SHORTNOSE STURGEON

- Telephone conversations with John O'Herron on 28 March 2000 and 20 June 2001.
- Telephone conversation with Carrie Mc Daniel on 17 June 2001.
- National Marine Fisheries Service Biological Opinion dated January 31, 2001.
- Biological Assessment: Prepared by Corps of Engineers, Philadelphia District, entitled: "Effects of Rock Blasting on the Shortnose Sturgeon" – May 2000.
- O'Herron, J.C. II, Able, K.W., and Hastings, R.W., 1993, *Movements of the Shortnose Sturgeon (Acipenser brevirostrum) in the Delaware River,* Estuaries 16 (2): 235 – 240.
- Dadswell, M.J., B.D. Taubert, T.S. Squiers, D. Marchette, and J. Buckley. 1984. *Synopsis of biological data on the shortnose sturgeon (Acipenser brevirostrum) (LeSueur, 1818).* NOAA Technical Report, NMFS 14, National Marine Fisheries Service. October 1984. 45 pp.

GROUND WATER

- Evaluation of Ground-Water Flow from Dredged Material Disposal Sites in Gloucester and Salem Counties, New Jersey (USGS, 1995).
- Hydrogeologic Conditions Adjacent to the Delaware River, Gloucester, Salem and Cumberland Counties, New Jersey (USGS, 1996).
- USGS letter prepared by Anthony S. Navoy dated January 23, 1996 to Mr. Stan Lulewicz, Corps of Engineers.
- Selected Hydrogeologic and Chloride-Concentration Data for the Northern and Central Coastal Area of New Castle County, Delaware (USGS, 1998)

WATER QUALITY MONITORING

- Water Quality Monitoring For Salem River Dredging, Prepared for U.S. Army Corps of Engineers by Versar, Inc. February 1996.

SHORTNOSE STURGEON

Telephone Conversation - [illegible]
With - Carrie McDonnell

6-[illegible]

Hal Brundage. ERC 610-558-1662

Carrie McDonnell - No specific studies on juveniles
Based on other estuaries

Conn.

Tagging work - intensive studies
None on Delaware.

SOW -
Biological opinion on blasting.

Need work on juveniles.

Telephone Conversation - John Brady 3-28-00

with - John O'Herron

Upstream side of salt line

Oligo/fresh boundary

juveniles -

54 92

Artificial Island to Schuylkill

Winter - lower in river

No new data

Telephone conversation - John Brody 6-20-01

with - John O'Heron

1) Juvenile work in early 80's - few found.

Trenton + ~~Phila~~ Petty Island
No YOY ~~½~~ 1" stretch
Gill net (~~1½~~ mesh)
(All in channel)

2) Just or upstream - Hudson
~~Bill Povel~~ Povel
(1+ juvenile)

3) No feeding habits for juveniles in Delaware.

YOY - small copepods. ~~+~~
worms
Dadswell - 198~~4~~

No studies in Mercer Hook

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST REGION
One Blackburn Drive
Gloucester, MA 01930

Mr. Robert Callegari
Chief, Planning Division
Environmental Resources Branch
Department of the Army
Philadelphia District, Corps of Engineers
Wanamaker Building, 100 Penn Square East
Philadelphia, PA 19107-3390

JAN 31 2001

Dear Mr. Callegari:

Enclosed is the National Marine Fisheries Service's (NMFS) biological opinion on the impacts of the Army Corps of Engineers (ACOE) Philadelphia District proposed rock blasting during the construction of the Delaware River Main Channel Deepening Project on endangered shortnose sturgeon. This biological opinion was prepared pursuant to the inter-agency consultation requirements of Section 7 of the Endangered Species Act.

Based on our review of the ACOE's Biological Assessment, the Delaware River Main Channel Deepening Project Supplemental Environmental Impact Statement, and available scientific information, NMFS concludes that rock blasting conducted from December 1 to March 15 in the Delaware River (river mile 76.4 to river mile 84.6) may adversely affect, but is not likely to jeopardize the continued existence of listed species under NMFS' jurisdiction.

The enclosed biological opinion provides an Incidental Take Statement (ITS) for endangered shortnose sturgeon, as well as reasonable and prudent measures and terms and conditions necessary for the ACOE to minimize impacts to the species. The ITS authorizes the take of two (2) shortnose sturgeon from injury or mortality for the Delaware River rock blasting project conducted from December 1 to March 15. As stated in the project description, a portion of the rock blasting project involves setting sink gillnets around the blast area to prevent shortnose sturgeon from entering the blasting zone. The aforementioned observed take of 2 shortnose sturgeon will be inclusive of any shortnose sturgeon injured or killed as a result of the gillnetting effort. However, a large amount of non-lethal incidental take (from harass, trap, capture, or collect) may result from the gillnetting effort and it is very difficult to predict how many sturgeon will be captured in these gillnets. The assignment of a number is highly speculative and in instances such as these, the NMFS designates the expected level of take from harass, trap, capture, or collect for the rock blasting project as unquantifiable.

The NMFS expects the ACOE to implement the reasonable and prudent measures and terms and conditions as outlined in the ITS. The measures of the ITS are non-discretionary and must be undertaken by the ACOE for the incidental take exemption to apply.

This biological opinion concludes consultation for the proposed rock blasting portion of the Delaware River Main Channel Deepening Project. Reinitiation of this consultation is required if: (1) the amount or extent of taking specified in the ITS is exceeded; (2) new information reveals effects of these actions that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) project activities are subsequently modified in a manner that causes an effect to the listed species that was not considered in this biological opinion; or (4) a new species is listed or critical habitat designated that may be affected by the identified actions. As identified in the biological opinion, NMFS Northeast Regional staff should be contacted immediately if an interaction with a shortnose sturgeon occurs.

For further information regarding any consultation requirements, please contact Mary Colligan, Acting Assistant Regional Administrator for Protected Resources, NMFS Northeast Regional Office, at (978) 281-9116.

I look forward to continued cooperation with the ACOE during future Section 7 consultations.

Sincerely,

Patricia A. Kurkul
Regional Administrator

Enclosure

cc: ACOE – John Brady
GCNE – Collins
F/NER3 – McDaniel
F/NER-SH – Riportella
F/PR3 – Cain

File Code: 1514-05 (A) ACOE – Delaware River Deepening/Blasting

NATIONAL MARINE FISHERIES SERVICE
ENDANGERED SPECIES ACT SECTION 7 CONSULTATION
BIOLOGICAL OPINION

AGENCY:	Army Corps of Engineers, Philadelphia District
ACTIVITY CONSIDERED:	Delaware River Main Channel Blasting Project (F/NER/2001/00047)
CONDUCTED BY:	National Marine Fisheries Service Northeast Regional Office
DATE ISSUED:	2/2/01
APPROVED BY:	Peter A Kurd ...

This is the National Marine Fisheries Service's (NMFS) biological opinion on the effects of the Army Corps of Engineers' (ACOE) proposed rock blasting during the construction of the Delaware River Main Channel Deepening Project (Deepening Project) on threatened and endangered species in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). The correspondence between the NMFS and the ACOE on October 6, 2000, initiated formal consultation.

This biological opinion is based on information provided in the May 2000 Biological Assessment (BA) prepared by the ACOE, the July 1997 Delaware River Main Channel Deepening Project Supplemental Environmental Impact Statement (SEIS), correspondence with Mr. John Brady, ACOE, and other sources of information. A complete administrative record of this consultation is on file at the NMFS Northeast Regional Office.

CONSULTATION HISTORY

On August 17, 1992, NMFS met with the ACOE regarding the ESA consultation responsibilities on hopper dredging projects in the Philadelphia District. Due to the possibility of multiple ACOE projects using hopper dredges in both the lower and upper Delaware River, it was determined that a district-wide consultation on the cumulative effects of dredging in the Delaware River Basin should be conducted.

On September 29, 1995, the ACOE submitted a BA and requested initiation of formal consultation on Delaware River Federal Navigation Projects from Trenton to the sea. On November 26, 1996, the NMFS issued a biological opinion for all dredging projects permitted, funded, or conducted by the ACOE Philadelphia District. This biological opinion concluded that dredging projects within the Philadelphia District may adversely affect sea turtles and shortnose sturgeon, but are not likely to jeopardize the continued existence of any threatened or endangered species under NMFS' jurisdiction. The anticipated incidental take level was three shortnose sturgeon and four loggerhead sea turtles, or one Kemp's ridley or green sea turtle per year.

In January 1998, three shortnose sturgeon were discovered in the dredge spoil for that year's maintenance dredging operations in the Florence to Trenton section of the upper Delaware River, thus reaching the incidental take limit. On March 24, 1998, the ACOE requested reinitiation of formal consultation to amend the incidental take statement to account for additional takes of shortnose sturgeon during future maintenance dredging operations. As a result, on May 25, 1999, the NMFS issued an amended incidental take statement that replaced the original issued in November 1996. The amended incidental take statement authorized the annual take of four shortnose sturgeon and specified additional reasonable and prudent measures and terms and conditions necessary to minimize and monitor the impacts of dredging on listed species. The authorized take of sea turtles remained unchanged from the previous take statement.

In letters dated February 14, 1997, and December 29, 1997, which responded to the draft Environmental Impact Statement for the Delaware River Main Channel Deepening Project submitted by the ACOE, the NMFS stated that the 1996 biological opinion included all aspects of the proposed Deepening Project except for rock blasting. This correspondence also stated that sea turtles and marine mammals are not likely to be found in the proposed blasting area, but shortnose sturgeon may occur in the vicinity of the proposed project. Informal consultation discussions with ACOE and NMFS were not able to adequately ensure that shortnose sturgeon would not be adversely affected by the blasting project, thus it was determined that formal consultation was necessary. NMFS recommended that ACOE initiate consultation for the rock blasting portion of the Deepening Project to ensure compliance with the requirements of the ESA.

The Delaware Basin Fish and Wildlife Management Cooperative previously developed recommendations for seasonal restrictions in the Delaware River based on the distribution of fish resources. This document identified the recommended time of year to conduct activities involving bucket dredging, non-hopper hydraulic dredging (i.e., pipeline), hopper dredging, and blasting/overboard disposal. These seasonal restrictions were intended to provide guidance for construction and to be periodically amended as new information becomes available. On November 4, 1998, NMFS recommended revising the seasonal restrictions based on the incidental takes of shortnose sturgeon between the Kinkora to Trenton Range of the Delaware River. The proposed project involves blasting in the vicinity of Marcus Hook, which falls in the range between the Delaware Memorial Bridge to the Betsy Ross Bridge. The Delaware Basin Fish and Wildlife Management Cooperative's Seasonal Restrictions prohibit blasting in this area from March 15 to November 30.

On May 26, 2000, the ACOE submitted a BA and requested initiation of formal consultation on the rock blasting project. Before NMFS could initiate formal consultation, additional information was needed to adequately assess the impacts to shortnose sturgeon. On August 22, 2000, NMFS requested additional information on the project details in an e-mail to John Brady. During a meeting on October 3, 2000, the ACOE supplied NMFS with details on the blasting project in the Delaware River.

On October 6, 2000, NMFS informed the ACOE that all of the information necessary for a formal section 7 consultation and the preparation of a biological opinion had been received and reminded ACOE not to make any irreversible or irretrievable commitment of resources that would prevent the NMFS from proposing or the ACOE from implementing any reasonable and prudent alternatives to avoid jeopardizing shortnose sturgeon.

While the 1996 biological opinion considers the impacts of the Deepening Project on shortnose sturgeon, NMFS will be revising the 1996 opinion in the future. NMFS believes that it is more appropriate to assess the dredging projects independently, or grouped by region, as opposed to including all projects in the same biological opinion. On March 29, 1999, NMFS informed ACOE that the actions currently addressed through the existing 1996 consultation should be considered under multiple consultations organized by geographic region and by the potential for adverse impacts to listed species. The ACOE and NMFS are currently discussing options for fulfilling this request. At this time, however, the 1996 opinion remains in effect and includes the potential impacts of the dredging portion of the Deepening Project.

DESCRIPTION OF THE PROPOSED ACTION

The ACOE proposes to blast bedrock from the Delaware River in order to deepen the federal navigation channel to a depth of 47 feet mean low water, pursuant to the Water Resources Development Act of 1996. Approximately 70,000 cubic yards of bedrock will be removed by blasting. The area to be blasted covers 18 acres near Marcus Hook, Pennsylvania (river mile 76.4 to river mile 84.6; figure 1). Blasting operations will occur up to five days a week between December 1 and March 15, with approximately 2 to 6 blasts per day. The depth and placement of the holes and the size of the charges control the amount of rock that is broken.

While the blasting will break up the rock into small pieces, there is the potential for a large amount of debris to be generated from the blasting operations. The ACOE informed NMFS that if the channel depth were 47 feet after the blasting, the ACOE would not remove the debris from the channel. If the channel depth is less than 47 feet after blasting, the debris smaller than 6" will be placed at an upland disposal site at Ft. Miflin, Pennsylvania.

In the SEIS, the ACOE identified several construction methods that will be used in the Delaware River blasting project:

- Plan the blasting program to minimize the size of explosive charges per delay (time lag during detonation and the number of days of explosive exposure);
- Subdivide the explosives deployment, using electric detonating caps with delays (preferable) or delay connectors for detonation cord (less useful), to reduce total pressure;
- Use decking (explosives separated by delays) in drill holes to reduce total pressure;
- Use angular stemming material (rock piled at an angle on top of drill holes) to reduce energy dispersal;
- Use scare charges for each blast; and
- Monitor impacts to fish from blasting.

During a discussion about the project details, the ACOE informed NMFS that the protocol for the Wilmington Harbor, North Carolina blasting project would be used for the Delaware River blasting project. The ACOE shared the Wilmington Harbor (Lower Brunswick Channel to Keg Island Channel Dredging) specifications with NMFS. The following measures are included in the Wilmington Harbor specifications and/or in the ACOE's BA as Reasonable and Prudent Measures to minimize impacts. Several of these specifications correspond to the aforementioned construction methods listed in the SEIS. Consequently, the following are considered part of the proposed action:

- The pre- and post-blast monitoring for shortnose sturgeon shall be conducted under the supervision of a principal biologist that has at least a Master of Science degree in fisheries biology or similar fields approved by the Contracting Officer. In addition, the principal biologist must have at least 3 years of experience in the estuarine/marine environment, which includes working with shortnose sturgeon, and the principal biologist must have issued in their name the appropriate ESA permits to work with shortnose sturgeon.
- Before each blast, four sinking gillnets (5.5 inch stretched mesh, 328 feet [100 meters] long, 9.8-13.1 feet [3-4 meters] high) will be set to surround each blast area as near as feasible. These nets shall be in place for at least 3 hours and none of the nets will be removed any sooner than 1 hour before the blast. This may require overnight sets. The nets shall be manned continuously to prevent obstructing the channel to ship traffic. Any sturgeon removed (shortnose or Atlantic) shall be tagged and released at a location approved by the NMFS.
- Within 10 minutes of blast, channel nets (1-2 inch mesh) will be set during daylight hours downcurrent of the blast area and within approximately 300 feet from the blast area in order to capture and document dead or injured fish. The channel net shall have a minimum head rope length of 100 feet and should be retrieved approximately one hour later.
- Surveillance for schools of fish will be conducted by vessels with sonar fish finders (with a LCD display screen) for a period of 20 minutes before each blast. The surveillance zone will be approximately circular with a radius of about 500 feet extending outward from each blast set. If fish schools are detected, blasting will be delayed until they leave.
- Two scare charges shall be used at each blast. The scare charges shall be detonated in close proximity to each blast. Each individual scare charge shall not exceed a TNT-equivalent weight of 0.1 lb. The detonation of the first scare charge will be at 45 seconds prior to the blast, with the second scare charge detonated 30 seconds prior to the blast. It is necessary to employ the scare charges and conduct the surveillance surveys before each blast, as some fish have been found to recolonize the blast zone soon after a detonation.
- All blast holes will be stemmed to suppress the upward escape of blast pressure from the hole. The minimum stemming shall be 2 feet thick. Stemming shall be placed in the blast hole in a zone encompassed by competent rock. Measures shall be taken to prevent bridging of explosive materials and stemming within the hole. Stemming shall be clean, angular to subangular, hard stone chips without fines having an approximate diameter of 1/2-inch to 3/8-inch. A barrier shall be placed between the stemming and explosive product, if necessary, to prevent the stemming from setting into the explosive product.
- Blast pressures will be monitored and upper limits will be imposed on each series of 5 blasts.
- Average peak pressure shall not exceed 70 pounds per square inch (psi) at a distance of 140 feet.
- Maximum peak pressure shall not exceed 120 psi at a distance of 140 feet.
- Pressure will be monitored for each blast only at a distance of 140 feet.

Action area

The action area is defined in 50 CFR §402.02 as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action." The blasting area consists of 18 acres near Marcus Hook, Pennsylvania extending from river mile 76.4 to river mile 84.6 (Figure 1). While the entire Delaware River population of shortnose sturgeon has the potential to be in the project area, the direct impacts of the blasting should not extend past the immediate area. Blasting could result in indirect impacts throughout the Delaware River with the likely increase in large vessel traffic. However, the increases in vessel traffic were considered in the previous dredging BO (NMFS 1996) and do not need to be readdressed in this consultation. Therefore, the action area for this biological opinion is the area identified for blasting.

STATUS OF SPECIES OR CRITICAL HABITAT

The only endangered or threatened species under NMFS' jurisdiction in the action area is the endangered shortnose sturgeon (*Acipenser brevirostrum*). No critical habitat has been designated for shortnose sturgeon.

Status of Shortnose Sturgeon Rangewide

At hatching, shortnose sturgeon are blackish-colored, 0.28-0.43 in. long and resemble tadpoles (Buckley and Kynard 1981). In 9-12 days, the yolk sac is absorbed and the sturgeon develops into larvae, which are about 0.59 in. total length (TL; Buckley and Kynard 1981). Sturgeon larvae are believed to begin downstream migrations at about 0.79 in. TL. Laboratory studies suggest that young sturgeon move downstream in a 2-step migration: a 2-day migration by larvae followed by a residency period by young of the year, then a resumption of migration by yearlings in the second summer of life (Kynard 1997). At the larval stage, sturgeon are believed to be even more benthic than the adults. They are rarely found in the water column and possibly spend the majority of their time in intersitial spaces in the gravel (Pottle and Dadswell 1979).

Shortnose sturgeon have similar lengths at maturity (17.7-21.7 in. fork length) throughout their range, but, because sturgeon in southern rivers grow faster than those in northern rivers, southern sturgeon mature at younger ages (Dadswell et al. 1984). Generally, shortnose sturgeon reach sexual maturity between approximately 6 and 10 years of age. Based on limited data, females spawn every three to five years while males spawn every two years. The spawning period is estimated to last from a few days to several weeks. Spawning begins from late winter/early spring (southern rivers) to mid to late spring (northern rivers) when the freshwater temperatures increase to 8-9°C.

