.6-8.2 cm stretch mesh nets for croaker, weakfish, and perch. Rate of mortality in the Chesapeake Bay bycatch is unknown. The U.S. Fish and Wildlife Service reward program was for live captures. Thus few dead sturgeon were reported. It is likely however, that rates of mortality were low. The gillnet fishery where highest mortality would be expected, occurs in cold water months which increases survival. Most captures in warm water months occurred in pound nets which normally have very low rates of mortality.

The bycatch of Atlantic sturgeon in commercial shad fisheries of South Carolina and Georgia was studied in 1994 - 1996 (Collins et al. 1996). The American shad fisheries generally occur in rivers and estuaries from mid January through mid April. Catch rates reported a combined catch per unit effort (CPUE) for both sturgeon species. CPUE varied between 0.010-0.013 (fish per 91.4 m of gill-net-hour) for Winyah Bay, SC and 0.020-0.066 for the lower Savannah River (Table 4.8).

4.3 Mortality of Bycatch

Survival of Atlantic sturgeon in commercial gears is poorly documented. Observations by Manomet (1998) in the fall and winter of 1997 noted that survival in gillnets set for monkfish was highest in nets set over one or two days and lowest in sets made over three days. Mean survival was 0.60. Shirey (1997) summarized status of recaptured Atlantic sturgeon initially tagged in the Delaware River from 1991 through 1996. Recaptures occurred from ME through NC. Lowest survival of captured sturgeon (90 %) occurred in anchored gillnets (Table 3.4.6). Highest survival (100%) occurred in trawls and pound nets. Collins and Smith (1996) noted that 11, 20, and 6 percent of the sturgeon were dead in the bycatch of the Winyah Bay shad anchored gillnet fishery in 1994, 1995, and 1996 (Table 4.8). A mean of 13 percent were dead and an additional 19 percent were released with some injury during the three year period. They noted that survival decreased with increasing water temperature.

4.4 Population Level Impacts of Bycatch

Effects of bycatch at the population level are essentially unknown. The best insight on levels of mortality caused by bycatch is provided by tagging of subadult Atlantic sturgeon in the lower Delaware River by Delaware Div. of Fish and Wildlife in 1991-1997 (Shirey et al. 1997). Recaptures came from commercial fisheries from North Carolina through Maine (Table 3.4.6). Out of the 1,700 tagged Atlantic sturgeon released over the time period, 78 were recaptured by gillnet, 15 by trawl, two by pound net, and two by unknown gear (Table 3.4.6). Only nine recaptures were reported as dead in the bycatch through the time period. These data suggest a bycatch mortality rate of 0.005. We consider this to be a lower bound estimate because recaptures were reported on a volunteer basis and live fish were more likely to be reported. An upper bound estimate can be obtained from these data by applying the 40% mortality reported in monkfish gillnets above (Manomet 1998) to the 78 fish recaptured in gillnets. This results in 41 fish dead in gillnets plus one dead in unknown gear and a bycatch mortality of 0.025.

Any level of bycatch mortality will delay recovery. However, reductions in recovery rate of Atlantic sturgeon cannot be quantified with available data. Estimates of bycatch mortality from the Delaware River tagging data probably apply to the Delaware and Hudson River stocks (Section 3.4.2). The estimate of F =0.005 - 0.025 is below the target fishing rate for the Hudson River population (F = 0.03, Section 3.3.4). However, the rate of 0.03 was for a restored stock. It is very likely that the level of bycatch will be reduced with continued effort, conservation engineering and increased restrictions on fisheries which encounter sturgeon. There is a clear need to better document bycatch, mortality in various gears, and population level impact.

Table 4.1. Bycatch of Atlantic sturgeon in various fisheries along the US Atlantic coast.