In populations that have free access to the total length of a river (e.g., no dams within the species' range in a river: Saint John, Kennebec, Altamaha, Savannah, Delaware and Merrimack Rivers), spawning areas are located at the farthest upstream reach of the river (NMFS 1998). Sturgeon spawn in upper, freshwater areas and feed and overwinter in both fresh and saline habitats. Shortnose sturgeon spawning migrations are characterized by rapid, directed and often extensive upstream movement (NMFS 1998). Shortnose sturgeon typically leave the spawning grounds soon after spawning. Non-spawning movements include rapid, directed post-spawning movements to downstream feeding areas in spring and localized, wandering movements in summer and winter (Dadswell et al. 1984, Buckley and Kynard 1985, O'Herron et al. 1993). Kieffer and Kynard (1993) reported that post-spawning migrations were correlated with increasing spring water temperature and river discharge.

The species appears to be estuarine anadromous in the southern part of its range, but in some northern rivers, it is "freshwater amphidromous" (i.e., adults spawn in freshwater but regularly enter saltwater habitats during their life; Kieffer and Kynard 1993). Adult sturgeon occurring in freshwater or freshwater/tidal reaches of rivers in summer and winter often occupy only a few short reaches of the total length (Buckley and Kynard 1985). Summer concentration areas in southern rivers are cool, deep, thermal refugia, where adult and juvenile shortnose sturgeon congregate (Flournoy et al. 1992, Rogers and Weber 1994, Rogers and Weber 1995, Weber 1996). While shortnose sturgeon are occasionally collected near the mouths of rivers, they are not known to participate in coastal migrations (Dadswell et al. 1984). Juvenile shortnose sturgeon generally move upstream in spring and summer and move back downstream in fall and winter; however, these movements usually occur in the region above the saltwater/freshwater interface (Dadswell et al. 1984, Hall et al. 1991).

Shortnose sturgeon are benthic omnivores but have also been observed feeding off plant surfaces (Dadswell et al. 1984). Generally, shortnose sturgeon feed on crustaceans, insect larvae, worms, molluscs, and small fish (NMFS 1998). Juveniles typically eat crustaceans and insects. Feeding patterns vary seasonally between northern and southern river systems.

Shortnose sturgeon were listed as endangered on March 11, 1967 (32 FR 4001). Shortnose sturgeon remained on the endangered species list with enactment of the ESA in 1973. A shortnose sturgeon recovery plan was published in December 1998, to promote the conservation and recovery of the species.

Although the shortnose sturgeon was originally listed as endangered rangewide, in the final recovery plan NMFS recognized 19 separate distinct populations occurring in New Brunswick, Canada (1); Maine (2); Massachusetts (1); Connecticut (1); New York (1); New Jersey/Delaware (1); Maryland/Virginia (1); North Carolina (1); South Carolina (4); Georgia (4); and Florida (2). In the plan, NMFS stated that loss of a single shortnose sturgeon population segment may risk the permanent loss of unique genetic information that is critical to the survival and recovery of the species and that, therefore, each shortnose sturgeon population should be managed as a Distinct Population Segment (DPS) for the purposes of section 7 of the ESA. Because of this, each DPS is treated as a separate recovery unit for the purposes of section 7 consultation. Under this policy, actions that could adversely affect a DPS would be evaluated in terms of their potential to jeopardize the continued existence of an individual population segment (as opposed to the existence of shortnose sturgeon rangewide).

The Shortnose Sturgeon Recovery Plan (NMFS 1998) identifies habitat degradation or loss (resulting, for example, from dams, bridge construction, channel dredging, and pollutant discharges) and mortality (resulting, for example, from impingement on cooling water intake screens, dredging, and incidental capture in other fisheries) as principal threats to the species' survival. The recovery goal is identified as delisting shortnose sturgeon populations throughout their range and the recovery objective is to ensure that a minimum population size is provided such that genetic diversity is maintained and extinction is avoided.

Status of Shortnose Sturgeon in the Delaware River
Shortnose sturgeon have been reported in the Delaware River for over 170 years but became rare after about 1913 (Hastings et al. 1987, O'Herron et al. 1993). It is possible that shortnose sturgeon suffered a decline as a result of overfishing and water pollution. However, some historical literature states that the shortnose sturgeon was apparently never an abundant fish in the Delaware River (Hoff 1965). Regardless of historical numbers, the current Delaware River DPS of shortnose sturgeon is not considered to be at a sustainable level. NMFS' goal for shortnose sturgeon in the Delaware River is to recover the Delaware River DPS to a level that would support reclassifying this sturgeon from endangered to threatened and eventually removing them from the federal list of threatened and endangered species.

Hastings et al. (1987) used Floy T-anchor tags in a tag-and-recapture experiment to estimate the Delaware River population size in the Trenton to Florence reach, between 1981 to 1984. Population sizes by three estimation procedures ranged from 6,408 to 14,080 adult sturgeon. These estimates compare favorably with those based upon similar methods in similar river systems. This is the best available information on population size, but because the recruitment and migration rates between the population segment studied and the total population in the river are unknown, model assumptions may have been violated.

Shortnose sturgeon occur in the Delaware River from the lower bay upstream to at least Lambertville, New Jersey (river mile 148). Tagging studies by O'Herron et al. (1993) found that the most heavily used portion of the river appears to be between river mile 118 below Burlington Island and river mile 137 at the Trenton Rapids. From November through March, adult sturgeon overwinter in dense sedentary aggregations in the upper tidal reaches of the Delaware River between river mile 118 and 131. The areas around Duck Island and Newbold Island seem to be regions of intense overwintering concentrations. However, unlike sturgeon in other river systems, shortnose sturgeon in the Delaware River do not appear to remain as stationary during overwintering periods. Overwintering fish have been found to be generally active, appearing at the surface and even breaching through the skim ice (ACOE 2000). Due to the relative active nature of these fish, the use of the river during the winter is difficult to predict. However, O'Herron et al. (1993) found that the typical overwintering movements are fairly localized and sturgeon appear to remain within 1.24 river miles of the aggregation site (O'Herron and Able 1986). The overwintering location of juvenile shortnose sturgeon is not known but believed to be on the fresh side of the oligohaline/fresh water interface (O'Herron and Able 1990). In the Delaware River, the oligohaline/freshwater interface occurs in the area between Wilmington, Delaware and Marcus Hook, Pennsylvania (O'Herron and Able 1990).

Spawning in the Delaware River occurs in late March through April. While actual spawning has not been documented in this area, the concentrated use of the Scudders Falls - Trenton Rapids region in the spring by large numbers of mature male and female shortnose sturgeon indicate that this is a major spawning area (O'Herron et al. 1993). The same area was identified as a likely spawning area based on the collection of two ripe females in the spring (Hoff 1965). During the spawning period, the males remain on the spawning grounds for approximately a week while females only stay for a few days (O'Herron and Hastings 1985). After spawning, in late spring and early summer, shortnose sturgeon move rapidly downstream to the Philadelphia area.

Historically, sturgeon were relatively rare below Philadelphia due to poor water quality. In the past few decades, the water quality in the Philadelphia area has improved leading to an increased use of the lower river by shortnose sturgeon. After adult sturgeon migrate to the area around Philadelphia, many adults return upriver to between river mile 127 and 134 within a few weeks, while others gradually move to the same area over the course of the summer (O'Herron 1993). By November, adult sturgeon have returned to the overwintering grounds around Duck Island and Newbold Island. These patterns are generally supported by the movement of radio-tagged fish in the region between river mile 125 and river mile 148 as presented by Brundage (1986).

It is likely that the area above Philadelphia is of primary importance to the Delaware River DPS, but fish have been previously documented below Philadelphia. Brundage and Meadows (1982) have reported incidental captures in commercial gillnets in the lower Delaware River. In addition, during a study focusing on Atlantic sturgeon in 1998, Shirey et al. (1999) captured 9 shortnose sturgeon. During the June through September study period, Atlantic and shortnose sturgeon were found to use the area on the west side of the shipping channel between Deep Water Point, New Jersey and the Delaware-Pennsylvania line. The most frequently utilized areas within this section were off the northern and southern ends of Cherry Island Flats in the vicinity of the Marcus Hook Bar. While the available information does not identify the area below Philadelphia as a concentration area for adult shortnose sturgeon, it is apparent that this species does occupy the lower Delaware River during certain times of the year.

Due to the limited information on juvenile shortnose sturgeon, it is difficult to ascertain their distribution and nursery habitat (O'Herron 2000, pers. comm.). In other river systems, juvenile sturgeon (less than 10 years) move downstream to tidal areas and concentrate at, or just upstream of, the salt front during the summer months (June through August). However, there is no evidence that this population moves into the region of the freshwater-saltwater interface during the summer. In the Delaware River, the oligohaline/fresh interface can range from as far south as Wilmington, Delaware, north to Philadelphia, Pennsylvania, depending upon meteorlogical conditions such as excessive rainfall or drought. As a result, it is possible that in the Delaware River, juveniles could range from Artificial Island (river mile 54) to the Schuylkill River (river mile 92; O'Herron 2000, pers. comm.). O'Herron (2000, pers. comm.) believes that if juveniles are present within this range they would likely aggregate closer to the downstream boundry in the winter when freshwater input is normally greater. However, due to a lack of data, the exact status of juvenile shortnose sturgeon in the Delaware River has yet to be determined. Hypotheses constructed about juvenile shortnose sturgeon distribution in the Delaware River have been based on comparisons of sturgeon in other river systems.

While shortnose sturgeon forage on a variety of organisms, in the Delaware River, sturgeon primarily feed on the Asiatic river clam (*Corbicula manilensis*). *Corbicula* is widely distributed at all depths in the upper tidal Delaware River, but it is considerably more numerous in the shallows on both sides of the river than in the navigation channels. Foraging is heaviest immediately after spawning in the spring and during the summer and fall, and lighter in the winter. Juvenile sturgeon primarily feed in 33 to 66 feet deep river channels, over sand-mud or gravel-mud bottoms (Pottle and Dadswell 1979). However, little is known about the specific feeding habits of juvenile shortnose sturgeon in the Delaware River.

ENVIRONMENTAL BASELINE

By regulation, environmental baselines for biological opinions include the past and present impacts of all State, Federal or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process (50 CFR §402.02). The environmental baseline for this biological opinion includes the effects of several activities including dredging, scientific studies, contaminants, water quality, and fisheries, which may have affected the survival and recovery of threatened and endangered species in the action area.

Dredging

The Delaware River is an essential waterway that links the city of Philadelphia with ports all over the world. Each year over 3000 ships travel in and out of Philadelphia, making it one of the busiest ports in the U.S. Atlantic (The Port of Philadelphia and Camden 2000). The construction and maintenance of Federal navigation channels have been identified as a source of sturgeon mortality. The Delaware River Federal Navigation Channel is maintained by the ACOE, and the ACOE works in the Delaware River under the constraints of a general biological opinion issued in 1996. The Delaware Main Channel is dredged using a hopper dredge, but the other smaller channels in the Delaware River usually employ a hydraulic pipeline dredge. The 1996 biological opinion found that shortnose sturgeon may be adversely affected by entrainment and harassment during dredging projects that occur in the Delaware River. This opinion outlined terms and conditions that would minimize potential impacts, but nevertheless, dredging projects could have caused shortnose sturgeon mortality or injury, and/or affected shortnose sturgeon distribution and foraging habitat.

Since dredging involves removing the bottom material down to a specified depth, the benthic environment could be severely impacted by dredging operations. As shortnose sturgeon are benthic omnivores, the alteration of the benthic habitat could have affected sturgeon prey distribution and/or foraging ability. Entrainment is the most imminent danger for shortnose sturgeon during selected dredging operations because hopper dredges are known to entrain these species. Hopper dredges move relatively rapidly and can entrain and kill sturgeon, presumably as the drag-arm of the moving dredge overtakes the slower moving sturgeon, sucking the species into the dredge draghead, pumping it through the intake pipe, and then killing the fish as it cycles through the centrifugal pump and into the hopper. In March 2000, a juvenile Atlantic sturgeon was taken by a hopper dredge in the entrance to the Charleston Harbor, South Carolina.

Other types of dredges can cause injury or mortality to shortnose sturgeon as well. In mid-March 1996, three subadult shortnose sturgeon were found in a dredge discharge pool on Money Island, near Newbold Island on the Delaware River. The dead sturgeon were found on the side of the spill area into which the hydraulic pipeline dredge was pumping, and the presence of large amounts of roe in two specimens would infer that the fish were alive and in good condition prior to entrainment. In January 1998, three shortnose sturgeon were discovered in the hydraulic maintenance dredge spoil in the Florence to Trenton section of the upper Delaware River. The only visible physical damage to two of the shortnose sturgeon was damage around the gill plate, while the other fish had physical damage to the stomach area. There was little to no evidence of decomposition or scavenging in any of the three fish. These instances are outside the action area, but similar dredging activities in the action area could have resulted in undetected shortnose sturgeon mortality or injury.

Scientific studies
Fish resources in this region have been the focus of a prolonged history of scientific research. While few studies have focused on shortnose sturgeon in the action area, sampling efforts targeting other species have incidentally captured shortnose sturgeon and subject these fish to handling and/or tagging. For example, during an Atlantic sturgeon study in 1998, Shirey et al. (1999) captured 9 shortnose sturgeon. It is possible that research in the action area may have significantly influenced and/or altered the migration patterns, reproductive success, foraging behavior, and survival of shortnose sturgeon.

Contaminants and Water Quality
Historically, shortnose sturgeon were rare in the area below Philadelphia, likely a result of poor water quality (e.g., the "pollution zone"). However, in the past 20 to 30 years, the water quality has improved, most likely because of controls on non-point source pollution. As a result, sturgeon have been found farther downstream. It is likely that contaminants remain in the water and in the action area, albeit to reduced levels. Sewage, industrial pollutants and waterfront development have likely contributed to the impaired water quality in the action area.

Contaminants, including heavy metals, polychlorinated aromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs), can have substantial deleterious effects on aquatic life (e.g., production of acute lesions, growth retardation, and reproductive impairment; Ruelle and Keenlyne 1993). Ultimately, toxins introduced to the water column become associated with the benthos and can be particularly harmful to benthic organisms like sturgeon. Heavy metals and organochlorine compounds are known to accumulate in fat tissues of sturgeon, but their long term effects are not yet known. Available data suggest that early life stages of fish are more susceptible to environmental and pollutant stress than older life stages (NMFS 1998).

Although there is scant information available on levels of contaminants in shortnose sturgeon tissues, some research on other related species indicates that concern about the effects of contaminants on the health of sturgeon populations is warranted. Detectable levels of chlordane, DDE (1,1-dichloro-2, 2-bis(p-chlorophenyl)ethylene), DDT (dichlorodiphenyl-trichloroethane), and dieldrin, and elevated levels of PCBs, cadmium, mercury, and selenium were found in pallid sturgeon tissue from the Missouri River (Ruelle and Keenlyne 1993). These compounds may affect physiological processes and impede a fish's ability to withstand stress. Elevated levels of environmental contaminants, including chlorinated hydrocarbons, in several other fish species are associated with reproductive impairment, reduced egg viability, and reduced survival of larval fish. PCBs are believed to adversely affect reproduction in pallid sturgeon and some researchers have speculated that PCBs may reduce the shortnose sturgeon's resistance to fin rot.

Several characteristics of shortnose sturgeon (i.e., long lifespan, extended residence in estuarine habitats, benthic predator) predispose the species to long-term and repeated exposure to environmental contamination and potential bioaccumulation of heavy metals and other toxicants. In the Connecticut River, coal tar leachate was suspected of impairing sturgeon reproductive success. Kocan et al. (1993) conducted a laboratory study to investigate the survival of sturgeon eggs and larvae exposed to PAHs, a by-product of coal distillation. Approximately 5% of sturgeon embryos and larvae survived after 18 days of exposure to Connecticut River coal-tar contaminated sand in a flow-through laboratory system. This study demonstrated that coal-tar (i.e., PAH) contaminated sediment is toxic to shortnose sturgeon embryos and larvae under laboratory exposure conditions (NMFS 1998).

Point-source discharges (i.e., municipal wastewater, paper mill effluent, industrial or power plant cooling water or wastewater) affect water quality and may also contribute to impacts on shortnose sturgeon. Compounds associated with these discharges, including metals, dioxin, dissolved solids, phenols, and hydrocarbons, can alter the quality of receiving waters, which may lead to mortality, alterations in fish behavior, deformations, and reduced egg production and survival.

Contaminants have been found to occur in the action area. PCBs have been detected in elevated levels in various species of fish. No contaminant sampling of shortnose sturgeon has been conducted, but it is possible that sturgeon may have levels of PCBs in their tissue. The waterfront in this portion of the Delaware River is highly industrialized. Sewage treatment facilities, refineries, manufacturing plants and power generating facilities all intake and discharge water directly from the Delaware River. Large temperature variations and the discharge of heavy metals, dioxins, dissolved solids, phenols, and hydrocarbons may alter the water quality, eventually leading to fish mortality. Industrial development, especially the presence of refineries, has also resulted in the leakage of hazardous waste products into the Delaware River. Presently, 13 Superfund sites have been identified in Marcus Hook and one dumpsite has yet to be labeled as a Superfund site, but does contain hazardous waste. It is possible that the presence of these contaminants in the action area may have adversely affected shortnose sturgeon abundance, reproductive success, and survival.

As mentioned, the waterfront in Marcus Hook and north and south of the city is highly industrialized. Refineries, sewage treatment facilities, a generating plant, manufacturing plants, and shipping traffic are what characterize waterfront development in the action area (Breitenstein 2000, pers. comm.). This coastal development often results in excessive water turbidity, extreme water temperature variations, and changes to the benthic environment due to construction, increased shipping traffic and water intakes and discharges. These impacts may have adversely affected shortnose sturgeon in the action area.

Fisheries

Unauthorized take of shortnose sturgeon is prohibited by the ESA. However, shortnose sturgeon are taken incidentally in anadromous fisheries along the East Coast and are probably targeted by poachers (NMFS 1998). The incidental take of shortnose sturgeon on the Hudson River has been documented in both commercial shad fisheries as well as recreational hook and line fisheries. Although commercial fisheries are prohibited in Pennsylvania State waters, New Jersey and Delaware do permit commercial fisheries to operate in designated portions of the Delaware River (Miller 2000, pers. comm.; Boriek 2000, pers. comm.). American shad, eel, and blue crab are targeted by commercial fishermen, however, in the action area the level of commercial fishing is very minimal (Miller 2000, pers. comm.; Boriek 2000, pers. comm.). Recreational hook and line fisheries target largemouth bass, striped bass, white catfish and channel catfish, and are permitted throughout the entire action area (Coughman 2000, pers. comm.; Boriek 2000, pers. comm.). Despite that there are no documented takes of shortnose sturgeon, it is possible that unreported incidental takes have occurred in recreational hook and line fisheries and commercial fisheries operating in the action area (Coughman 2000, pers. comm.).

EFFECTS OF THE PROPOSED ACTION

This section of a biological opinion assesses the direct and indirect effects of the proposed action on threatened and endangered species or critical habitat, together with the effects of other activities that are interrelated or interdependent (50 CFR §402.02). Indirect effects are those that are caused later in time, but are still reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend upon the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration (50 CFR §402.02).