State	Source	Area	Target species	Gear	Gear Specs	Gear Size	Season	Life stage
ME	a	Gulf of ME	dogfish	gill net	fixed		Jul	
NH	b							
MA	a	Cape Cod Bay	dogfish	gill net		10 in mesh	Jun - Oct	
	a		summer flounder	trawl			Jul	
	a		Atlantic cod	gill net				
	a		Atlantic cod	hook & line				
RI	a		dogfish	gill net			Aug	
	a		unkown	unkown			Jun, Oct	
	a		summer flounder	trawl			Oct-Nov	
CT	c	Long Island Sound	unknown	trawl			Oct-Nov	
NY	d	Hudson River	American shad	gill net	fixed	5.5 in mesh	April	juvenile
	a	ocean	summ floun/bluefish	trawl			Jun, Jul, Oct, Nov	
	a	ocean	bluefish	gill net			Oct	
NJ	e	Del Bay and Ocean	American shad	gill net	fixed and drift	4.25-5.75 in	Apr, May	juvenile
	e	Ocean	monkfish, dogfish	gill net	fixed		May, Jun, Dec	
	e	Ocean	groundfish	trawl	bottom			juvenile
DE	a	Delaware Bay	American shad	gill net	fixed		April	
	a	Delaware Bay	weakfish	gill net	fixed		April	
MD	a, f	Chesapeake Bay	S bass/menheden/unk	pound net			Apr, May, Jun, Oct, Nov	
	f	Chesapeake Bay		gill net			Feb, Mar, Nov, Dec	
	f	Chesapeake Bay		trawl			Sep	
	a	ocean	dogfish	gill net	fixed		Nov, Dec	
	a	ocean	summer flounder	trawl			Sep, Oct	
	a	ocean	American shad	gill net			Mar, Apr	
VA		Chesapeake Bay	American shad	pound net				
	g	Chesapeake Bay	striped bass	gill net		>=5 in	Feb,Mar, Apr, May	
	h	ocean	American shad	gill net				
	a	Chesapeake Bay	river herring	gill net			Mar	

Table 4.1. Bycatch of Atlantic sturgeon in various fisheries along the US Atlantic coast.

State	Source	Area	Target species	Gear	Gear Specs	Gear Size	Season	Life stage
NC	a	Pamlico Sound	mixed	pound net			Nov	
	a	Pamlico River		gill net			Sep	
		ocean		sink net				
	a		weakfish/bluefish	gill net			Feb	
	a		Weakfish/spot	gill net			Sep	
SC	i	Winyah Bay	American shad	gill net				
	i	ocean	shrimp, whelk, fish	trawl				
GA	j	ocean	shrimp	trawl		1.875 - 2 in		juvenile
	j	ocean	whelk	trawl		4. 0 in		mixed
	k		American shad	gill net				
FL								

a - From Shirey et al. (1997)
b - From
c - From Tom Savoy, personal communication
d - From NYSDEC sampling
e - From Bill Andrews, personal communication
f - From Jorgen Skjeveland, personal communicaton
g - From Spells (1997)
h - From Lou Gillingham, personal communication
i - From Collins et al. (1996)
j - From Dominic Guadagnoli, personal communication
k - From Ron Michaels, personal communication

Table 4.2 Live weight (kilograms) of Atlantic sturgeon landed in Atlantic coastal states, ME to FL, 1990-1997.

State	1990	1991	1992	1993	1994	1995	1996	1997
ME	116	25	0	29	0	0	0	0
NH	64	0	0	0	0	0	0	0
MA	255	482	52	218	27	201	0	0
RI	1003	1358	1197	457	62	263	171	24
CT	728	1252	0	0	0	317	95	0
NY	21919	37808	17784	10391	19648	10235	11	66
NJ	58241	53190	38139	16243	23300	5795	2421	0
DE	0	0	0	1524	0	0	0	0
MD	1566	1828	614	1920	343	94	206	71
VA	0	0	0	0	0	0	0	0
NC	3065	1667	0	0	0	0	0	0
SC	0	0	0	0	0	0	0	0
GA	1876	c	981	c	c	c	c	0
FL	0	0	0	0	0	0	0	0
Total	88833	97610	58767	30783	43380	16905	2904	161

c-confidential

Table 4.3 Live weight (kilograms), by gear, of Atlantic sturgeon landed in Atlantic coastal states, ME to FL, 1990-1997.