The purpose of this assessment is to determine if it is reasonable to expect that the ACOE's proposed action will have direct or indirect effects on threatened and endangered species that will appreciably reduce their likelihood of both survival and recovery in the wild by reducing the reproduction, numbers, or distribution of that species [which is the "jeopardy" standard established by 50 CFR §402.02].

It is important to assess the impacts of the proposed project on the status of the species in the action area, but the distribution of shortnose sturgeon in the lower Delaware River is relatively unknown. While the action area (river mile 76.4 to river mile 84.6) is not a known concentration area for adult sturgeon, the species has been documented below Philadelphia and in the vicinity of the blasting area. As mentioned previously, the distribution and abundance of juvenile shortnose sturgeon in the Delaware River has not been documented or studied. It has been speculated that juveniles could range from Artificial Island (river mile 54) to the Schuylkill River (river mile 92), which includes the blasting area. Therefore, shortnose sturgeon may be present in the action area and may be either directly or indirectly affected by blasting operations. Species in the action area may be physically injured or killed by the detonations. Indirect effects include modification of habitat and disruption of prey resources, and alteration of normal distribution. Both direct and indirect effects should be considered when determining the impact of blasting on the overall survival and recovery of the species.

Numerous studies have assessed the direct impact of underwater blasting on fish. While not all of the studies have focused exclusively on shortnose sturgeon, the results demonstrate that blasting does have an adverse impact on fish. Teleki and Chamberlain (1978) found that several physical and biological variables were the principal components in determining the magnitude of the blasting effect on fish. Physical components include detonation velocity, density of material to be blasted, and charge weight, while the biological variables are fish shape, location of fish in the water column, and swimbladder development. Composition of the explosive, water depth, and bottom composition also interact to determine the characteristics of the explosion pressure wave and the extent of any resultant fish kill. Furthermore, the more rapid the detonation velocity, the more abrupt the resultant hydraulic pressure gradient, and the more difficulty fish appear to have adjusting to the pressure changes.

A blasting study conducted in Nanticoke, Lake Erie, found that fish were killed in radii ranging from 65.6 to 164 ft (20-50 m) for 50 lbs. (22.7 kg) per charge and from 147.6 to 360.9 ft (45-110 m) for 600.5 lbs. (272.4 kg) per charge (Teleki and Chamberlain 1978). Approximately 201 blasts were detonated in 13.1 to 26.2 ft (4-8 m) of water. Of the thirteen fish species studied, mortality differed by species at identical pressure. No shortnose sturgeon were tested. Common blast induced injuries included swimbladder rupturing and hemorrhaging in the coelomic and pericardial cavities.

The effects of blasting on thirteen species of fish were measured in deep water (151 ft) explosion tests in the Chesapeake Bay opposite the mouth of the Patuxent River (Wiley et al. 1981). No shortnose sturgeon were tested. Fish were held in cages at varying depths during 16 midwater detonations with 70.5 lbs. (32 kg) explosives. For the 70.5 lbs. charges, the pressure wave was propagated horizontally most strongly at the depth at which the explosion occurred. While the extent of the injury varied with species, the fish with swimbladders were far more vulnerable than those lacking swimbladders, and toadfish and catfish were the most resistant to damage of those species with a swimbladder.

Many fish exposed to blasting exhibit injuries to the kidney and swimbladder, thus affecting their fitness (Wiley et al. 1981). Efficient osmoregulation is very important in fishes; even slight bruises to the kidney could seriously affect this efficiency, causing at least a higher expenditure of energy. Burst swimbladders cause the fish to lose their ability to regulate the volume of their swimbladders (destroying buoyancy control) and probably increases their vulnerability to predators.

Wiley et al. (1981) found that the oscillatory response of the swimbladder was a likely cause of the fishes' injuries. Their analyses demonstrate that fish mortality is strongly dependent on the depth of the fish. For larger fish (like shortnose sturgeon) at shallower depths (23 to 36 ft), the swimbladder does not have time to fully respond to the positive portion of the explosion wave. Thus, at shallow depth the larger fish are in effect protected from harm by their swimbladders, while at the resonance depth their swimbladders are burst.

Burton (1994) conducted experiments to estimate the effects of blasting to remove approximately 1,600 cubic yards of bedrock during construction of a natural gas pipeline in the Delaware River near Easton, Pennsylvania (upriver from the action area). American shad and smallmouth bass juveniles were exposed to charges of 248 and 2109.8 lbs. (112.5 and 957 kg) of explosives in depths ranging between 1.6 and 6.6 ft (0.5 and 2 m). The fish were caged at a range of distances from the blasts. Tests with American shad were inconclusive due to an unavoidable delay between stocking the chambers and detonation of the explosives; however, successful tests with smallmouth bass suggested that the explosives created a maximum kill radius of 39.4 ft (12 m) for both charge magnitudes. No fish were killed by the shock wave at the 78.7 ft (24 m) position and beyond.

The preceding studies were conducted on other fish species, but the nature of the injuries and the optimal "safe" distance from the detonations could be applied to blasting activities and shortnose sturgeon. However, the effects of blasting on shortnose sturgeon have been examined. Test blasting was conducted in Wilmington Harbor, North Carolina, in December 1998 and January

1999 in order to adequately assess the impacts of blasting on shortnose sturgeon, the size of the LD1 area (the lethal distance from the blast where 1% of the fish died), and the efficiency of an air curtain for mitigating blast effects. An air curtain is a steam of air bubbles created by a manifold system on the river bottom surrounding the blast. In theory, when the blast occurs the air bubbles are compressed, and the blast pressure is reduced outside the air curtain.

The test blasting consisted of 32-33 blasts (3 rows of 10 to 11 blast holes per row with each hole and row 10 feet apart), about 52.9 to 61.7 lbs. (24 to 28 kg) of explosives per hole, stemming each hole with angular rock, and an approximate 25 msec delay after each blast. During test blasting, 50 hatchery reared juvenile striped bass and shortnose sturgeon were placed in 0.25 in. plastic mesh cylinder cages (2 feet in diameter by 3 feet long) 3 feet from the bottom (worst case scenario for blast pressure as confirmed by test blast pressure results) at 35, 70, 140, 280, and 560 feet upstream and downstream of the blast location. For each test, 200 caged shortnose sturgeon were held at a control location 0.5 mi from the test blast area. The caged fish had a mean weight of 55 grams. The cages were enclosed in a 0.6 in. nylon mesh sock to prevent the escape of any sturgeon if the cage was damaged during blasting.

Three test blasts were conducted with the air curtain in place and 4 were conducted without the air curtain. The air curtain (when tested) was 50 feet from the blast. The caged fish were visually inspected for survival just after the blast and after a 24-hour holding period. The survival pattern just after the blast and after the 24-hour holding period was similar. Survival at the monitoring locations 140 feet and beyond just after the blast (with or without the air curtain) was not significantly different. This 140-foot distance equaled 2.1 acres and was the edge of the LD1.

The condition of the fish and the potential for their future survival was estimated based on necropsies performed on 70 shortnose sturgeon surviving after the post-blast holding period. Most of the necropsies were performed on fish caged 35 feet from the blast, but one cage of sturgeon located 70 feet from the blast was examined. The mean Index of Injury values for each blast revealed no clear reduction in the degree of injury when the air curtain was in place, and shortnose sturgeon generally suffered less significant degree of injury than striped bass. While sturgeon had relatively little damage to their swimbladders, they more often had distended intestines with gas bubbles inside and hemorrhage to the body wall lining. In the fish caged 70 feet away, there was no sign of hemorrhage or swimbladder damage but two of the fish exhibited distended intestines, which may have been caused by the blast. Moser (1999) speculated that sturgeon fared better than striped bass because their swimbladder has a free connection to the esophagus, allowing gas to be expelled rapidly without damage to the swimbladder. Additionally, there was no clear relationship between size and the Index of Injury, size and gut fullness, or Index of Injury and gut fullness.

The external observations of the fish in the Wilmington Harbor study were not sufficient to identify all blast related injuries, as many of the fish that exhibited no outward signs of stress or physical discomfort had extensive evidence of internal damage. It would seem that this type of internal damage would be far more debilitating than it appeared to be. While sturgeon placed in holding tanks exhibited no greater long-term mortality (two months) than fish not exposed to blasting, Moser (1999) reported that many of the injuries documented would have likely resulted in eventual mortality. Consequently, the results of the external examination of fish following the blasting experiments underestimated the blast effects.

Shortnose sturgeon appear to be able to withstand some degree of blasting at a certain distance from the detonation, but it is apparent from the study results that blasting may injure the species both internally and externally. While it is difficult to measure the degree of internal damage if the fish appear to be functioning normally, it is especially problematic if the injured fish are not visible. Previous studies found that from 11 to 50% of all fish killed by blasts sank to the bottom (Fitch and Young 1948, Coker and Hollis 1950, Ontario Ministry of Transportation and Communications 1974 in Teleki and Chamberlain 1978). Teleki and Chamberlain (1978) also found that 47% of the total blast mortality was not visible from the water surface. If this is the case with shortnose sturgeon (likely as sturgeon are benthic species), one would not expect all of the fish injured by the blasts to be floating on the surface. However, dead or severely injured fish should float downstream, and the downstream channel nets should capture most fish directly impacted by the detonation.

Blasting operations can cause indirect impacts to adult and juvenile shortnose sturgeon in the action area. The most notable indirect effect is the destruction of the benthic habitat and foraging resources. The action area is not a prime foraging spot during the proposed project period (December to March) and sturgeon only engage in light foraging during the winter, but any disruption of the benthic habitat could have a negative impact on sturgeon.

Shortnose sturgeon generally feed when the water temperature exceeds 10° C and in general, foraging is heavy immediately after spawning in the spring and during the summer and fall, with lighter foraging during the winter (ACOE 2000, NMFS 1996). The likelihood that sturgeon are actively foraging in the action area is low, but shortnose sturgeon could still be feeding in the vicinity of the blasting. As mentioned previously, shortnose sturgeon in the Delaware River primarily forage on the Asiatic river clam (*Corbicula manilensis*). Fine clean sand, clay, and coarse sand are preferred substrates for this clam, although this species may be present in lower numbers on almost any substrate (Gottfried and Osborne 1982, Belanger et al. 1985, Blalock and Herod 1999). The substrate in the area proposed for blasting is primarily rock and is not expected to be a concentration area for this prey species, but *Corbicula* has been found on gravel and bedrock substrates in the Susquehanna River. Thus, this species (or any other secondary prey species) may be found in the action area and any organism present on the rock to be removed by blasting or in the immediate project area would be destroyed. The impact should not extend beyond the action area as previous studies indicate that invertebrates are relatively insensitive to pressure related damage from underwater detonations (ACOE 2000). This could be attributable to the fact that all the invertebrate species tested lack gas-containing organs, which have been implicated in internal damage and mortality in vertebrates (Keevin and Hempen 1997). Nevertheless, the area immediately surrounding the blast zone would be void of preferred sturgeon prey after the detonations and thus, shortnose sturgeon would not be likely to forage in this area.

It is important to note however, that while blasting will destroy all of the prey resources in the action area, the impacts will not be permanent and the benthic community will likely reestablish after a couple years. Benthic sampling done by O'Herron and Hastings (1985) in association with past ACOE maintenance dredging in the Delaware River found that *Corbicula* recolonized the dredge areas during the subsequent growing season. However, the post-dredge individuals collected were smaller than pre-dredge individuals and provided less biomass. O'Herron and Hastings (1985) found that adult shortnose sturgeon may not be able to efficiently utilize new molluscan colonizers due to the limited biomass until the end of the second growing season after dredging. Due to their relative small individual size as compared to adults, one year or older juvenile shortnose sturgeon should be able to more effectively utilize the small *Corbicula* colonists during the first growing season. These results can be applied to the proposed rock blasting project, as the impact of blasting on the benthic community will be relatively similar to the impact of dredging. Furthermore, the temporary reduction in foraging habitat would not greatly affect sturgeon, as *Corbicula* can be found in other areas in the Delaware River.

Blasting could also disrupt the normal distribution or abundance of the species in the action area. Large detonations would likely deter fish from the action area. If adult or juvenile shortnose sturgeon were in the vicinity of the project area, blasting and a large amount of in-water work would likely disturb the normal distribution and/or foraging patterns. Any anthropogenic deterrence of endangered species from an area is considered harassment (and thus a take) under the ESA. However, the number of sturgeon potentially displaced by the blasting activities is unknown, as a large number of adults have not been documented in the action area and the distribution of juveniles throughout the Delaware River is uncertain.

The use of sinking gillnets around the blast area may entangle sturgeon. While this activity is intended to eliminate the presence of fish in the detonation zone, this take should be considered in the indirect effects of the proposed project. However, the impacts of short-term entanglement on shortnose sturgeon are much less than the potential impacts to a fish in the vicinity of the explosives.

CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, tribal, local or private actions that are reasonably certain to occur within the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Scientific Studies

It is likely that additional scientific studies will be conducted on shortnose sturgeon in the action area. Continued capturing, handling, tagging, and tracking of shortnose sturgeon may affect their migration, reproduction, foraging, and survival.

Contaminants and Water Quality

Contaminants found in the action area are directly linked to industrial development along the waterfront. PCBs, heavy metals, and waste associated with point source discharges and refineries are likely to be present in the future due to continued operation of industrial facilities. In addition, many contaminants such as PCBs remain present in the environment for prolonged periods of time and would not disappear even if contaminant inputs were to decrease. It is likely that shortnose sturgeon will continue to be affected by contaminants in the action area in the future.

Industrialized waterfront development will continue to impact the water quality in and around the action area. Refineries, sewage treatment facilities, manufacturing plants, and generating facilities present in the action area are likely to continue to operate. Excessive water turbidity, water temperature variations, and increased shipping traffic are likely with continued future operation of these facilities. As a result, shortnose sturgeon foraging and/or distribution in the action area may be adversely affected.

Fisheries
Incidental take of shortnose sturgeon is likely with the continued operation of hook and line and commercial fisheries in the action area. There have been no previously documented takes in the action area, however, there is always the potential for this to take place when fisheries are known to occur in the presence of shortnose sturgeon. Thus, the operation of these recreational hook and line and commercial fisheries could result in future shortnose sturgeon mortality and/or injury.

INTEGRATION AND SYNTHESIS OF EFFECTS

The shortnose sturgeon is endangered throughout its entire range. It exists as 19 separate DPS that should be managed as such; specifically, the extinction of a single shortnose sturgeon population risks permanent loss of unique genetic information that is critical to the survival and recovery of the species. The Delaware River shortnose sturgeon form one of the 19 distinct sturgeon populations.

Shortnose sturgeon in the action area may be adversely affected by the Delaware River Main Channel Blasting Project. However, the degree of the impact depends on the number of individuals in the action area. Adult shortnose sturgeon are not considered to be abundant in the project area from December through March, but little is known about their distribution in the action area. Historically poor water quality below Philadelphia limited adult distribution, however, improvements within the last 10 to 20 years have lead to an increase in habitat use below the city. As a result, although adult shortnose do not concentrate in large aggregations in the action area, there is the potential that some adults may be in the area during blasting and could be adversely affected. However, during the proposed project period (December through March), the majority of adult shortnose sturgeon would likely be overwintering in regions further upstream.

Juvenile shortnose sturgeon may also be in the action area during blasting. Although no scientific research has determined the distribution and/or nursery habitat of juveniles in the Delaware River, in other river systems, juveniles aggregate just on the fresh side of the oligohaline/fresh water interface. In the Delaware River, this interface ranges from approximately Wilmington, Delaware to Philadelphia, Pennsylvania. As a result, O'Herron (2000, pers. comm.) believes that juveniles could range from Artificial Island through the Schuylkill River, concentrating closer to the downstream boundary during the winter when fresh water input is greater. Based on this information, it is quite possible that they may be present in the action area and thus could be adversely affected by blasting.

The presence of adults and/or juveniles in the action area during blasting could result in direct injury and or/mortality. Results from previous blasting studies conducted on thirteen species of fish, other than shortnose sturgeon, revealed that swimbladder rupture and hemorrhaging in the pericardial and ceolomic cavities were common injuries. While a study on shortnose sturgeon revealed that they also suffer from swimbladder ruptures, more common blast induced injuries were distended intestines with gas bubbles inside and hemorrhage to the body wall lining (Moser 1999). Overall, however, it is difficult to determine the extent of internal injury because many fish did not exhibit external stress or physical discomfort despite extensive internal damage (as determined from the necropsies).

Blasting can also result in indirect effects to shortnose sturgeon by destroying the benthic habitat (and prey resources), thus altering and/or limiting distribution and foraging patterns. Although the blasting area is not apparently a major foraging ground for sturgeon during the winter, any disruption to the benthic community could affect their foraging patterns. Underwater noise may also limit the distribution of shortnose sturgeon. Large detonations and the presence of heavy machinery working beneath the water may deter sturgeon from entering the blasting area. If juvenile and adult shortnose sturgeon are in the action area, their distribution and foraging habitat may be affected by activities and results associated with the blasting.

The possibility that shortnose sturgeon may be affected by blasting has led to proposed measures to minimize the impacts. For example, before the blast, four sinking gillnets will be set around the blast area to deter fish from entering the immediate blast zone. Two scare charges will also be detonated immediately prior to the blast in order to scare aquatic organisms out of the immediate blasting area and to reduce the number of organisms that may be affected by the blast. Further, the presence of schools of fish will be monitored by boats scanning the blasting area with sonar fish finders. If detected, blasting will be delayed until the fish move out of the area. Blasting pressures will also be monitored and upper limits will be set for each blasting series.

Based on the mitigative measures being employed, the time of year the project is to be completed, and the apparent relative low density of shortnose sturgeon in the action area, NMFS believes that there is only a small chance that incidental shortnose sturgeon takes will occur, either directly or indirectly. Considering the environmental baseline, the effects of the proposed action, and future cumulative effects in the action area, the proposed project is not likely to reduce the reproduction, numbers, and distribution of the Delaware River DPS in a way that appreciably reduces their likelihood of survival and recovery in the wild.

CONCLUSION

After reviewing the current status of the species discussed herein, the environmental baseline for the action area, the effects of the proposed action and the cumulative effects, it is the NMFS' biological opinion that the proposed action may adversely affect but is not likely to jeopardize the continued existence of the Delaware River subpopulation of shortnose sturgeon. No critical habitat has been designated for this species, therefore, none will be affected.

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined to include any act which actually kills or injures fish or wildlife and includes significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering. Harass is defined as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by ACOE so that they become binding conditions for the exemption in section 7(o)(2) to apply. ACOE has a continuing duty to regulate the activity covered by this Incidental Take Statement. If ACOE (1) fails to assume and implement the terms and conditions or (2) fails to adhere to the terms and conditions of the Incidental Take Statement through enforceable terms, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, ACOE must report the progress of the action and its impact on the species to the NMFS as specified in the Incidental Take Statement [50 CFR §402.14(i)(3)].

NMFS anticipates that the Deepening Project rock blasting conducted from December 1 to March 15 may result in the observed take of two (2) shortnose sturgeon from injury or mortality. A portion of the rock blasting project involves setting sink gillnets around the blast area to prevent shortnose sturgeon from entering the blasting zone. The aforementioned observed take of 2 shortnose sturgeon will be inclusive of any shortnose sturgeon injured or killed as a result of the gillnetting effort. However, a large amount of non-lethal incidental take (from harass, trap, capture, or collect) may result from the gillnetting effort and it is very difficult to predict how many sturgeon will be captured in these gillnets. The assignment of a number is highly speculative and in instances such as these, the NMFS designates the expected level of take from harass, trap, capture, or collect for the rock blasting project as unquantifiable.

It is difficult to ascertain future take of shortnose sturgeon as there has not been a previous blasting project conducted in this area. However, the NMFS believes that this level of incidental take is reasonable given the (1) previous level of take in the upper Delaware River dredging activities; (2) the distribution and abundance of adult shortnose sturgeon in the immediate project area; (3) the lack of information and hypotheses on juvenile distribution in the lower Delaware River; (4) the proposed measures to reduce the impact of blasting on fish; and (5) the time of year proposed for the project. Consultation must be reinitiated if the take level is exceeded.

In the accompanying biological opinion, the NMFS determined that this level of anticipated take is not likely to result in jeopardy to the species.

Reasonable and prudent measures
The NMFS believes the following reasonable and prudent measures are necessary and appropriate to minimize impacts of incidental take of endangered shortnose sturgeon:

1. The ACOE will use standard, accepted methods as described in, but not limited to, the project description to limit the number of shortnose sturgeon taken as a result of the use of explosives.

2. The ACOE must have qualified shortnose sturgeon experts present during the detonation of all explosives.

3. Personnel onboard the vessels involved in the blasting must follow specific instructions on proper shortnose sturgeon handling techniques.

4. The ACOE must develop and follow a system to provide timely reporting to the NMFS on any takes of protected species.

Terms and conditions
In order to be exempt from prohibitions of section 9 of the ESA, ACOE must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

1. The ACOE must incorporate all of the measures outlined in the project description section into the Delaware River blasting specifications. In addition, the opening of the mouth of the channel net (with a minimum head rope length of 100 feet) will be set less than 6 feet high off the bottom when it is in place.

2. The principal biologist conducting the pre and post-blast monitoring (including setting and removing gillnets around the blast area, fish surveillance before blasting, setting and removing downstream channel nets after blasting) must be present during all detonations in order to observe any takes of shortnose sturgeon.

3. The supervisory principal biologist, or at least one individual present during the blasting event, must be able to:

   a) identify shortnose sturgeon, including the morphological differences between shortnose and Atlantic sturgeon;
   b) handle live shortnose sturgeon and be knowledgeable of holding and release procedures;
   c) acquire standard field measurements of samples (total length and fork length); and
   d) fill out necessary reporting form (Appendix A) when an incidental take occurs.

4. If any whole shortnose sturgeon (alive or dead) or sturgeon parts are taken incidental to the project, Carrie McDaniel (978) 281-9388 or Mary Colligan (978) 281-9116 must be contacted within 24 hours of the take. An incident report for shortnose sturgeon take (Appendix A) should also be completed by the observer and sent to Carrie McDaniel via FAX (978) 281-9394 within 24 hours of the take. Every incidental take (alive or dead) should be photographed and measured, if possible. The supervisory principal biologist will have had training in shortnose sturgeon biology, so if a sturgeon is injured, he/she should be able to recognize the severity of the shortnose sturgeon's injury. If the fish are badly injured,

the ACOE should retain the species, if possible, until obtained by a NMFS-recommended facility.

5. A final report summarizing the results of the blasting and any takes of listed species must be submitted by the ACOE to Carrie McDaniel, NMFS Protected Resources Division, One Blackburn Drive, Gloucester, MA 01930 (978-281-9388; FAX 978-281-9394), within 30 working days of completion of the blasting project.

6. The ACOE must notify NMFS when the Delaware River blasting reaches 50% of the incidental take level for shortnose sturgeon (1 fish from injury or mortality).

NMFS anticipates that no more than 2 shortnose sturgeon will be incidentally taken from injury or mortality as a result of the proposed rock blasting portion of the Delaware River Deepening Project. NMFS anticipates that an unquantifiable amount of shortnose sturgeon will be incidentally taken from harass, trap, capture, or collect as a result of the sink gillnets set around the blast area. The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the potential for and impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, the level of incidental take is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided. When the incidental take has been reached/exceeded, the ACOE must immediately provide an explanation of the causes of the taking and review with the NMFS the need for possible modification of the reasonable and prudent measures.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. NMFS has determined that the rock blasting portion of the Deepening Project as proposed is not likely to jeopardize the continued existence of endangered shortnose sturgeon located in the project area. To further reduce the adverse effects of the blasting project on listed species, NMFS recommends that ACOE implement the following conservation measures.

1. ACOE should support future research to identify the occurrence, distribution, and the ecology of shortnose sturgeon in the portion of the Delaware River below Philadelphia. Of primary importance is the distribution of juveniles. Very little information is known about the abundance, distribution, and ecology of juvenile shortnose sturgeon in the Delaware River, and a project addressing these data deficiencies would promulgate effective future management. The Delaware River is the site of intense human activity, and dredging (and potentially similar blasting activities) will most likely be needed in the future. Knowledge of the distribution of adult sturgeon below Philadelphia and juvenile sturgeon throughout the system will assist the ACOE in planning future dredging projects by predicting where, when, and if shortnose sturgeon are inhabiting these waters. A more accurate assessment of

shortnose sturgeon abundance within the Delaware River would also help to adequately protect this species.

2. To facilitate future management decisions on listed species occurring in the action area, ACOE should maintain a database mapping system to: 1) create a history of use of the geographic areas affected; and, 2) document endangered/threatened species presence/interactions with project operations.

3. ACOE should support future biological monitoring to determine the composition and/or density of benthic fauna. The ACOE would be able to use the data on the benthic environment to establish the recolonization rate of the disturbed areas, and the functional use of the area by higher-trophic level populations. This biological monitoring data could be used to help predict the habitat suitability of a particular area for shortnose sturgeon and other fish species. Benthic data for the area would also provide a baseline for evaluating the recovery of the benthic community after disturbances such as blasting or dredging.

4. ACOE should support research to evaluate the effects of blasting on shortnose sturgeon in the Northeast. There are several studies on the impacts of blasting on fish, but very few focus on shortnose sturgeon. The best available information on the effects of blasting on shortnose sturgeon was obtained from a Southeast study in Wilmington Harbor, North Carolina. While blasting projects in the Northeast have the potential to invoke similar threats to sturgeon due to the same operating procedures, it is important to ensure the study results are appropriate to use in the Northeast. The abundance, distribution, and ecology of shortnose sturgeon are likely different in northeastern waters and thus the impacts of blasting on the species could vary.

REINITIATON OF CONSULTATION

This concludes formal section 7 consultation on the rock blasting actions outlined in the BA and SEIS for the Deepening Project. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of taking specified in the incidental take statement is exceeded; (2) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) the identified action is subsequently modified in a manner that causes an effect to listed species or critical habitat that was not considered in this biological opinion; or (4) a new species is listed or critical habitat designated that may be affected by the identified action. In instances where the amount or extent of incidental take is exceeded, section 7 consultation must be reinitiated immediately.

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APPENDIX A.

Incident Report of Shortnose Sturgeon Take
Delaware Blasting Project

Species ______________ Date _______________ Time (specimen found) ______________

Geographic Site ____
Location: Lat/Long ____
Blast # (that week) _________________________ Blast # (that day) ____________________

Sampling method (e.g., gillnets around blast zone, downstream channel nets, observations on surface) ____
Location where specimen recovered ____
____

Condition of equipment where specimen recovered____
____

Weather conditions ____
____
Water temp: Surface __________________ Below midwater (if known) ________________

Species Information: *(please designate cm/m or inches.)*

Total length: _______________ Fork length: __________________ Weight: _______________
Condition of fish/description of animal ____
____
____

Fish tagged: YES / NO / DON'T KNOW
Please record all tag numbers. Tag # ___________________________

Photograph attached: YES / NO
(please label *species, date,* and *geographic site* on back of photograph)

Comments/other ____
____
____
____

Observer's Name ____________________________________
Observer's Signature ____________________________________

DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT

BIOLOGICAL ASSESSMENT:

EFFECTS OF ROCK BLASTING ON THE SHORTNOSE STURGEON (*Acipenser brevirostrum*)

PHILADELPHIA DISTRICT U.S. ARMY CORPS OF ENGINEERS

MAY 2000

DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT

BIOLOGICAL ASSESSMENT EFFECT OF ROCK BLASTING ON THE SHORTNOSE STURGEON (*Acipenser brevirostrum*)

TABLE OF CONTENTS

FIGURES

1.0 INTRODUCTION:

1.1 PURPOSE: Section 7 of the Endangered Species Act, as amended November 10, 1978, requires that a Biological Assessment be prepared on all major Federal actions involving construction when Federally listed or proposed endangered or threatened species may be affected. The purpose of this assessment is to examine the potential impacts associated with rock blasting on the endangered shortnose sturgeon (*Acipenser brevirostrum)* that will be under taken as part of the Delaware River Main Channel Deepening Project conducted by the Philadelphia District.

1.2 ENDANGERED SPECIES ACT: This "biological assessment" is part of the formal consultation process provided under Section 7 of the Endangered Species Act. Detailed procedures for this consultation process are defined in 50CFR402.

1.3 JEOPARDIZED SPECIES: The primary concern with the shortnose sturgeon is whether or not impacts associated with rock blasting will "jeopardize their continued existence." Federal regulation defines this term as "engaging in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the listed species in the wild by reducing the reproduction, numbers, or distribution of that species."

2.0 CHRONOLOGY OF EVENTS LEADING UP TO THIS ASSESSMENT:

In September 1995 the Philadelphia District initiated formal consultation under Section 7 of the Endangered Species Act of 1977 (16 U.S. C. 1531 et seq.), with regard to maintenance dredging of Delaware River Federal Navigation Projects from Trenton to the Sea, and potential impacts to the Federally endangered shortnose sturgeon. "A Biological Assessment of Federally Listed Threatened and Endangered Species of Sea Turtles, Whales, and the Shortnose Sturgeon within Philadelphia District Boundaries: Potential Impacts of Dredging Activities" was forwarded to NMFS for their review.

It was determined by the Corps that maintenance dredging activities in the southern reaches of the Delaware River, specifically from Philadelphia to the Sea, were not of concern with respect to impacting shortnose sturgeon. The area, between Philadelphia and Wilmington, was considered the "pollution zone" and was only utilized as a migratory route by adults during the early spring and late fall. This area is no longer considered a pollution zone and may be utilized by shortnose sturgeons (Green, 2000). South of Wilmington the shortnose sturgeon population is limited to adults due to increased salinity.

The Corps has followed certain recommended dredging windows established by the Delaware River Basin Fish and Wildlife Management Cooperative (Cooperative), and has conducted informal consultation for maintenance dredging activities. The Cooperatives' Fisheries Technical Committee (FTC) decided to implement the following restrictions as part of the Cooperatives Dredging Policy effective as of April 1997:

Hydraulic dredging, is prohibited from the Delaware Memorial Bridge to the Kinkora Range in non-Federal areas between April 15th and June 21st. No hydraulic dredging restrictions exist for the Federal channel or anchorages.

Overboard disposal and blasting are prohibited from the Delaware Memorial Bridge to the Betsy Ross bridge in all areas between March 15th and November 30. Bucket dredging is prohibited from March 15 to May 31 from the Delaware Memorial Bridge to the Kinkora Range. In all areas in the Delaware Bay to the Delaware Memorial Bridge, turtle monitors are required from June 1 to November 30 on hopper dredges.

A Biological Opinion was issued by the NMFS on November 26, 1996 (Montanio, 1996) for all dredging projects permitted, funded, or conducted by the District. The Opinion stated that dredging projects within the Philadelphia District may adversely affect sea turtles and shortnose sturgeon, but are not likely to jeopardize the continued existence of any threatened or endangered species under the jurisdiction of the NMFS. For projects within the Philadelphia District, the anticipated incidental take by injury or mortality is three (3) shortnose sturgeon.

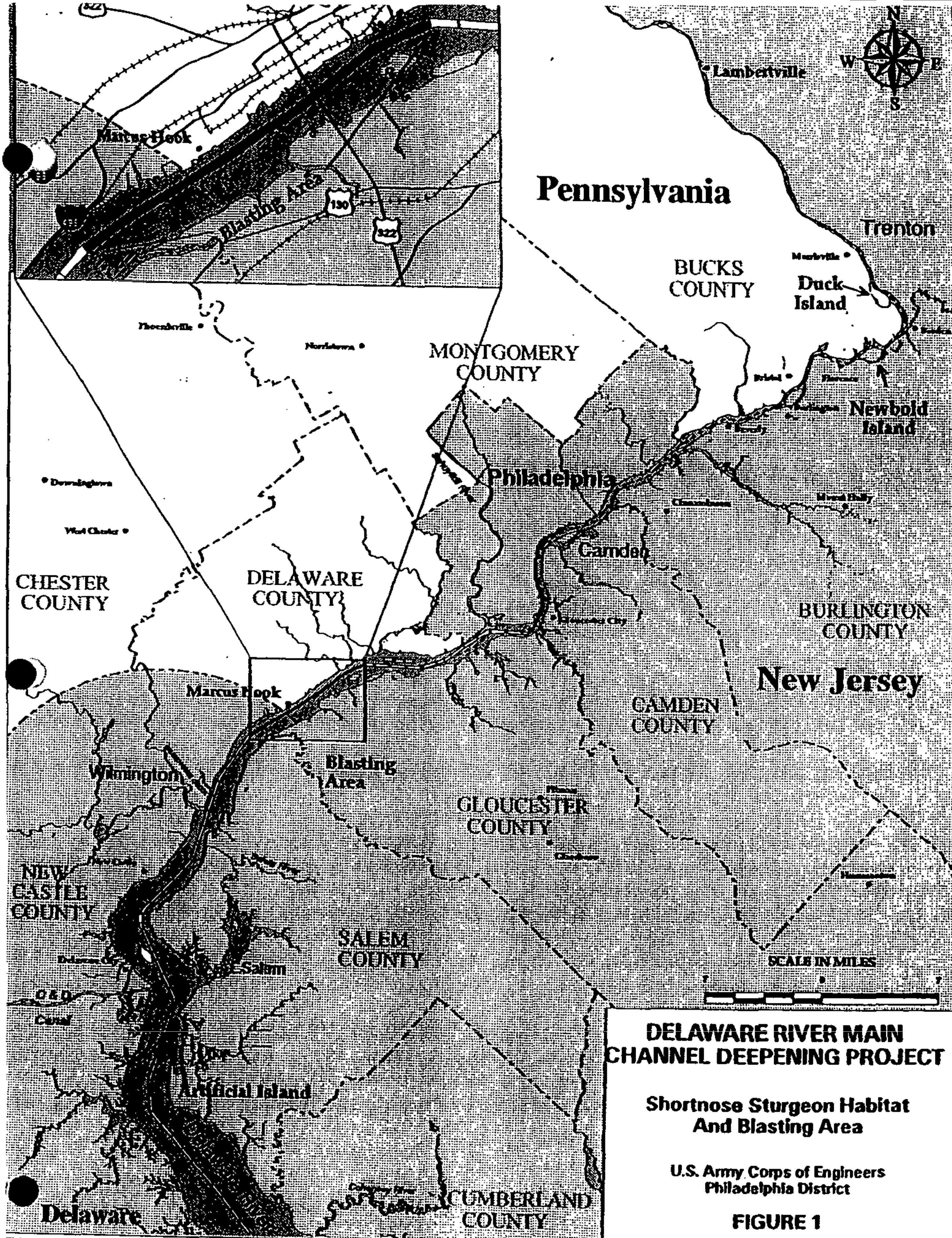
In letters dated 14 February 1997 and 29 December 1997, the United States Department of Commerce, the parent agency of the National Marine Fisheries Service (NMFS) stated that the Biological Opinion issued by the NMFS does not cover blasting. They further stated that sea turtles and marine mammals are not likely to be found in the Marcus Hook area where blasting will occur, but shortnose sturgeon may be found in the area. This is due in part to the fact that the Chester – Philadelphia "pollution zone no longer exists (Fruchter, 1997). They requested that the Corps continue to coordinate with the NMFS to ensure compliance with the requirements of the Endangered Species Act. This environmental assessment is in response to that request.

3.0 PROJECT DESCRIPTION AND LOCATION.

Approximately 70,000 cubic yards of bedrock from the Delaware River, covering 18 acres near Marcus Hook, Pennsylvania (River Mile 76.4 to River Mile 84.6) (see figure 1), would be removed to deepen the navigation channel to a depth of 47-ft mean low water. Blasting operations would occur up to five days a week between 1 December and 15 March, but the actual blasting would only occur for a brief period each day (Philadelphia District, 1997).

4.0 BIOLOGY DISTRIBUTION AND STATUS RELATED TO THE PROJECT.

4.1 Population Information: Shortnose sturgeon occur in the Delaware Estuary from the lower bay upstream to at least Lambertville, New Jersey (River Mile 148). Preliminary population estimates by Hastings (1987) indicate that the adult population of shortnose sturgeon in the upper tidal Delaware River is between 6,000 and 14,000


Marcus Hook
Blasting Area
130
322
Pennsylvania
Lambertville
Trenton
BUCKS COUNTY
Duck Island
MONTGOMERY COUNTY
Newbold Island
Philadelphia
Camden
CHESTER COUNTY
DELAWARE COUNTY
BURLINGTON COUNTY
New Jersey
Marcus Hook
CAMDEN COUNTY
Blasting Area
Wilmington
GLOUCESTER COUNTY
NEW CASTLE COUNTY
SALEM COUNTY
Salem
SCALE IN MILES
C&D Canal
Artificial Island
Delaware
CUMBERLAND COUNTY
DELAWARE RIVER MAIN CHANNEL DEEPENING PROJECT
Shortnose Sturgeon Habitat And Blasting Area
U.S. Army Corps of Engineers Philadelphia District
FIGURE 1

individuals. A draft recovery plan estimates the Delaware River population at 6,408 (adults only) (NMFS, 1996).

Tagging studies done by O'Herron et al. (1993) show that the most heavily used portion of the river appears to be between river mile 118 below Burlington Island and the Trenton Rapids at river mile 137.

Sturgeon overwinter from November to March in dense sedentary aggregations in the upper tidal reaches of the Delaware between river mile 118 and river mile 131, especially near Duck Island and Newbold Island. However, as opposed to shortnose sturgeon in Maine rivers, Delaware River shortnose sturgeon do not appear to remain as stationary during overwintering periods. Therefore, their use of the river is difficult to predict. Refer to figure 1 for the locations of important shortnose sturgeon habitat.

Spawning occurs in late March through April, between Trenton and at least the Scudders Falls area. During this period, males appear to stay on the spawning grounds for a longer time than do the females, a week or so as opposed to a few days, respectively (O'Herron and Hastings, 1985). In late spring and early summer, after spawning, shortnose sturgeon move rapidly downstream at least as far as Philadelphia. Additional information shows that improving water quality in the Philadelphia area has resulted in increase use of the lower river by shortnose sturgeon. Historically, they were rare in this area, possibly due to poor water quality. Many adult shortnose sturgeon return upriver to between river mile 127 and 134 within a few weeks, while others gradually move to the same area over the course of the summer (O'Herron, 1993). By November, adult shortnose sturgeon have returned to the overwintering grounds near Duck Island and Newbold Island.