Year	Gill net	Trawl	Other	Total
1990	74997	10069	3768	88833
1991	77718	17911	2706	98336
1992	49408	8872	487	58767
1993	27981	2942	463	31386
1994	38569	4065	826	43459
1995	14833	1966	552	17352
1996	2738	11	261	3011
1997	66	0	95	161

Table 4.4 Juvenile Atlantic Sturgeon Tagged in South Carolina And Recaptured Outside of the Tagging Area (G. Ulrich, SC DNR)

Tagging Location	Date Tagged	Recapture Date	Days Out	Recapture Location	Min. Mi. Moved	Recapture Gear	Recapture Age
Winyah Bay (entrance)	04/09/87	04/22/89	744	Cape Fear, NC (Ocean)	85	Gill-net	IV
S. Edisto R. (river mi. 4)	03/28/89	11/27/89	244	Cape Fear, NC (Ocean)	185	Trawl (shrimp)	III+
Edisto R. (river mi.18)	03/18/94	12/30/94	287	St. Helena Sound, SC	26	Trawl (shrimp)	II+
Edisto R. (river mi.18)	03/22/94	12/16/94	269	St. Helena Sound, SC	20	Trawl (shrimp)	II+
Edisto R. (river mi.18)	03/22/94	12/19/94	272	St. Helena Sound, SC	26	Trawl (shrimp)	II+
Edisto R. (river mi.18)	03/24/94	12/28/94	279	Mayport, FL (Ocean)	186	Trawl (shrimp)	III+
Edisto R. (river mi.18)	04/11/95	11-12/96	~585	Pritchards Inlet, SC (Ocean)	40	Trawl (shrimp)	IV+
Edisto R. (river mi.18)	05/08/95	11-12/96	~557	Pritchards Inlet, SC (Ocean)	40	Trawl (shrimp)	III+
St. Helena Sound, SC	12/20/95	12/11/96	357	Blackbeard Is., GA (Ocean)	110	Trawl (shrimp)	II+
Edisto R. (river mi.18)	03/15/96	12/18/97	643	St. Simons Is., GA (Ocean)	140	Trawl (shrimp)	III+
Edisto R. (river mi.18)	04/18/96	11-12/96	~212	Pritchards Inlet, SC (Ocean)	40	Trawl (shrimp)	III+
Edisto R. (river mi.18)	05/14/96	04/28/97	349	Pamlico River, NC	409	Gill-net	II
Edisto R. (river mi.18)	05/22/96	12/28/96	220	St. Helena Sound, SC	25	Trawl (shrimp)	I+

Table 4.4 continued

Edisto R. (river mi.18)	06/21/96	12/?/97	~530	Port Royal Sound, SC	50	Trawl (shrimp)	III+
Edisto R. (river mi.18)	08/20/96	11-12/96	~88	Pritchards Inlet, SC (Ocean)	40	Trawl (shrimp)	I+
Edisto R. (river mi.18)	09/09/96	01/03/98	481	St. Helena Inlet, SC (Ocean)	29	Trawl (shrimp)	II+
Edisto R. (river mi.18)	10/03/96	12/17/97	440	St. Helena Inlet, SC (Ocean)	29	Trawl (shrimp)	II+
Edisto R. (river mi.18)	11/20/96	12/30/96	40	St. Helena Sound, SC	23	Trawl (shrimp)	I+
Edisto R. (river mi.18)	11/22/96	01/14/97	53	St. Helena Sound, SC	23	Trawl (shrimp)	I+

Table 4.5 Number and percent of Atlantic sturgeon tagged in the Altamaha River GA (n=1534) and caught as bycatch in various Georgia fisheries.

Portion of Table 2 in Collins et al . 1996

State	Target	Gear	Number	%
GA	shad	driftgill	46	47%
GA	shad	fixgill	5	5%
GA	shrimp	trawl	38	39%
GA	whelk	trawl	2	2%
NC	fish	trawl	1	1%
GA	sturgeon	gillnet	1	1%
	unknown		4	4%
Total			97	

Table 4.6 Kilograms per trip of Atlantic sturgeon caught in gill net and trawl target fisheries along the US Atlantic coast, NMFS Observer Program data.

		Year								Mean
Gear type	Trip Target	1990	1991	1992	1993	1994	1995	1996	1997*	Total
Gill net	Cod, Atlantic	3.18	7.19	5.49	21.23	6.50	37.88			10.43
	Pollock		18.14							18.14
	Monkfish					22.45	24.83	24.79	27.22	24.71
	Flounder, witch		13.49		29.48					15.27
	Flounder, yellowtail			9.98	8.16		7.26	15.88		10.12
	Flounder, winter			7.26	7.86					7.71
	Flounder, mixed		6.87	5.44	10.43					7.23
	Groundfish, mixed		10.40	10.14	17.01	4.54	16.99	20.87	20.87	14.10
	Bass, Striped						6.80		22.68	12.10
	Weakfish & S. bass							4.99		4.99
	Tuna				3.63					3.63
	Dogfish,smooth					12.31	3.63	7.11		9.05
	Dogfish, spiny					18.67	26.41	11.10	5.67	21.30
	Shad						7.94	6.03	2.04	6.02
	Pelagic fish					3.52				3.52
	Dogfish		9.02	11.50	10.61	28.10	14.29			16.48
	Weakfish						1.36			1.36
	Finfish		9.53		9.07	7.71				8.42
	other			12.05			7.94			10.56
Gill net Mean Total by year		3.18	9.38	9.42	13.85	18.59	22.37	12.96	10.84	15.52
Trawl	Flounder, summer		1.81	9.98		9.30	7.86	31.30		12.66
	Groundfish, mixed			9.37						9.37
	Weakfish & S. bass						15.88			15.88
	Weakfish						18.14	17.66		17.72
	Finfish				7.26					7.26
	Shrimp			20.41	4.54					12.47
	Crab, Horseshoe							14.67		14.67
	Squid		21.17	11.34						17.24
	Squid, longfin						4.54	7.94		7.26
	Flounder & hake						22.68			22.68
	Other			26.76						26.76
Trawl Mean total by year			16.33	13.10	5.90	9.30	12.12	16.45		14.10

* 1997 data through early April

Table 4.7 Kilograms of Atlantic sturgeon and suspected (unspecifed) Atlantic sturgeon caught in gill net and trawl fisheries along the US Atlantic coast, NMFS Observer Program data.

		Year									
Gear Type	Month	1989	1990	1991	1992	1993	1994	1995	1996	1997*	Total
Atlantic sturgeon											
Gill net	Jan		0	0	13	16	41	222	116	39	447
	Feb		0	0	5	0	24	123	159	6	317
	Mar		0	0	0	26	399	1125	48	31	1629
	Apr		0	0	10	127	135	320	247	21	859
	May		0	0	194	72	39	270	280	0	855
	Jun		0	177	79	36	48	21	148	0	509
	Jul		0	183	90	0	0	9	0	0	283
	Aug		0	83	8	0	0	0	0	0	91
	Sep		0	31	4	4	0	0	0	0	38
	Oct		3	37	0	6	0	0	26	0	72
	Nov		0	33	61	46	32	161	308	0	640
	Dec		0	18	7	0	567	432	4	0	1028
Gill net Total		0	3	563	471	332	1283	2684	1335	98	6768
Unspecified sturgeon											
Gill net	Jan	0		0	0	0	0	0	14	0	14
	Feb	0		0	0	0	29	0	0	36	66
	Mar	0		0	0	0	36	0	23	0	59
	Apr	0		5	0	0	0	0	0	0	5
	May	0		0	0	91	0	0	0	0	91
	Jun	0		9	0	0	0	14	4	0	26
	Jul	0		0	0	0	0	0	0	0	0
	Aug	0		0	0	0	0	0	0	0	0
	Sep	0		0	0	0	0	0	0	0	0
	Oct	0		0	0	0	0	0	0	0	0
	Nov	0		0	45	0	0	0	0	0	45
	Dec	8		0	0	0	0	61	0	0	69
Gill net Total		8	0	15	45	91	66	75	40	36	375
Atlantic sturgeon											
Trawl	Jan		0	0	0	0	0	0	0	0	0
	Feb		0	0	0	0	0	0	57	0	57
	Mar		0	0	27	5	0	0	0	0	32
	Apr		0	0	27	0	0	0	0	0	27
	May		0	54	9	0	0	0	0	0	64
	Jun		0	2	19	0	0	24	23	0	67
	Jul		0	0	0	0	0	5	9	0	14
	Aug		0	9	0	0	0	0	0	0	9
	Sep		0	0	0	0	0	0	0	0	0
	Oct		0	0	20	0	0	57	100	0	176
	Nov		0	0	0	7	19	0	91	0	117
	Dec		0	0	16	0	0	0	0	0	16
Trawl Total		0	0	65	118	12	19	85	280	0	578
Unspecified sturgeon											
Trawl	Jan	0		0	0	0	0	0	0	0	0
	Feb	0		0	0	0	1	0	0	0	1
	Mar	0		0	0	0	0	0	0	0	0
	Apr	0		16	0	0	0	0	0	0	16
	May	0		64	0	0	5	0	0	0	68
	Jun	7		0	0	0	0	0	0	0	7
	Jul	0		0	0	0	0	0	0	0	0
	Aug	0		0	0	0	0	0	0	0	0
	Sep	68		0	0	0	0	0	0	0	68
	Oct	59		0	0	0	0	0	0	0	59
	Nov	41		0	0	0	0	0	0	0	41
	Dec	0		0	0	3	0	0	0	0	3
Trawl Total		175	0	80	0	3	6	0	0	0	264