Little is known about the movements of larvae and young-of-year shortnose sturgeon in the Delaware River, and nursery habitat has not been identified (Montanio, 1996; O'Herron, 2000). However Dadswell reports (1984) that post spawning adults and juvenile young of the year in other river systems move downstream to tidal areas and concentrate at, or just upstream of, the salt front during the summer months (June through August). The summer concentration zone in Winyah Bay estuary in South Carolina corresponds to the area with a salinity of 0.5 to1.0 ppt. Here the juveniles spend the next 2 to 8 years of life, moving up and down stream with the movements of the salt wedge until they reach a size of approximately 45 centimeters. O'Herron (2000) believes that the juveniles could range between Artificial Island (river mile 54) and the Schuylkill River (river mile 92) with the juveniles being closer to the downstream boundary during the winter when river freshwater input is normally greater.

4.2 Foraging: According to Dadswell (1984), shortnose sturgeon appear to be strictly benthic feeders. Adults eat mollusks, insects, crustaceans and small fish. Juveniles eat crustaceans and insects. In the Delaware River, Asiatic river clam (*Corbicula manilensis*) is considered to be the primary food source for the shortnose sturgeon (O'Herron and Hastings, 1985). *Corbicula* is widely distributed at all depths in the upper tidal Delaware River, although it is considerably more numerous in the shallows on both sides of the river than in the navigation channels.

Feeding in freshwater is largely confined to periods when water temperatures exceed 10 degrees C (Dadswell, 1979 and Marchette and Smiley, 1982). In general, feeding is heavy immediately after spawning in the spring and during the summer and fall, and lighter in the winter.

Juveniles feed primarily in 10 to 20 m deep river channels, over sandy-mud or gravel-mud bottoms (Pottle and Dadswell 1979). However, little is known about the specific feeding habits of juvenile shortnose sturgeon in the Delaware River because attempts to locate them in the upper tidal river have been unsuccessful (NMFS, 1996).

4.3 Overwintering: In the Delaware River, shortnose sturgeon form dense overwintering aggregates between river mile 118 and 131, especially in the Duck Island and Newbold Island area. One was found in the winter of 1985-1986 off Duck Island on the New Jersey side of the channel (O'Herron and Able, 1986). Tagging studies by Brundage (1986) also support this finding. According to O'Herron's study, the overwintering fish were generally active, appearing at the surface and even breaching through the skim ice. Tagging studies by O'Herron et al. (1993) found that the typical overwintering movements of the shortnose sturgeon are fairly localized. Based upon sonic survey data, they appear to remain within 1.24 river miles of the aggregation site (O'Herron and Able, 1986). This data applies to adult shortnose sturgeon; the location of the juvenile shortnose sturgeon is not known, but is believed to be on the fresh side of the oligohaline/fresh water interface (0.5 ppt) (O'Herron, 2000).

5.0 ASSESSMENT OF POTENTIAL IMPACTS

Blasting could impact the shortnose sturgeon in two ways: physical injury or mortality to individual fish, and damage to habitat.

5.1 Physical Injury

Several studies have demonstrated that underwater blasting can cause fish mortality (Teleki and Chamberlain 1978, Wiley et al. 1981, and Burton 1994). These studies have shown that size of charge and distance from detonation are the two most important factors in determining fish mortality from blasting. Depth of water, type of substrate, and the size and species of fish present also affect the number of fish killed by underwater explosions.

Teleki and Chamberlain (1978) conducted blasting mortality experiments in Long Point Bay, Lake Erie, at depths of 4 to 8 m. Fish were killed in radii ranging from 20 to 50 m for 22.7-kg charges and from 45 to 110 m for 272-kg charges during 28 monitored blasts. Explosives were packed into holes bored into the lake bottom. The kind of substrate determined the decay rate of the pressure wave, and mortality differed by species at identical pressure. Teleki and Chamberlain (1978) presented their results for several species in terms of 10% and 95% mortality radii (i.e., radii at which 10% and 95% of the caged fish were killed).

Wiley et al. (1981) measured the movement of fish swim bladders to estimate blast mortality for fish held in cages at varying depths during midwater detonations of 32-kg explosives in the Chesapeake Bay. Pressure gages were placed in cages that contained spot (*Leiostomus xanthurus)* and white perch (*Morone americana*). The study was conducted at the mouth of the Patuxent River in depths of about 46 m. Using data collected during 16 blasts, Wiley and colleagues predicted the distances at which 10%, 50%, and 90% mortality of white perch occurred. For 32-kg charges, the pressure wave was propagated horizontally most strongly at the depth at which the explosion occurred.

Burton (1994) conducted experiments on the Delaware River to estimate the effects of blasting to remove approximately 1,600 cubic yards of bedrock during construction of a gas pipeline. Charges of 112 and 957 kg of explosives were detonated in the river bed near Easton, Pennsylvania, during July 1993 in depths ranging between 0.5 and 2.0 m. Smallmouth bass (*Micropterus dolomieui)* were caged at a range of distances from the blasts. In the larger of the two blasts all fish in cages positioned farther than 24 meters (78 feet) from the blast survived

In Wilmington Harbor, Wilmington, North Carolina, studies were done to determine the impacts of blasting on shortnose sturgeon (Wilmington District, 2000). To determine the impacts of blasting on shortnose sturgeon and size of the LD1area (the lethal distance from the blast where 1 % of the fish died), test blasting was performed in Wilmington Harbor in the fall/winter of 1998/99. During test blasting, 50 hatchery reared shortnose sturgeon were placed in cages (2 feet diameter by 3 feet long plastic cylinders) 3 feet from the bottom (worst case survival scenario for blast pressure as confirmed by test blast pressure results) at 35, 70, 140, 280 and 560 feet up and downstream of the blast. Also, 200 caged sturgeon were held at a control location about 1/2mile from the blast location. The caged fish had a mean weight of 55 grams and were young of the year fish. Sturgeon cages were enclosed in a 0.6 inch nylon mesh sock to prevent any sturgeon from escaping if the cage was damaged. This was necessary for preservation of the genetic integrity of the resident fish population since the hatchery reared shortnose sturgeon were not the same subspecies as the shortnose sturgeon in the Cape Fear River. Stemming and an approximate 25 msec delay between holes were used with 52-62 pounds of explosives per hole. Stemming is the use of a selected material, usually angular gravel or crushed stone, to fill a drill hole above the explosive. Stemming is commonly used to contain the explosive force and increase the amount of work done on the surrounding strata. Large explosive charges can be broken into a series of smaller charges by use of timing delays (Keevin and Hempen, 1997).

There were 3 test blasts with an air curtain in operation and 4 without an air curtain in operation. An air curtain is a stream of air bubbles created by a manifold system on the river bottom surrounding the blast. In theory, when the blast occurs the air bubbles are compressed, and the blast pressure is reduced outside the air curtain. The air curtain when tested, was 50 feet from the blast.

The caged fish were visually inspected for survival just after the blast and after a 24hour holding period. The survival pattern just after the blast and after the 24 hour holding period were similar. Survival at the monitoring locations 140 feet and beyond just after the blast (with or without air curtain) was not significantly different. This 140 foot distance equals 2.1 acres and would be the edge of the LD1. Necropsies performed on the sturgeon also indicate that the impact area would not exceed 2.1 acres (Moser, 1999). A blast in the rock was calculated to be 0.014 of a blast in open water. In other words a 52 to 62 pound blast in rock is equivalent to a 0.73 to 0.87 pound blast in open water (Wilmington District, 2000).

5.2 Habitat.

Tagging studies done by O'Herron et al. (1993) show that the most heavily used portion of the river appears to be between river mile 118 below Burlington Island and the Trenton Rapids at river mile 137, which is about 33 river miles above the blasting project which is located below river mile 84.6. Spawning habitat has been located above Trenton, New Jersey (O'Herron and Hastings, 1985), about river mile 131. This is over 46 river miles above the blasting and should not be impacted. Overwintering concentrations of adult shortnose sturgeon have been found between river mile 118 and 131 (NMFS, 1996) which is also over 33 river miles from the blasting site which is located below river mile 84.6.

Shortnose sturgeon generally feed when the water temperature is greater than 10° C (Dadswell, 1979 and Marchette and Smiley, 1982) and in general, feeding is heavy immediately after spawning in the spring and during the summer and fall, and lighter in the winter (NMFS, 1996). Since this project is planned for the winter months, there should be no impact on sturgeon foraging. The Asiatic river clam (*Corbicula manilensis, or Corbicula fluminea*) is considered to be the primary food source for the shortnose sturgeon (O'Herron and Hastings, 1985). Fine clean sand, clay, and coarse sand are preferred substrates for this clam, although this species may be found in lower numbers on most any substrate (Gottfried, and Osborne, 1982; Belanger et al., 1985; Blalock and Herod, 1999). Gottfried and Osborne (1982) reported density as lowest on bottoms composed of silty organic sediments. Since the substrate is primarily rock, it is not considered prime habitat for the Asiatic clam; however, Scott (1992) found high numbers (2596.14 per square meter) of *Corbicula* below Conowingo Dam on gravel and bedrock substrates in the Susquehanna River. The high densities may be the result of the high oxygen concentrations immediately below the dam. Much lower concentration (512 clams per square meter) were found in Florida in its preferred sand habitat (Blalock, H.N., and J.J. Herod. 1999). Any benthic organisms that occur on the rock that is removed by blasting would be destroyed. The impact should not extend beyond the area of immediate impact since previous studies indicate that invertebrates are insensitive to pressure related damage from underwater explosions, which may be due to the fact that all the invertebrate species tested lack gas-containing organs which have been implicated in internal damage and mortality in vertebrates (Keevin and Hempen, 1997). Although there is no known information about invertebrate recovery time after blasting, data from other disturbances indicates that the benthic communities should become reestablished on the underlying rock within 2 years or less (New York District, 1999). It is unlikely that the blasting of rock to deepen the navigation channel will have a significant impact on the food source of shortnose sturgeons since the fish do light foraging during the time period when blasting would occur (winter) and since *Corbicula,* their favorite food source, is wide spread in the fresh water portion of the Delaware Estuary in more preferred habitats.

5.3 Juvenile Shortnose Sturgeon.

Very little data exists about the location of juvenile shortnose sturgeon. In other river systems, they are found upstream of the salt water – freshwater boundary (0.5 to 1.0 ppt) (Dadswell, et al., 1984). In the Delaware River, the location of the juvenile shortnose sturgeon is not known, but is believed to be on the fresh side of the oligohaline/fresh water interface (0.5 ppt). During the year, juvenile sturgeon could be found between Artificial Island (rm 54) and the Schuykill River (rm 92) (O'Herron, 2000). The locations of selected isohalines were modeled for monthly average inflows and for regulated drought conditions from August to November (Philadelphia District, 1997). The average location of the maximum intrusion of the 0.5 ppt isohaline during monthly average infows for November was river mile 73.9 under current dredging and at river mile 88.9 during regulated drought conditions. Although no information is available, the 0.5 ppt isohaline would likely be downstream of the November location during December through March since larger freshwater inflows enter the river during this period. Nevertheless, it is possible that juvenile shortnose sturgeon could be present in the vicinity of the blasting and could be impacted.

6.0 ALTERNATIVES CONSIDERED

A number of alternatives were evaluated by the Philadelphia District using economic, engineering and environmental criteria and are discussed in detail in the *Final Interim Feasibility Report and Environmental Impact Statement* (Philadelphia District, 1992).

7.0 REASONABLE AND PRUDENT MEASURES TO MINIMIZE IMPACTS:

Information presented above indicates that there may be a potential impact to overwintering juvenile shortnose sturgeon from rock blasting performed between 1 December and 15 March, although the location of juveniles is not known. The measures listed below focus on preventing physical injury to juveniles that may be near the blasting area, but would likely protect the larger adult fish if any were present since there is evidence that smaller fish are more vulnerable to injury than larger fish (Philadelphia District, 1997). Studies have shown that size of charge and distance from detonation are the two most important factors in determining fish mortality from blasting (Teleki and Chamberlain 1978, Wiley et al. 1981, and Burton 1994). In addition, the measures listed below were used in North Carolina to successfully minimize impacts to shortnose sturgeon:

- Before each blast, four (4) sinking gillnets (5.5 inch mesh, 100 meters long) will be set to surround the blast area as near as feasible. These nets will be in place for at least 3 hours and none of the nets will be removed any sooner than 1 hour before the blast. This may require overnight sets. Any sturgeon removed (shortnose or Atlantic) will be released at a location approved by the National Marine Fisheries Service.

- Channel nets will be set downcurrent of the blast area within 10 minutes of blast discharge in order to capture and document dead or injured fish.

- Scare charges will be used for each blast. A scare charge is a small charge of explosives detonated immediately prior to a blast for the purpose of scaring aquatic organisms away from the location of an impending blast Two scare charges will be used for each blast. The detonation of the first scare charge will be at 45 seconds prior to the blast, with the second scare charge detonated 30 seconds prior to the blast. Some marine mammals and fish may not locate the origin of the first scare charge. The second scare charge allows these creatures to better locate the source of the charge and maneuver away from the source.

- Blast pressures will be monitored and upper limits will be imposed on each series of 5 blasts.

- Average pressure shall not exceed 70 pounds per square inch (psi) at a distance of 140 feet.

- Maximum peak pressure shall not exceed 120 psi at a distance of 140 feet.

- Pressure will be monitored for each blast only at a distance of 140 feet.

- Surveillance for schools of fish will be conducted by vessels with sonar fish finders for a period of 20 minutes before each blast, and if fish schools are detected, blasting will be delayed until they leave. The surveillance zone will be approximately circular with a radius of about 500 feet extending outward from each blast set.

8.0 CONCLUSIONS

There should be no significant impacts to shortnose sturgeon provided the measures listed above are implemented.

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Movements of Shortnose Sturgeon (*Acipenser brevirostrum*) in the Delaware River

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ABSTRACT: Data from sonic tracking during the period 1983–1987 enabled us to define the areas used and the seasonal pattern of movement by adult shortnose sturgeon (*Acipenser brevirostrum*) in the Delaware River. Tagged adults (n = 28) ranged from 544 mm to 871 mm fork length and 1,510 g to 7,125 g. Twenty-six tags were carried for 7–225 d. Most of the tagged sturgeon were relocated in the tidal portion of the river. Sturgeon that overwintered in the upper tidal river near Trenton, New Jersey, began traveling upstream in late March to the nontidal river above Trenton where spawning presumably occurred from late March through April. After spawning, sturgeon traveled rapidly downstream into the tidal portion of the river near Philadelphia, Pennsylvania, where they remained through the end of May. Before the end of June, most sturgeon returned upstream and re-entered the upper tidal river near Trenton, where most apparently remained for the summer and winter. In general, the same pattern was apparent for both sexes. As a result of the intensive use of the river between Philadelphia to just above Trenton, any alterations or additional insults to the river should consider the impact on this endangered species.

Introduction

Shortnose sturgeon, *Acipenser brevirostrum*, have been reported from the Delaware River for over 170 yr. The species was originally described from Delaware River specimens by LeSueur (1818). He particularly noted the desirability of shortnose sturgeon and their occurrence in the spring at the Philadelphia market. Unfortunately, much of the limited pre-1980s literature on Delaware River shortnose sturgeon is lacking in detail and, in some instances, is contradictory. Brundage and Meadows (1982) compiled all the available capture records for the period 1817–1979 and discussed the distribution of shortnose sturgeon in the Delaware River. Hoff (1965) documented the capture of two ripe female shortnose sturgeon in the lower nontidal river. More recently, Hastings et al. (1987) described the occurrence, distribution, and abundance of shortnose sturgeon between Trenton and Philadelphia. We were prompted to continue these studies because we wanted to determine which habitats of the Delaware River were important for spawning and overwintering of this endangered species.

Materials and Methods

Study Area

The study area extended from just above Stockton, New Jersey, downstream to just below Philadelphia, Pennsylvania (Fig. 1). The river is nontidal above the fall line (Trenton Rapids) at Trenton, New Jersey, and is characterized by pools, riffles, and rapids. The width varies from 160 m to 400 m and depth from 0.6 m to 3.0 m (Anonymous 1979). The substrate is composed primarily of sand, gravel, and cobbles, but soft sediments are found in areas of weak current. Water flow and velocity in the nontidal portion of the river are related

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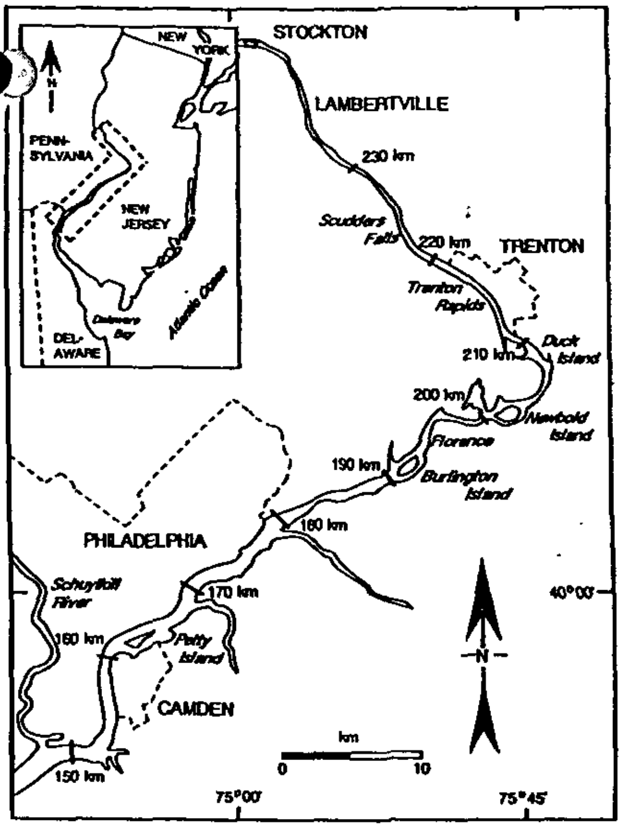

Fig. 1. Map of the Delaware River study area with important localities mentioned in the text.

generally to season (power plants and major reservoirs interfere with the natural relationship), with the highest levels usually occurring during March–April (Bauersfeld et al. 1983). In the tidal portion of the river, variations in freshwater input, tidal stage and amplitude, and regional meteorological conditions may displace the freshwater-oligohaline boundary (Anonymous 1980), bringing oligohaline waters into the vicinity of Philadelphia. Tidal amplitude is normally about 1.9 m, but maximum tidal amplitudes may reach 4.2 m (Hastings 1983). Channel depths range from 5 m to 20 m and river width ranges from 270 m at Trenton to 1,750 m just below Philadelphia (Hastings et al. 1987). The surrounding landscape is highly urbanized and heavily industrialized to the edge of the water. The tidal portion of the river is extensively used by ship, barge, and tugboat traffic. Water quality is subject to industrial and sewage effluents, which create a serious decline in dissolved oxygen levels in the Philadelphia area during the summer months (Tyrawski 1979).