* 1997 data through early April

Table 4.8 Sturgeon bycatch of the shad gill net fishery in Winyah Bay 1994-1996. IN Collins and Smith 1996.

Year	Observed bycatch					Total	Mean	Estimated Catch		
	ATS	SNS	Total	Dead	Injured	Net-hours	CPUE	ATS	SNS	Total
1994	23	4	27	11%	15%	11490	0.011	98	17	115
1995	18	7	25	20%	24%	15438	0.013	145	56	201
1996	13	5	18	6%	17%	24069	0.008	132	51	183

5.0 MANAGEMENT RECOMMENDATIONS AND RECOVERY GOALS

5.1 Management Recommendations

Atlantic coastal states should implement a moratorium on harvest and possession of Atlantic sturgeon. Furthermore, ASMFC should recommend that harvest not be permitted from the EEZ. Since Atlantic sturgeon historically had up to 40 year classes in the spawning population, we recommend that the moratorium remain in place for each stock until it can be documented that the spawning population includes at least 20 protected year classes of females. Given that median maturity of female Atlantic sturgeon does not occur until about age 18, the moratorium can be expected to remain in place for a minimum of 38 years from the initiation of a moratorium on harvest on a given stock. The stock assessment committee recommended that harvest in reopened fisheries should only occur within a natal system to assure that only the recovered stock is harvested.

The 38 year minimum may differ among rivers since a clinal variation in age of maturation is likely for Atlantic coast stocks. Southern stocks grow more quickly and mature at earlier ages than northern stocks.

5.2 Recovery goals

The Atlantic sturgeon stock assessment committee initiated work on defining restored stocks and criteria for reopening fisheries at a meeting in SC in March of 1997. These deliberations should continue until definitions of restored stocks and reopening criteria have been developed. This effort should also determine monitoring needs to track stock restoration. Goals will be tempered by changes in available habitat.

5.3 Additional needs

States with significant spawning populations of Atlantic sturgeon should explore options for monitoring relative abundance of juvenile Atlantic sturgeon.

All states need to characterize and quantify bycatch (i.e. numbers of fish caught, mortality, time of year and gear by targeted species).

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Appendix A: Fishery Restrictions for Atlantic sturgeon for US Atlantic coast states

Table A1 History of Atlantic sturgeon regulations for Atlantic coastal states.

State	Date	Fishery Status	Regulations: Size Limit	Regulations: Other
ME		closed		
NH		closed		
MA		closed		
RI	pre 1997	open	7 ft	
	1997	closed		
CT	pre 1997	open	7 ft	
	1997	closed		
NY	pre 1993	open	4 ft	no season, no harvest quota
	1993-95	restricted	5 ft	five week season, mandatory reporting, quotas
	1996	closed		possession ban
NJ	pre 1993	open	42 in	
	1993	restricted	5 ft	annual quota with possession limit of tags
	1996	restricted		annual quota = zero
PA		closed		
DE	1990	open	54 in	
	1991	open	7 ft	
MD	1990		25 lb	minimum weight
	1996	closed		possession ban
DC		closed		
PRFC		closed		
VA		closed		
NC		closed		
SC	1985	closed		
GA		open	7 ft	
	1997	closed		
FL		closed		

Appendix B: Atlantic sturgeon coast-wide landings

Table B1Coast-wide commerical landings of Atlantic sturgeon (thousands of kilograms).

YEAR	ME	NH	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC	SC	GA	FL		TOTAL
1849	145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	145
1880	0	0	5	0	0	65	136	68	259	65	187	198	118	161	1		1263
1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1882	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1883	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1884	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1885	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1886	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1887	0	0	3	0	0	5	1495	28	1281	4	0	108	83	87	0		3093
1888	0	0	2	0	0	5	1670	29	1270	3	0	122	114	79	0		3294
1889	0	0	0	0	0	18	1629	29	602	0	0	103	129	96	20		2627
1890	0	0	0	0	0	18	2068	27	591	45	371	1	98	38	14		3348
1891	0	0	0	0	0	14	2053	24	592	33	328	0	0	0	0		3044
1892	0	0	0	0	0	0	2036	27	477	0	0	0	0	0	0		2541
1893	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1894	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1895	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1896	0	0	0	0	0	142	0	0	0	0	0	0	0	0	0		142
1897	0	0	0	0	0	194	885	5	212	64	265	183	218	71	4		2102
1898	5	0	4	0	0	231	589	5	127	66	287	0	0	0	0		1314
1899	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1900	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1901	0	0	0	0	0	51	77	0	34	49	83	0	0	0	0		295
1902	0	0	0	0	0	0	0	0	0	0	0	66	43	0	158		267
1903	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1904	0	0	0	0	0	5	103	5	38	74	82	0	0	0	0		308
1905	3	0	5	0	1	0	0	0	0	0	0	0	0	0	0		9
1906	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1907	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1908	0	0	0	0	0	0	0	0	0	0	0	28	0	45	28		102
1909	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0		3
1910	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0		4
1911	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0		9
1912	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0		4
1913	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		1
1914	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1915	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1916	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1917	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1918	0	0	0	0	0	0	0	0	0	0	0	4	54	18	2		77
1919	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0

Table B1Coast-wide commerical landings of Atlantic sturgeon (thousands of kilograms).

YEAR	ME	NH	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC	SC	GA	FL	TOTAL
1920	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	10
1921	0	0	0	0	0	15	21	0	5	0	0	0	0	0	0	42
1922	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1923	0	0	0	0	0	0	0	0	0	0	0	9	23	15	3	49
1924	2	0	3	1	0	0	0	0	0	0	0	0	0	0	0	6
1925	0	0	0	0	0	0	0	0	0	9	30	0	0	0	0	39
1926	0	0	0	0	0	4	3	0	3	0	0	0	0	0	0	10
1927	0	0	0	0	0	0	0	0	0	0	0	12	6	1	4	23
1928	0	0	1	0	0	0	0	0	0	0	0	4	10	1	7	25
1929	0	0	3	0	0	1	4	0	5	0	4	1	8	2	6	36
1930	0	0	4	0	0	1	2	0	7	0	2	1	7	2	4	31
1931	0	0	2	0	0	1	5	0	2	0	3	0	12	1	7	35
1932	1	0	3	0	0	1	3	0	1	0	2	1	10	2	2	28
1933	1	0	2	0	0	1	12	0	0	0	4	0	0	0	0	22
1934	0	0	0	0	0	0	0	0	0	0	4	1	23	5	0	34
1935	0	0	1	0	0	4	5	0	0	0	3	0	0	0	0	15
1936	0	0	0	0	0	0	0	0	0	0	12	2	27	5	14	60
1937	1	0	3	0	0	0	3	0	0	0	6	0	11	4	15	45
1938	0	0	4	1	0	2	2	0	0	0	7	0	12	4	16	50
1939	0	0	2	0	0	2	3	0	0	0	4	0	0	3	8	23
1940	0	0	3	0	0	2	5	0	0	0	5	0	1	2	1	23
1941	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
1942	0	0	1	0	0	8	7	0	0	2	4	0	0	0	0	22
1943	0	0	1	0	1	6	3	0	0	0	0	0	0	0	0	12
1944	0	0	3	1	0	4	1	0	0	1	2	0	0	0	0	13
1945	0	0	5	0	0	5	2	0	0	3	5	0	16	2	3	44
1946	0	0	3	0	1	10	2	0	0	1	10	0	0	0	0	29
1947	0	0	2	0	1	6	2	0	0	2	8	0	0	0	0	24
1948	0	0	4	1	5	9	3	0	0	2	17	0	0	0	0	41
1949	0	0	3	1	0	5	2	0	5	2	5	0	0	0	0	24
1950	0	0	3	1	0	6	1	0	0	1	7	5	8	7	1	43
1951	0	0	3	1	0	3	2	0	0	2	6	2	7	2	1	31
1952	0	0	2	2	1	5	5	0	0	3	6	7	11	3	5	51
1953	1	0	2	1	1	4	3	0	2	3	5	7	10	11	9	59
1954	1	0	3	1	1	6	5	0	1	9	8	5	4	10	1	54
1955	0	0	2	2	1	5	3	0	1	3	5	1	30	4	5	64
1956	0	0	2	1	1	2	3	0	1	5	6	5	36	17	6	86
1957	0	0	2	2	1	5	3	0	5	3	2	7	20	5	11	69
1958	0	0	2	1	0	14	4	0	1	3	3	10	16	2	7	63
1959	0	0	4	1	1	6	4	0	0	1	5	9	15	2	3	53
1960	0	0	4	1	3	7	3	0	0	5	8	10	19	3	0	64