Tagging

Shortnose sturgeon were captured with gill nets either set or drifted on the bottom. Set gill nets were 30–100 m long and 1.8–3.0 m deep of 2.5–20.3 cm stretched mesh. Drift gill nets were usually 30–50 m long and 1.8 m deep of 12.7 cm, 15.2 cm, or 17.8 cm stretched mesh. Captured individuals (Table 1) were measured, tagged with T-tags, and handled in a manner identical to that described by Hastings et al. (1987). Males were identified by the external presence of milt after pressure on the body cavity and females by the darkly colored ova visible through the ventral abdominal wall (Dadswell 1979). Twenty-eight shortnose sturgeon were tagged with an ultrasonic transmitter which was mounted with stainless-steel wire on the two most suitable of the first five predorsal scutes. Selection of sturgeon to be tagged was biased for individuals with well-developed predorsal scutes and known sex, where possible. Transmitters (Custom Telemetry & Consulting, Inc., Smith-Root Incorporated, and Sonotronics, Inc.) were individually pulsed or coded for discrete identification at nominal frequencies of 32 kHz, 36 kHz, 74 kHz, or 75 kHz with a working life of 12 months or more. Nominal transmission ranges were 1,000 m for standard power transmitters and 1,500–3,000 m for high power transmitters. Transmitters weighed 0.86–4.66% of a respective sturgeon's weight in air. Surveys were conducted 1–21 times a month between Scudders Falls (rkm 225) to the lower Philadelphia area (rkm 150) (Fig. 1). Occasional random surveys were conducted between rkm 110 and rkm 285. Signals were detected with a Smith-Root TA-25 or TA-60 receiver and matching hand-held hydrophone. The first ten transmitters released were of standard power and their relocation was very difficult because of the limited signal range and ambient conditions within the river (high noise levels and signal scattering by particulates). Higher power transmitters, attached after May 1984, were reliably relocated regardless of ambient conditions. Failing tags were detected by increases or decreases in output and breakdown in pulse interval or code. Movement of such tags between relocation dates indicated that they were still being actively carried. Detached tags were detected by no change in position over time and a gradual attenuation of the signal between relocation dates. Temperature and depth were measured at all relocation sites.

Results

Spatial and Temporal Distribution

The 28 shortnose sturgeon tagged with ultrasonic transmitters (sonic tags) between November 1983 and March 1987 (Table 1) ranged from 544 mm to 871 mm fork length ($\bar{x}$ = 750.0 mm FL) and from 1,510 g to 7,125 g ($\bar{x}$ = 4,000.2 g). Two of the 28 were never relocated. Thus, 26 sonic tags

TABLE 1. Summary of data for ultrasonically tagged shortnose sturgeon in the Delaware River, November 1983–June 1987.

Signal	Release Date	Number Days Tracked	Times Relocated
75-2	February 24, 1984	101	1
75-3	February 24, 1984	184	8
75-4	May 24, 1984	33	4
75-5	November 14, 1983	225	10
75-6	November 17, 1983	200	14
75-7	November 14, 1983	137	7
75-8	November 17, 1983	137	6
75-10	February 28, 1984	35	2
75-11	February 28, 1984	97	7
01135	May 24, 1984	33	3
01136	May 24, 1984	29	4
01137	May 24, 1984	48	7
12 p/m	May 30, 1985	7	3
2114	June 18, 1985	17	4
2123	June 18, 1985	17	5
2124	August 9, 1985	28	8
2135	August 28, 1985	21	10
2136	October 29, 1985	47	12
25 p/m*	December 31, 1985	65	24
32 p/m	December 31, 1985	63	21
2228	February 19, 1986	128	21
2237	March 25, 1986	90	19
2246	April 5, 1986	83	18
2255	April 2, 1986	61	8
2264	May 15, 1986	55	19
23 p/m	February 20, 1987	117	35
22 p/m	March 24, 1987	58	17

* Previous signal 12 p/m.

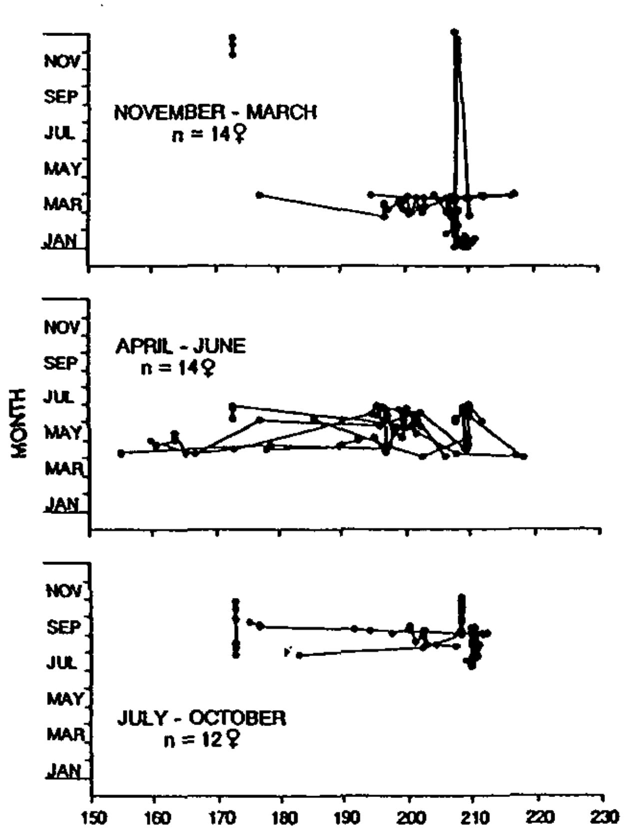

Fig. 2. Movements of sonically tagged female shortnose sturgeon in the Delaware River during November 1983–June 1987.

were carried for 7–225 d ($\bar{x} = 78.4$ d) and relocated 1–35 times ($\bar{x} = 11.0$ times). Tagged sturgeon were relocated throughout the study region (Figs. 2 and 3). Sturgeon were relocated 286 times in the tidal river and 15 times in the nontidal river. Fish were relocated within, or at comparable depths to, the navigation channel of the tidal river 94.8% of the time, but seldom (4.2%) relocated in the shallows (<3.05 m mean low water) and rarely (1.0%) found in depths intermediate to the shallows and navigation channel depths. The location and movement of females, males, and those of undetermined sex appeared to be similar during all seasons (Figs. 2 and 3). Many of those of unknown sex were likely males based on the generally smaller size and slimmer shape.

The location and movement of individuals varied with season. During November to late March, 14 shortnose sturgeon were sonically tagged and released. Eleven of these were relocated during November to late March and were found only between river km 200 and river km 210, particularly in the area of Duck and Newbold islands (Fig. 1). Typical overwintering movements were localized, and individual signals were relocated within 0.6–9.6 km ($\bar{x} = 4.6$ km). No known males were tagged during November to late March; however, their wintertime behavior is likely very similar to that of known females (Figs. 2 and 3). Evidence for this is based on similar movement patterns of the unsexed individuals (n = 7) as well as the occurrence of males along with females during wintertime captures with gill nets (O'Herron and Able unpublished data).

The movements of shortnose sturgeon during the spawning to post-spawning period (April–June) were quite dynamic (Figs. 2 and 3). A total of 19 sonically tagged sturgeon were relocated from late March through June. Nine of these were from tagging efforts in the previous winter. Many tagged sturgeon became active in mid-to-late March and most moved upstream to approximately river km 220 from overwintering sites between river km 190 and river km 210. During the same period, some fish remained in the overwintering area. We were able to relocate five signals in the tidal river, individuals which had come upstream at least to within 3.0 km of the head of the tide (approximately river km 215) in the end of March and the first week in April. At that time, a period of flooding and increased currents in 1987, one of these in-

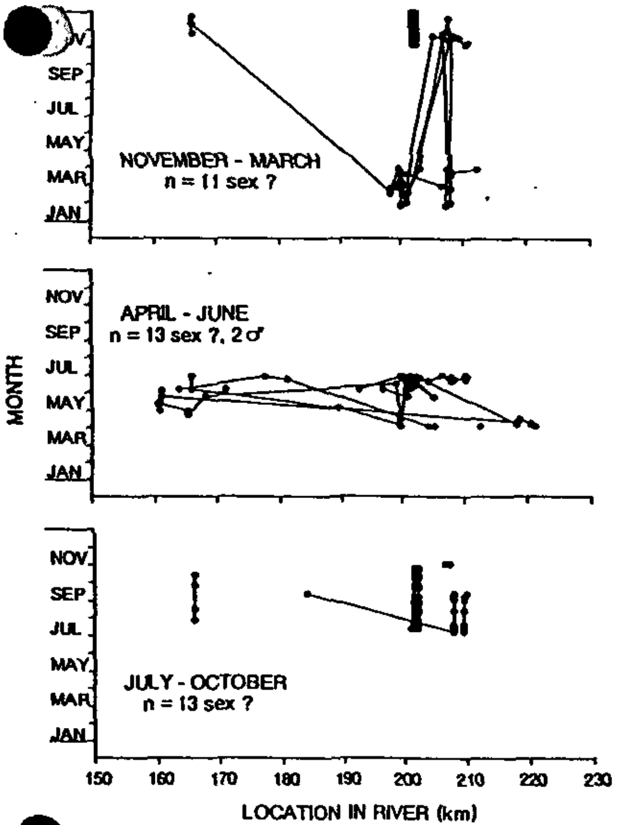

Fig. 3. Movement of sonically tagged shortnose sturgeon of unknown sex and males in the Delaware River during November 1985–June 1987.

dividuals was found among large submerged boulders and dense stands of inundated willow (*Salix* sp.) just downstream of Scudders Falls (Fig. 1). This female and another sonically tagged female were known to be present in this same general area of the nontidal river for 1–2 d in 1986 and 5–9 d in 1987, respectively. At the same approximate time of the year in 1986, two ripe male sturgeon were sonically tagged and released between Scudders Falls and Trenton (Fig. 1). Both of these sturgeon were visually observed days later in open riffles in the same area along with other shortnose sturgeon. These males were known to be present in this area for 5–8 d and 12–17 d, respectively. Movement, during the period that we interpret as postspawning, from the nontidal river to tidal areas downstream was rapid as indicated by the horizontal tracks of individuals (Figs. 2 and 3). There appeared to be no differences in the postspawning movements of females and males. Eight of the ten fish present between river km 190 and river km 220 during late March to April exhibited this downstream movement into the Philadelphia area (rkm 170).

During the summer period (July–October), shortnose sturgeon demonstrated both localized and long-distance movements. The localized movement pattern was apparent for four individuals (two females and two undetermined sex), which were relocated 1.1–9.3 km ($\bar{x}$ = 6.2 km) from their point of capture and release between rkm 195–215. These tags were functional for 17–55 d ($\bar{x}$ = 29.2 d). The sturgeon that covered the shortest distance carried its tag the longest time. Each of the two observed long-distance movements were singular in pattern. One female (signal 75-3) was present above Florence in June but relocated in the upper Philadelphia area at the end of July. Over the course of the next month this fish traveled upstream and lost the sonic tag in the upper Duck Island area. The other, a large gravid female (signal 2135), was sonically tagged on August 28, 1985, and immediately traveled directly from Trenton into the central Philadelphia area (37.3 km), where the tag malfunctioned and the fish was lost.

We have little information on the movements of sturgeon from late summer and early winter. One exception, a sturgeon of indeterminate sex, was tagged and released in the Duck Island area and ranged through an area of 4.0 km during the next 47 d. After mid-November, the range decreased to 1.7 km over 32 d before the tag was dropped within 300 m of its original release position.

Discussion

Delaware River shortnose sturgeon utilize the river from at least Lambertville into the Philadelphia area (Dadswell et al. 1984; O'Herron and Able unpublished data). The most heavily utilized portion of the river appears to be between river km 190 and river km 220. Gill net captures from 1981 to 1984 (Hastings et al. 1987) consistently found the greatest numbers of shortnose sturgeon within that area. Hastings et al. (1987) did not concretely document the presence of overwintering aggregations, but we now know that the channel area immediately off Duck Island (Fig. 1) is an important overwintering site. Other portions of the river appear to be used for shorter durations. In the spring (late March and April), shortnose sturgeon were collected with gill nets (O'Herron and Able unpublished data) and large numbers were observed between Scudders Falls and the Trenton Rapids. The gill net captures in this area documented the presence of many males with milt. Sonically tagged gravid females were observed to move out of the tidal river and upstream into these sites during the same times when mature males were captured. Although we have not documented actual spawning in this area, the concentrated use of the Scudders Falls - Trenton Rapids region in the spring by large numbers of mature male and female shortnose sturgeon indicate that this is a major spawning area. This same area was identified as a likely spawning area based on the collection of two ripe females (Hoff 1965).

The river below river km 190 is used, primarily in early spring and summer, after spawning has occurred (Figs. 2 and 3). Shortnose sturgeon move at least as far as Philadelphia and then move back upstream. These shorter duration movements explain the differences in distribution pattern observed based on gill net sampling (Hastings et al. 1987) versus sonic tracking. For the former, the available data suggest almost exclusive use of the area between river km 190 and river km 220. However, the sonic tracking demonstrated convincingly that shortnose sturgeon often moved from nontidal areas of the river above Trenton to near Philadelphia.

The data allow description of a generalized movement pattern (Fig. 4) from which seasonal movements can be reliably predicted. In brief, Delaware River shortnose sturgeon overwinter in dense, sedentary aggregations between river km 190 and river km 210, especially in the vicinity of Duck Island. In late March through April, spawning aggregations are found primarily between Scudders Falls and Trenton Rapids. Males appear to remain in the spawning area for longer periods, while females are present for a relatively short duration. Postspawning males and females move rapidly downstream into the Philadelphia area during April–May. Many of these return upriver to between river km 205 and river km 215 within a few weeks, while the others gradually move to the same area over the course of the summer. By November a substantial overwintering aggregation has formed once again in the vicinity of Duck Island. These patterns are generally supported by the movement of radio-tracked shortnose sturgeon in the region between river km 201 and river km 238 as presented by Brundage (1986). Few shortnose sturgeon have been taken below our study area. Less than 20 have ever been collected south of the Philadelphia area (Brundage and Meadows 1982; Dadswell et al. 1984). Thus it is likely that the area above Philadelphia is of primary importance to the Delaware River population. Any alteration to this portion of the river should consider its importance to this endangered species.

The movements of the Delaware River population are similar to other populations in many characteristics. Other populations, or portions of populations, migrate upstream in the fall to overwintering areas near the spawning area, although not all adults move at this time and not all participate in spawning (see Dadswell et al. 1984 for review). As elsewhere, spawning occurs in the spring in freshwater nontidal portions of the river where river velocities are high (Dadswell et al. 1984; Hall et al. 1991). After spawning the fish move rapidly downstream into or near the limits of salt water intrusion (Dadswell et al. 1984; Hall et al. 1991).

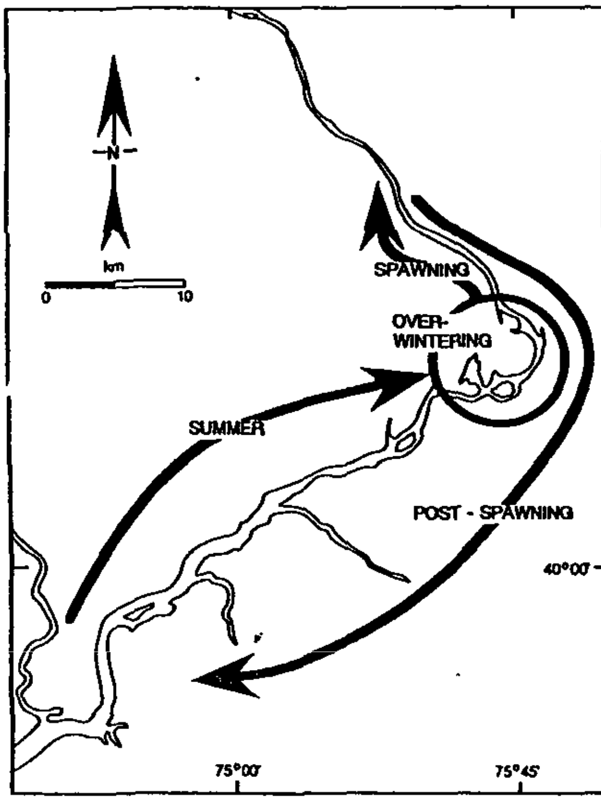

Fig. 4. Generalized movement pattern of shortnose sturgeon in the Delaware River.

The Delaware River population apparently overwinters in one relatively distinct area in fresh water, whereas others may overwinter in the estuary (Dadswell et al. 1984). There is no evidence that this population moves into the region of the freshwater-saltwater interface during the summer, and little evidence that they use the higher salinity portions of the Delaware River estuary or Delaware Bay as do populations in other systems (McCleave et al. 1977; Dadswell 1979). The movement patterns appear to be relatively simple, but Buckley and Kynard (1985), using telemetry to track the shortnose sturgeon in the lower Connecticut River, have found underlying complex patterns that they could relate to sex and reproductive condition. Our recapture and tracking data demonstrate residency within and consistent returns to the uppermost tidal portion of the river regardless of sex and reproductive condition.

Acknowledgments

This study is the product of many "hands" whom we acknowledge most appreciatively. K. Schick and M. Lazzari assisted with much of the sampling. Financial support was provided by the United States Department of the Interior (contract no. AFS-10-R-3), and the United States Army Corps of Engineers (contract nos. DACW-61-81-C-0138 and DACW-61-84-C-0007). M. Dadswell provided helpful comments on an earlier draft. The Rutgers University Research Council, Institute of Marine and Coastal Sciences and the American Littoral Society provided support. The Yapewi Aquatic Club, Bordentown, New Jersey, extended the courtesy of river access, storage, and assistance. This is Institute of Marine and Coastal Sciences Contribution No. 92-26.

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Synopsis of Biological Data on Shortnose Sturgeon, *Acipenser brevirostrum* LeSueur 1818

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and Jack Buckley

October 1984

FAO Fisheries Synopsis No. 140

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
National Oceanic and Atmospheric Administration
John V. Byrne, Administrator
National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries

CONTENTS

*No information available.

Synopsis of Biological Data on Shortnose Sturgeon, *Acipenser brevirostrum* LeSueur 1818

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DONALD MARCHETTE,[4] and JACK BUCKLEY[5]

ABSTRACT

Information on the biology and populations of the shortnose sturgeon, *Acipenser brevirostrum*, is compiled, reviewed, and analyzed in the FAO species synopsis style. New information indicates this species exhibits biological and life-cycle differences over its north-south latitudinal range and that it is more abundant than previously thought.

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Acipenser brevirostrum LeSueur 1818 Ref: Trans. Am. Philos. Soc. 2:383. Type locality: Delaware River. Type specimen lodged at Academy of Natural Sciences of Philadelphia, ANSP 16953.