Table B1Coast-wide commerical landings of Atlantic sturgeon (thousands of kilograms).

YEAR	ME	NH	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC	SC	GA	FL	TOTAL
1961	1	0	2	0	4	4	7	0	0	6	5	18	23	2	6	80
1962	0	0	2	1	5	5	9	0	1	4	2	22	18	1	6	76
1963	0	0	3	1	4	2	6	0	1	3	2	20	24	1	14	81
1964	0	0	2	2	5	5	6	0	1	7	5	15	29	1	4	83
1965	0	0	2	1	2	3	7	0	0	16	10	35	23	1	3	103
1966	0	0	1	2	1	7	6	0	1	6	12	27	20	0	4	88
1967	1	0	1	1	1	5	4	0	0	3	5	17	15	0	3	58
1968	0	0	1	0	1	5	4	0	0	2	6	21	20	0	26	89
1969	1	0	1	1	0	6	3	0	0	3	9	60	18	0	5	109
1970	3	0	1	2	0	6	6	0	0	2	10	54	3	2	8	98
1971	0	0	1	2	0	4	5	0	0	1	8	35	35	2	11	106
1972	0	0	1	1	0	2	5	0	0	2	5	70	31	4	2	123
1973	0	0	1	0	0	2	8	0	0	4	8	25	20	1	4	75
1974	0	0	1	1	0	3	5	0	0	2	4	42	21	1	2	83
1975	1	0	1	0	0	3	6	0	0	2	3	20	30	1	1	69
1976	1	0	0	0	0	2	5	0	0	1	1	21	40	0	0	73
1977	2	0	1	0	0	8	5	0	0	1	2	14	52	1	0	88
1978	1	0	2	0	0	6	6	0	0	2	1	15	43	5	0	81
1979	1	0	0	0	0	9	6	0	0	1	3	19	36	1	0	78
1980	2	0	1	0	0	12	5	0	0	0	1	14	59	6	0	102
1981	1	0	1	0	0	5	5	0	1	0	1	14	42	10	0	82
1982	1	0	1	0	0	10	3	0	0	0	2	10	45	13	0	88
1983	1	0	2	1	0	9	8	0	0	1	2	8	9	5	0	45
1984	1	0	2	3	0	21	14	0	0	2	3	20	12	3	0	81
1985	1	0	3	4	0	19	9	0	0	1	1	12	7	9	0	65
1986	1	0	3	4	0	20	9	0	0	2	0	10	0	4	0	53
1987	0	0	3	2	0	17	9	0	0	0	0	6	0	3	0	42
1988	0	0	3	2	0	27	6	0	0	1	0	4	0		0	44
1989	0	0	0	1	1	9	39	0	0	1	0	3	0	3	0	59
1990	0	0	0	1	1	25	100	0	0	2	0	3	0	0	0	133
1991	0	0	0	1	1	34	53	0	0	1	0	0	0	0	0	91
1992	0	0	0	1	0	16	38	0	0	0	0	0	0	0	0	55
1993	0	0	0	0	0	8	10	0	0	0	0	0	0	0	0	18
1994	0	0	0	0	0	16	13	0	0	0	0	0	0	0	0	30
1995	0	0	0	0	0	9	4	0	0	0	0	0	0	0	0	13

Jan 1998: MORATORIUM in all states except DE which has 7 ft size limit; SC closed fishery in 1985, NC closed fishery in 1991
1880-1975 data from Murawski & Pacheco 1977; 1976-1995 NMFS except: NJ: state data 1990-1995, NY state data: 1993-1995, CT state data:1989-1995

Appendix C: Target Fishing Rate

The following summarizes our approach to determine a target fishing rate and potential yield from a range of realistic recruitment values for the Hudson River stock of Atlantic sturgeon.

Our analyses augments a basic yield per recruit (YPR) model with estimates of egg production for information on egg per recruit (EPR). Our model starts with recruits at age one. These recruits are decremented annually by natural mortality and a bycatch fishing mortality until they reach harvestable ages. They are then decremented by natural and fishing mortality through age 60. Harvest in numbers at age are summed for all ages. As survivors mature, the fraction of females of each age that is mature and present on the spawning grounds is multiplied by fecundity at that age. Resulting egg production by age is summed for all ages. In the final step, total harvest (numbers) and total egg production are each divided by the number of recruits at age one for an estimate of YPR and EPR. The model was run for a range of fishing rates (F) from zero to 0.3. Formulas used in model calculations are summarized below.

The target fishing rate was defined as that level of F that generated an EPR equal to .5 of the EPR at F = 0.0. YPR values at the target fishing rate were converted to total yield estimates (numbers and pounds) by multiplying YPR by various levels of assumed recruitment. Model inputs by age are those described in Section 3.3. All data are specific to the Hudson River stock.

Formulae used in Yield Model Analyses of Hudson River Atlantic sturgeon

Yield per recruit (YPR) was calculated as follows:

$$YPR = \frac{\sum_{j=t}^{n} N_j * \mu}{R} \tag{1}$$

Where: YPR = lifetime yield (number) per recruit
n = Maximum age in the population (60)
t = Age of first recruitment to a given minimum size limit
N_j = Number of individuals at the start of year j
u = Exploitation rate
R = Number of recruits at age one

Mortality was modeled using the negative exponential model:

$$N_{j+1} = N_j * \exp(-(F_j + M_j)) \tag{2}$$

Where: N_{j+1} = Number of fish alive at age j+1
N_j = Number alive at age j
F_j = Fishing mortality rate from j to j+1
M_j = Natural mortality rate from j to j+1

Knife-edge recruitment to the fishery was assumed as the fish grew into the vulnerable size. Age at recruitment was determined by comparing length at age data with the size limit being evaluated. Recruitment occurred at age 10 for males and age nine for females.

Sublegal fish were subjected to a bycatch mortality of F = 0.05. Once legal, all mortality went to the legal fishery.

Length at age was estimated using the standard Von Bertalanffy function:

$$L_j = L_\infty \{1 - exp[-K(j-j_0)]\} \qquad (3)$$

Where: L_j = Length at age j in cm
L_∞ = Asymptotic length
K = Brody growth coefficient
j_0 = Age at length equal to zero
j = Age

Data for parameter estimates are listed in section 3.3.2.

Natural mortality was considered age invariant and assigned a value of M = 0.07. It was obtained from the formula from Hoenig (1973):

$$\text{Log}_e \text{ M} = 1.46 - 1.01 * \text{Log}_e (T_{MAX}) \qquad (4)$$

Where: M = instantaneous rate of natural mortality
T_{MAX} = maximum age of the fished stock (60)

The model was run at fishing rates (F_j) of zero to 0.3 in 0.01 increments.

Exploitation was calculated as follows:

$$u_j = (F_j * A_j) / Z_j \qquad (5)$$

Where: u_j = Exploitation rate from j to j+1
F_j = Fishing mortality rate from j to j+1
A_j = Total mortality rate from j to j+1, calculated as 1-S, where S = exp($-Z_j$), $Z_j = F_j + M_j$

Egg per recruit (EPR) was calculated as:

$$EPR = \left(\frac{\sum_{j=t}^{n} N_j * P_j * p_j * G_j}{R} \right) * 10^{-6} \qquad (6)$$

Where:

EPR	= Lifetime egg deposition per recruit
n	= Maximum age in the population (60)
t	= Age of first maturity in females
N_j	= Number of females at age j (assumed to be 0.5* number of all fish at age j)
P_j	= Proportion of females mature at age j
p_j	= Fraction of mature females on spawning ground (Values were 1.0 through the age of full maturity Age 21) and 0.33 thereafter to account for spawning every third year.)
Gj	= Mean fecundity at age j females
R	= Number of recruits at age one

Maturity schedules for female Atlantic sturgeon were obtained from Young et al. (1988). Fecundity at age was from VanEenaaman (personal communication, see section 3.3.2).