1.12 Objective synonymy

Acipenser brevirostris Richardson 1836:278. Type locality: Eastern North America. Type specimen: None.
Acipenser lesueurii Valenciennes—Duméril 1870:166. Type locality: New York. Type specimen: Paris Muséum National d'Histoire Naturelle.
Acipenser microrhynchus Duméril 1870:164. Type locality: Hudson River. Type specimen: None.
Acipenser dekayii Duméril 1870:168. Type locality: Hudson River. Type specimen: None.
Acipenser rostellum Duméril 1870:173. Type locality: Hudson River. Type specimen: Paris Muséum National d'Histoire Naturelle.
Acipenser sinus Valenciennes Duméril 1870:175. Type locality: New York. Type specimen: Paris Muséum National d'Histoire Naturelle.
Acipenser brevirostris Jordan et al. 1930:34
Acipenser brevirostris Vladykov and Greeley 1963:36
Acipenser brevirostris Magnin 1963:87

LeSueur originally described the species from the Delaware River as *Acipenser brevirostrum*. *Acipenser* (masculine noun) is an old word for sturgeon and *brevirostrum*, short snout, (neuter, 2nd declension, noun in apposition). This was correct. Article 30 of the Rules of Zoological Nomenclature states only a species-group name which is an adjective has to agree. Others, starting with Richardson (1836) and followed by Jordan et al. (1930) and Vladykov and Greeley (1963), changed the species designation to *brevirostris* (ablative, masculine noun) to obtain agreement. This was unnecessary.

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1.2 Taxonomy

1.21 Affinities

Suprageneric

Kingdom Animalia
  Phylum Chordata
    Subphylum Vertebrata
      Superclass Gnathostomata
        Class Osteichthyes
          Subclass Actinopterygii
            Infraclass Chondrostei
              Order Acipenseriformes
                Family Acipenseridae
                  Subfamily Acipenserinae

Generic

Genus: *Acipenser* Linnaeus 1758
Ref: Systema naturae, ed. X, p. 237
Diagnostic characteristics:
Ref: Vladykov and Greeley 1963: Order Acipenseroidei. Mem. Sears Found. Mar. Res.

Body elongate and fusiform. Scutes in five rows: One dorsal, two lateral, two ventral; and scutes very sharp and strongly developed in young individuals, but becoming progressively blunter with age. Snout protruding, subconical. Mouth inferior, protractile. Teeth absent in adults. Barbels 4, in cross row anterior to mouth. Gills 4, and an accessory opercular gill. Gill rakers < 50, lanceolate. Gill membranes joined to isthmus, spiracles present, one branchiostegal (McAllister[6]). Opercle present, suboperculum present or absent. Head covered by bony plates separated by sutures, dermal skeleton without ganoine. Tail depressed, completely mailed, caudal fin with fulcra; tail heterocercal. Dorsal and anal fins behind ventrals. Air bladder large, simple, opening into oesophagus through a short, wide duct. Rectum with spiral valve. Anadromous and freshwater fishes of northern hemisphere; Upper Cretaceous to Recent, 16 species.

Specific

Key to North American, Atlantic coastal species of *Acipenser* (after Vladykov and Greeley 1963; Scott and Crossman 1973)

1a. Mouth width inside lips usually < 55% (range 43-66%) of interorbital width; interorbital width < 29% (range 22-36%) of head length (Fig. 1); average TL:FL = 1.14; gill rakers 17-27 ($\bar{X}$ = 21.6); postdorsal and preanal shields usually in pairs, usually 2-6 plates between anal base and lateral row of scutes (Fig. 2); dorsal plates generally touch or overlap; viscera pale; has fontanelle .... *Acipenser oxyrhynchus* Mitchill 1814

1b. Mouth width exceeds 62% (range 63-81%) of interorbital width; interorbital width usually exceeds 29% (range 29-40%) of head length (Fig. 1); average TL:FL = 1.12, gill rakers 22-40, postdorsal and preanal shields usually in single row, usually no plates between anal base and lateral scute row (Fig. 2); viscera blackish; n fontanelle ....

[6]D. E. McAllister, Curator of fishes, National Museum of Canada, Ottawa, Canada K1A 0M8, pers. commun. September 1979.

Figure 1.—Ventral view of Atlantic sturgeon (left) and shortnose sturgeon (right); note short snout and wide mouth of the shortnose sturgeon.

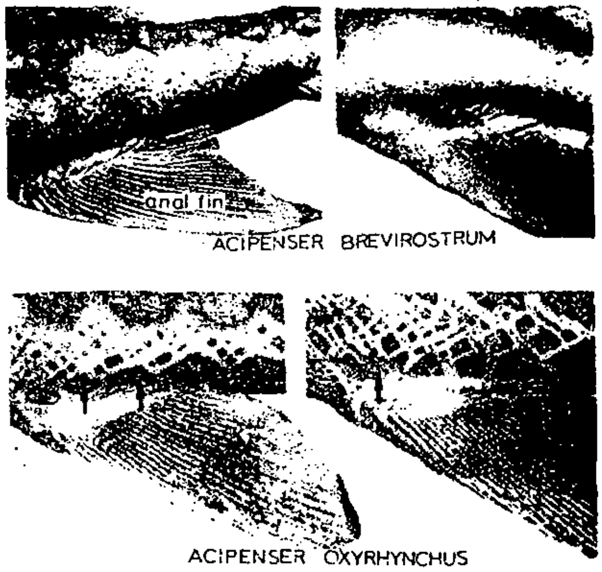

Figure 2.—Lateral view of shortnose sturgeon (above) and Atlantic stu (below); note small bony plates (arrows) above the anal fin of the A sturgeon (from Gorham and McAllister 1974).

2a. Anal fin rays 25-30; insertion of anal fin behind inse tion of dorsal fin; gill rakers 25-40 ($\bar{X}$ = 33.1); caud peduncle long, tip of anal fin not reaching origin caudal fin, lateral plates 29-42 ($\bar{X}$ = 35.4); interorbi width 29-35% of head length (adults); dorsal and later shields same color as background .... *Acipenser fulvescens* Rafinesque

2b. Anal fin rays 19-22; insertion of anal fin opposite inse tion of dorsal, gill rakers 22-29 ($\bar{X}$ = 25.4); caud peduncle short, tip of anal fin reaching origin of caud fin; lateral plates 22-33 ($\bar{X}$ = 28.3); interorbital wid 34-40% ($\bar{X}$ = 37%) of head length; dorsal and later shields pale, contrasting with dark background...... .... *Acipenser brevirostrum* LeSueur 1818 (l

Remarks on Identification. Among these three species, v characters change considerably with growth. Young have l snouts than adults and their scutes (shields) are sharper and together. Mouth width is the best character for separating all of shortnose sturgeon and Atlantic sturgeon including all l (Fig. 4) except prolarvae (Taubert and Dadswell 1980; Bath 1981). The absence of plates between the lateral scutes an anal fin is the best character for distinguishing dressed (hea shortnose sturgeon, but occasionally Atlantic sturgeon also these plates (Squiers and Smith 1978[7]). Morphologically, s nose sturgeon are quite variable. A complete gradation of m from sharp-plated, rough-skinned individuals to flat-p smooth-skinned shortnose sturgeon exist in the Saint John es (Dadswell, pers. obs.).

[7]Squiers, T. S., and M. Smith. 1978. Distribution and abundance of sh sturgeon and Atlantic sturgeon in the Kennebec River estuary. Prog. Rep. #AFC-19-1, Dep. Mar. Resour., Maine, 31 p.

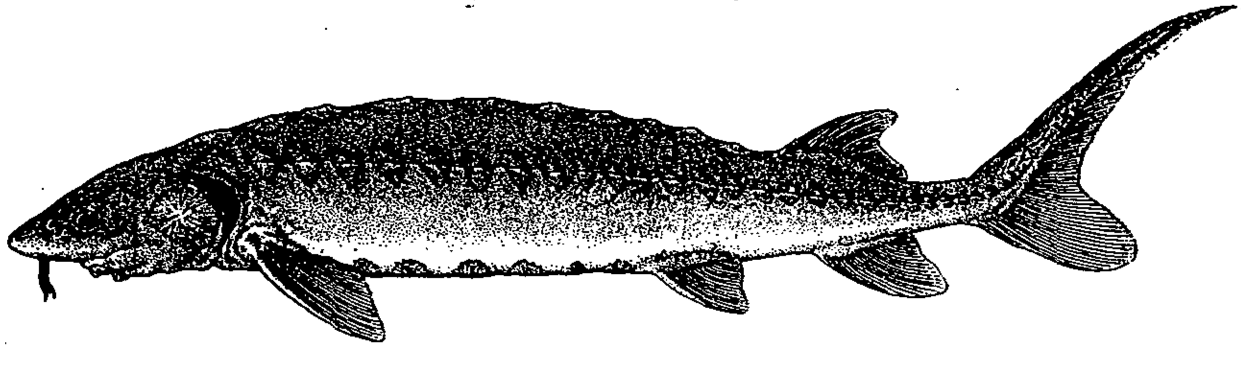

Figure 3.—*Acipenser brevirostrum.* Lateral view of spawning female (580 mm TL) from the Hudson River, N.Y. (after Vladykov and Greeley 1963).

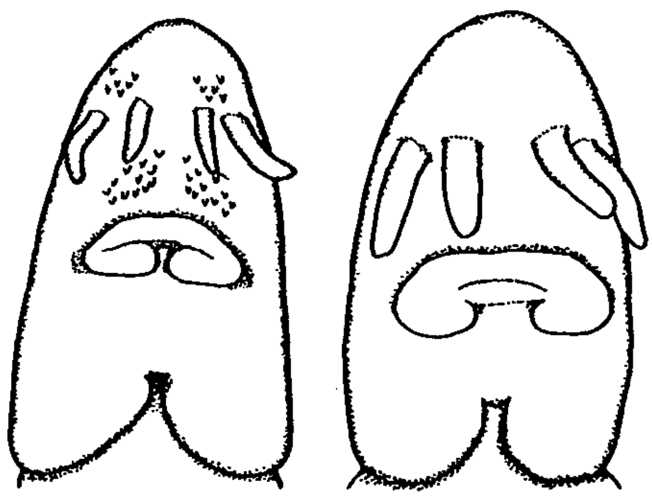

Figure 4.—Ventral view of heads of 17.0 mm larval *Acipenser oxyrhynchus* (left) and *A. brevirostrum* (right) from the Hudson River, N.Y., illustrating difference in mouth size and structure (after *W. L. Dovel. 1979. The biology and management of shortnose and Atlantic sturgeon of the Hudson River. N.Y. Dep. Environ. Conserv. Rep. AFS9-R, 54 p.*).

1.22 Taxonomic status

A morpho-species, not established by breeding data.

1.23 Subspecies

No subspecies described.

1.24 *Standard common names, vernacular names*

The standard common name is shortnose sturgeon (Robins et al. 1980). Vernacular names include shortnosed sturgeon, little sturgeon (Saint John River, N.B.), pinkster and roundnoser (Hudson River, N.Y.), bottlenose or mammose (Delaware River), salmon sturgeon (Carolinas), soft-shell or lake sturgeon (Altamaha River, Ga.).

1.3 Morphology

1.31 External morphology

Acipenser brevirostrum is distinguished by wide mouth, absence of a fontanelle, almost complete absence of the postdorsal shields, and by preanal shields usually arranged in a single row (paired preanals, Kennebec R., Squiers and Smith footnote 7).

Scutes in all five main rows not closely set, weakly developed in adults, sharp and close together in juveniles.

Dorsal scutes 7-13, lateral scutes 21-35, ventral scutes 6-11; scutes behind dorsal fin either in single row (75%) or paired (25%), enlarged supra-anal plates absent, double preanal scutes present (25%) or absent (75%); elongated fulcrum at base of lower caudal lobe shorter than base of anal fin (Table 1).

Head short, 22-28% of FL, snout short, blunt rounded (Fig. 3), 70% of postorbital length in adults, convex in side view but longer than postorbital length in young, sharp, triangular concave in side view; fontanelle absent; postorbital length in adults 51-61% (avg. 55%) of head length, but 33% in young; interorbital width 24-43% (avg. 37%) of head length, mouth width (excluding lips) 69-81% (avg. 74%) of interorbital width, no teeth; 4 barbels in front of mouth; gill rakers long, triangular, 23-32 (avg. 26) on first arch.

Fins: Single dorsal far back, above anal, trailing edge crescentic, 38-42 rays; caudal heterocercal, lower lobe long for sturgeon, no notch at tip of upper lobe, difference between TL and FL 11-12%; caudal peduncle short, tip of depressed anal reaching base of caudal fin; anal fin base about 60% of dorsal fin base, trailing edge emarginate, 18-24 rays; paired fins with heavy ossified first ray, pelvics abdominal, far back, pectoral large, pectoral girdle wider than head width; no lateral line.

Color: Body yellowish brown with green or purple cast in saltwater, to nearly black on head, back, and sides level to lateral plates, whitish to yellowish below. Young particularly yellowish in the Saint John River, Canada. Ventral surface and barbels white; all fins pigmented but paired fins outlined in white, scutes pale and obvious against dark background (Fig. 5). Young have melanistic (black) blotches (Fig. 6).

The skin of preserved specimens often acquires a greenish cast (Vladykov and Greeley 1963).

1.32 *Cytomorphology*

No data available.

Table 1.—Comparative morphometric and meristic data for adult *Acipenser brevirostrum*. TL = total length, MW = mouth width (inside lips), SL = snout length, IOW = interorbital width, POL = postorbital length, HL = head length, FL = fork length. In parentheses, juvenile data.

	Mean for river system					
	Saint John, Canada	Kennebec-Sheepscot	Connecticut	Hudson		Delaware
Character	Gorham and McAllister (1974)	Squiers and Smith (see text footnote 7) Fried and McCleave (1973)	Taubert (1980b)	Vladykov and Greeley (1963)	Hoff and Klauda (1979)[1]	Brundage and Meadows (1982)
MW/LS	0.60±0.08	0.71±0.09	71.6	—	0.58	0.71±0.10
MW/IOW	0.76±0.06	0.81±0.06	0.73	0.74 (same)	0.68	0.68±0.05
SL/HL	0.44±0.03	0.38±0.03		0.35	0.45	0.38±0.05
SL/POL	—	0.73±0.09		0.70 (1.83)	0.76	0.68±0.05
POL/HL	—	0.56±0.03		0.55 (0.33)	0.60	0.58±0.04
IOW/HL	—	0.34±0.03		0.37	0.39	0.39±0.01
HL/FL	—	0.20±0.01		0.22 (0.28)	0.19	0.21±0.02
TL/FL	1.2	1.11±0.02		1.1	1.1	
Gill rakers	27.6±2.5	26.2±0.03		25.5	25	
Anal rays	20.8±1.6	—		—	—	
Dorsal scutes	10.2±1.3	9.7±1.3	11.0	10	—	10.2±2.0
Ventral scutes	8.5±0.9	8.0±0.9	7.9	8	—	7.6±1.0
Lateral scutes	—	26.5±2.6	27.7	28	—	27.3±2.5

[1]Hoff, T. B., and R. J. Klauda. 1979. Data on shortnose sturgeon (*Acipenser brevirostrum*) collected incidentally from 1969 through June 1979 in sampling programs conducted for the Hudson River ecological study. Texas Instruments Inc., Buchanan, N.Y., MS Rep., 25 p.

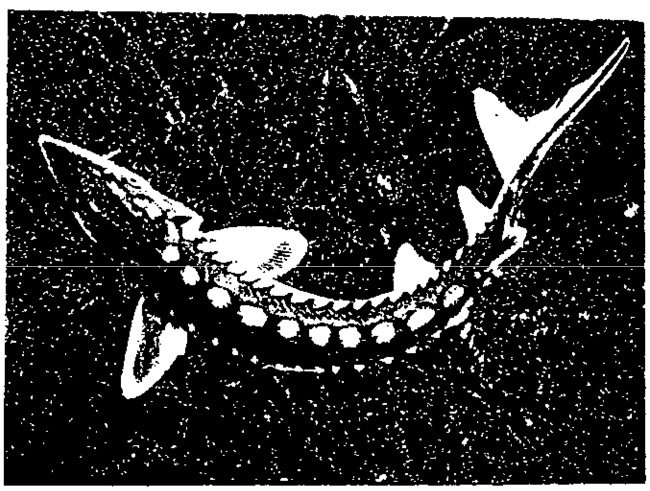

Figure 5.—*Acipenser brevirostrum*. Dorsal view of 430 mm FL juvenile from the Saint John River, Canada.

Figure 6.—*Acipenser brevirostrum*. Lateral view of juvenile from the Holyo Pool, Connecticut River, showing sharp, closely set scutes and melanis blotches.

1.33 Protein specificity

No data available.

1.34 Internal morphology

A considerable number of publications on the internal structure of sturgeon exist (Parker 1882; Jollie 1980), but little directly concerns shortnose sturgeon. Ryder (1890) illustrated the spiral valve, pyloric end of the stomach, and cartilaginous elements of the ventral fins of *A. brevirostrum*. Vladykov and Greeley (1963) described, but did not illustrate, other internal structures. Viscera is black and peritoneum pigmented.

2 DISTRIBUTION

2.1 Total area

Shortnose sturgeon are restricted to the east coast of Nor America (Vladykov and Greeley 1963). They have been record from the Saint John River, New Brunswick, Canada (Leim a Day 1959), to the Indian River, Fla. (Evermann and Bean 189 (Fig. 7a, b). Since the species is considered endangered, a sum mary of occurrence records and catches is given in Table 2.

Throughout its range, shortnose sturgeon occur in rivers, est aries, and the sea. The majority of populations have their greate abundance in the estuary of their respective river. All captures sea have occurred within a few miles of land (Schaefer 1967; Holland and Yelverton 1973; Wilk and Silverman 1976; Marchette and Smiley 1982 see Table 2, footnote 24). Partially landlocked populations are known from the Holyoke Pool section of the Connecticut River (Taubert 1980a) and the Lake Marion-Moultrie system South Carolina (Marchette and Smiley 1982 see Table 2, footnote 24).

This species has no known fossil record.

2.2 Differential distribution

2.21 Spawn, larvae and juveniles

The species is anadromous (Dadswell 1979) but can be landlocked (Taubert 1980a; Marchette and Smiley 1982 see Table 2, footnote 24). The young are hatched in freshwater usually above tidal influence. Ripe adults have been captured as far upstream as rkm (river kilometer) 186 in the Altamaha River, Ga. (Heidt and Gilbert 1978 see Table 2, footnote 27), rkm 198 on the Pee Dee River, S.C. (Marchette and Smiley 1982 see Table 2, footnote 24), rkm 222 in the Delaware River (Hoff 1965), rkm 246 in the Hudson River (Dovel 1981 see Table 2, footnote 15), and adults, eggs, and larvae have been taken at rkm 190 in the Connecticut River (Taubert 1980a).

Eggs are demersal and adhesive (Meehan 1910). Juveniles may remain inland of saline water until 45 cm FL. That length is attained between 2 and 8 yr of age depending on the geographical location of the population. Larvae and juveniles are benthic and occupy the deep channel areas of rivers where currents are strong (Dadswell 1979; Taubert 1980a).

2.22 Adults

Once shortnose sturgeon attain adult size (45-50 cm), they commence migratory behavior, travelling downstream in fall and upstream in spring (Dadswell 1979; Dovel 1981; Marchette and Smiley 1982 see Table 2, footnote 24; Buckley 1982). An unknown portion of most populations appear to move short distances to sea (Bigelow and Schroeder 1953; Schaefer 1967; Holland and Yelverton 1973; Wilk and Silverman 1976; Dadswell 1979). Each fall, in some of the large rivers (Hudson, Connecticut, Saint John), a portion of the adults which will spawn the following spring migrate upstream to deep, overwintering sites adjacent to the spawning grounds (Greeley 1935; Dadswell 1979; Dovel 1981 see Table 2, footnote 15; Buckley 1982). Males apparently lead the upstream migration (Pekovitch 1979 see Table 2, footnote 14; Dovel 1981 see Table 2, footnote 15; Dadswell, unpubl. data). Some ripening and most nonripening adults spend the winter in deep, saline sites (Fig. 8) (Dovel 1978 see Table 2, footnote 13; Dadswell 1979; Marchette and Smiley 1982 see Table 2, footnote 24). On the other hand, mass migrations were not noted in the Holyoke Pool population (Taubert 1980b), and some nonripening adults in most rivers remain in freshwater, do not concentrate, and may be active all winter (Dadswell 1979; Buckley 1982).

2.3 Determinants of distribution changes

2.31 Temperature

The preferred temperature range and upper and lower lethal temperatures for shortnose sturgeon are unknown.

Spring spawning migrations from overwintering sites or arrival on the spawning grounds occurs at temperatures of 8°-9°C (Dovel 1978 see Table 2, footnote 13; Squiers 1982 see Table 2, footnote 4). In the northern part of its range, shortnose sturgeon are seldom found in shallow water once temperature exceeds 22°C (Dadswell 1975;[8] Dovel 1978 see Table 2, footnote 13). In the Saint John River, Canada, surface temperatures over 21°C appeared to stimulate movement to deeper water. Heidt and Gilbert (1978 see Table 2, footnote 27), however, found shortnose sturgeon in the lower Altamaha River in June at water temperatures of 34°C and in the lower Connecticut River they were frequently captured in < 1 m of water at 27°-30°C (Buckley[9]).

Dadswell (1979) and Marchette and Smiley (1982 see Table 2, footnote 24) found a 2°-3°C decline in temperature during fall stimulated downstream migration. In the Saint John River, Canada, they overwinter in regions with temperatures between 0° and 13°C. In Winyah Bay, S.C., overwintering sites have temperatures of 5°-10°C (Marchette and Smiley 1982 see Table 2, footnote 24).

2.32 Current

Juveniles appear to prefer living in deep channel regions (Table 3) with strong currents (15-40 cm/s) (Pottle and Dadswell 1979 see Table 2, footnote 1). During summer, adults are generally found in regions of little or no current (McCleave et al. 1977; Dadswell 1979; Taubert 1980b).

2.33 Waves

No data.

2.34 Depth

See 2.22 and 2.31. Pottle and Dadswell (1979 see Table 2, footnote 1) found juveniles occupied depths in excess of 9 m in river channels. Trawling surveys in the Hudson River indicate a similar situation there (Dovel 1978 see Table 2, footnote 13; Hoff et al. 1977 see Table 2, footnote 12). Adults are found in shallow water in summer (2-10 m) (Dadswell 1979; Dovel 1981 see Table 2, footnote 15; Marchette and Smiley 1982 see Table 2, footnote 24) and in deep water in winter (10-30 m) (Dadswell 1979; Dovel 1981 see Table 2, footnote 15; Marchette and Smiley 1982 see Table 2, footnote 24).

2.35 Light

Light appears to be important in the biology of shortnose sturgeon but is still largely unassessed. Gilbert and Heidt (1979) found, although nets were fished during daylight and darkness, all shortnose sturgeon were caught during darkness. During radio tracking studies, they found tagged sturgeon remained more or less stationary in deep water during daylight but at night they moved into shallow water or extensively up- or down-stream.

[8]Dadswell, M. J. 1975. Biology of the shortnose sturgeon (*Acipenser brevirostrum*) in the Saint John estuary, New Brunswick, Canada. *In* Baseline survey and living resource potential study of the Saint John estuary, Vol. III Fish and fisheries, 75 p. Huntsman Marine Laboratory, St. Andrews, N.B.

[9]J. Buckley, Graduate Student, Massachusetts Cooperative Fishery Research Unit, Department of Forestry and Wildlife, University of Massachusetts, Amherst, MA 01002, pers. commun. February 1982.

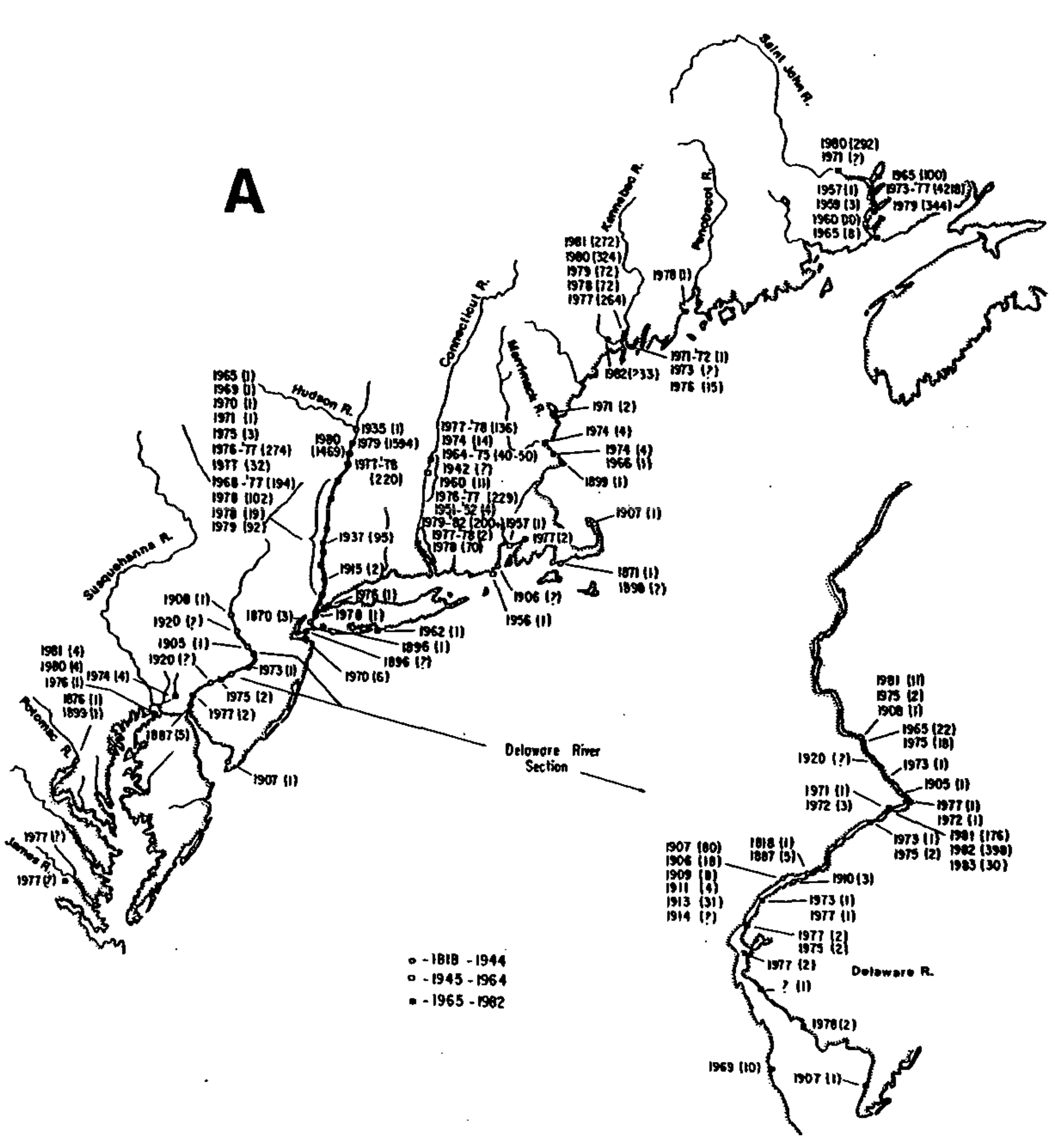

Figure 7.—A. Northern portion of shortnose sturgeon distribution indicating known occurrences with date of capture and number captured (in parentheses). B. Southern portion of shortnose sturgeon distribution indicating known occurrences with date of capture and number captured (in parentheses).

2.36 Turbidity

No data. Dadswell (pers. obs.) observed that catches of shortnose sturgeon in both invisible monofilament and heavy duty, multifilament gill nets increase appreciably on windy days when the water is more turbid than usual. This suggests shortnose sturgeon are more active under lowered light conditions, or such conditions as have been documented by Gilbert and Heidt (1979).

2.37 Substratum

Dadswell (1979) noted that foraging grounds of shortnose st geon in freshwater are over shallow, muddy bottoms with ab dant macrophytes and foraging grounds in saline waters were c gravel-silt bottoms 5-15 m deep. Marchette and Smiley (1982 Table 2, footnote 24) found shortnose sturgeon among mac phytes over sandy bottom in summer and over mud bottom

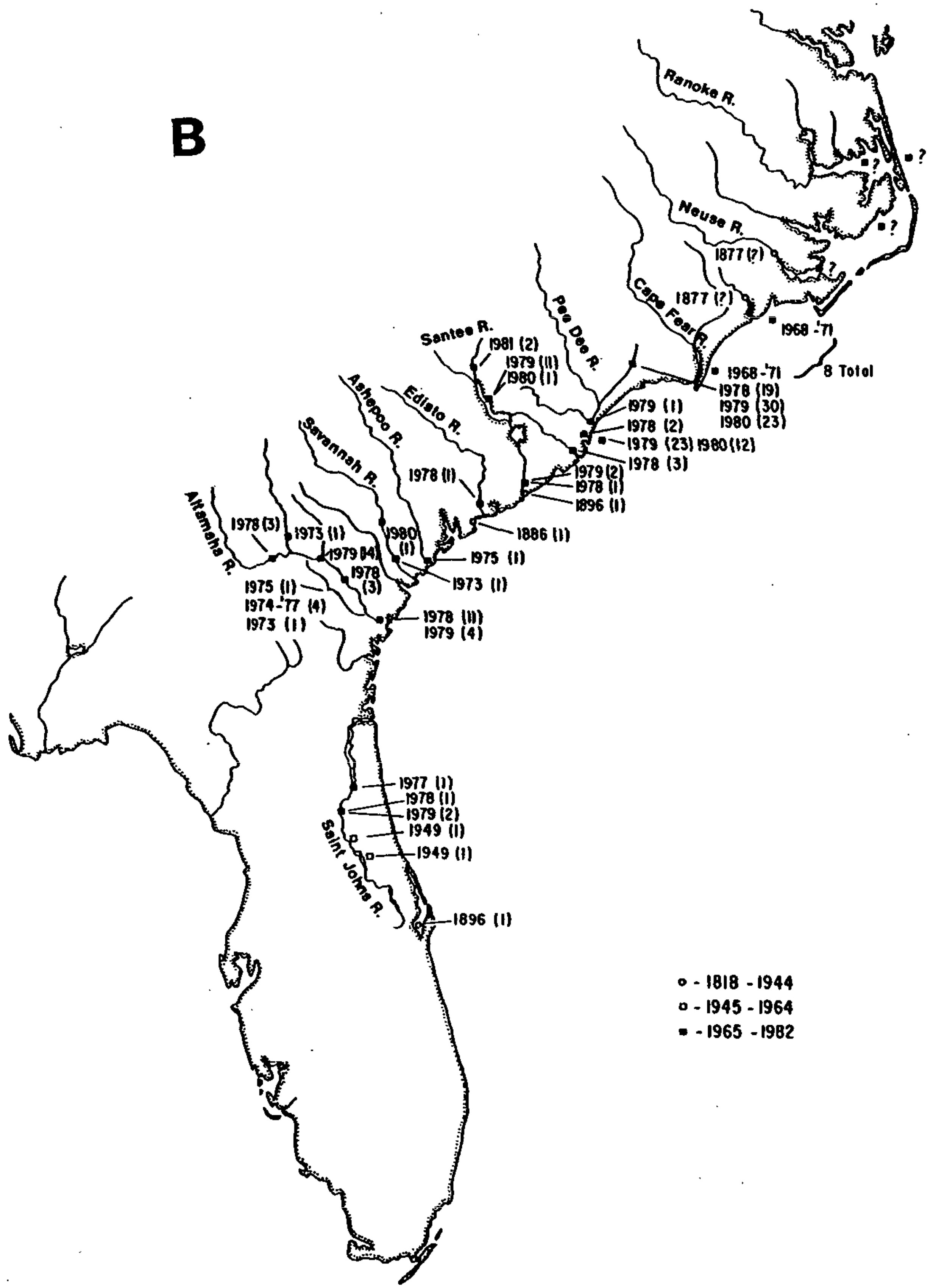

Figure 7.—*Continued.*

Table 2.—Occurrence and number captured of shortnose sturgeon collected on the east coast of North America since 1818.

Locality	Date	Number caught	Source
NEW BRUNSWICK, CANADA			
Saint John River	1957	1	Leim and Day (1959)
	1959	3	Vladykov and Greeley (1963)
	1960	10	Magnin (1963)
	1965	8	Gorham (1965)
	1971	99	Meth (1973)
	1971	45	Gorham (1971)
	1974	32	Gorham and McAllister (1974)
	1973-77	4,218	Dadswell (1979)
	1976	11	Appy and Dadswell (1978)
	1979	2 larvae, 300 juveniles, 42 adults	Pottle and Dadswell (1979)[1]
	1980	292	Anonymous (1980)[2]
MAINE			
Sheepscot Estuary	1971-73	31	Fried and McCleave (1973)
Montsweag Bay	1973	3	Fried and McCleave (1974)
	1976	15	McCleave et al. (1977)
Kennebec River-Montsweag Bay	1977	264	Squiers and Smith (see text footnote 7)
	1978	72	
	1979	72	Squiers et al. (1981)[3]
Montsweag Bay and Androscoggin River	1980	324	
	1981	272	Squiers (1982)[4]
	1982	233	
Penobscot River	1978	1	Squiers[5]
NEW HAMPSHIRE			
Piscataqua River	1971	1	Spurr[6]
Gulf of Maine	1971	1	
MASSACHUSETTS			
Provincetown	1907	1	Bigelow and Schroeder (1953)
Waquoit	?	1	
Rockport	?	1	Goode and Bean (1879) (unconfirmed)
Woods Hole	1871	1	Baird (1873)
	1898	?	Bumpus (1898)
Merrimack River	1949	1	McLaughlin[7]
	1974	4	
Parker River	1972	1	Rideout[8]
Holyoke Pool	1942	100+	McCabe (1942) (in fish markets)
Connecticut River	1964-75	40-50 +8 juveniles	Student collections, U. Mass., Amherst, Mass.
	1974	14	Texas Instruments (1975)[9]
	1976-77	229	Taubert (1980b)
	1977-78	13 larvae	
RHODE ISLAND			
Point Judith	1956	1	Gordon (1960)
Narragansett Bay	1957	1	Gordon (1960) (unconfirmed)
CONNECTICUT			
Lower Connecticut River	1951-52	4	Vladykov and Greeley (1963)
	1977-78	5	Taubert[10]
	1978	70	Reed and Buckley (1978)[11]
	1979	1	Impinged, Haddam Neck
	1979	71	Buckley (1982)
	1980	32	
	1981	22	
	1982	166	
NEW YORK			
Fire Island	1962	1	Schaefer (1967)
Hudson River	1870	3	Duméril (1870) (in Paris museum)
Hudson River (Gravesend Bay)	1896	1	Bean (1897)
Hudson River	1915	2	MacCallum (1921)
Hudson River (Albany)	1935	1	Greeley (1935)
Hudson River	1936	95	Greeley (1937); Curran and Ries (1937)
	1965	1	Boyle (1960)
	1969	1	

Table 2.—*Continued.*

Locality	Date	Number caught	Source
Hudson River	1969	1	Atz and Smith (1976)
	1970	1	Koski et al. (1971)
	1971	1	Raytheon Inc.
	1969-77	194	Hoff et al. (1977)[12]
	1975	3	Brundage and Meadows (1982)
	1976-77	274 (9 yoy & juveniles)	Dovel (1978)[13]
	1977	32 (4 larvae) (19 yoy)	Nalco Environmental Sciences
	1978	106	Texas Instruments, ESA Permit E20
	1978	174	Dovel, ESA Permit E11
	1979	1,594 (2 larvae) (10 yoy)	Pekovitch (1979)[14]
	1979	92	Texas Instruments, ESA Permit E20
	1980	1,469	Dovel (1981)[15]
NEW JERSEY			
Sandy Hook Bay	1970	6	Wilk and Silverman (1976)
Bay at Green Creek	1907	1	Vladykov and Greeley (1963)
Cape May Co., Delaware River	1817	1	LeSueur (1818) (type specimen)
Delaware River	1887	5	Ryder (1890)
	Apr. 1906	18	Meehan (1910)
Torresdale, Phil Co.		(4 ♀ ripe, 2 ♂)	
	1907	80-90	Meehan (1910) (50% ♂)
	1909	8	Meehan (1910) (2 ♀, 6 ♂)
	1911	4	Vladykov and Greeley (1963)
	1913	3	
Trenton	1905	1	Fowler (1905)
Delaware River	?	3	Fowler (1910)
Bristol, Bucks Co.	1908	1	Fowler (1912)
Delaware River	?	?	Fowler (1920)
Burlington Co., Mercer Co., Gloucester Co.	1914	?	Smith (1915) (commercial catch)
Scudders Falls	1954	2(20 seen)	Hoff (1965)
	1983 (Apr./May)	15	Brundage (unpubl. data)
Little Ck., Del.	1969	10	Carl Baren[16]
Rm 28	1969	1	
Lambertville	1972	2	
Rm 102-124	1973	1	
Rm 52-69	1975	2	
Rm 149	1977	1	
Rm 61	1977	1	
Trenton	1977	2	
Delaware Memorial Bridge			
Delaware River	1973	1	Miller et al. (1973)
Burlington Co.	1975	2	Martin Marietta Corp. (1976)[17]
Salem Nuclear Generating Station	1978	2	Masnik and Wilson (1980)
	1981	1	Brundage (unpubl. data)
Artificial Island	1979	2	Brundage and Meadows (1982)
Edgewater Park			
Rm 115	1982	1	Brundage (unpubl. data)
Lambertville	1981	11	Lupine[18]
Trenton, Delaware	1981	176	Hastings (1983)[19]
	1982	398	
	1983	30	
Newbold Island	1971	3	Anselmini (1976)
Mercer Zone	1972	3	Anselmini (1974)
MARYLAND			
Still Pond Neck	1976	1	Miller[20]
Upper Chesapeake			
Elk River	1978	4	S. Bristo
Upper Chesapeake Bay			
Susquahanna Flats	1980	4	Saul[21]
	1981	4	Hogan[22]

Table 2.—*Continued.*

Locality	Date	Number caught	Source
Potomac River	1876	1	Uhler and Lugger (1876)
	1899	?	Smith and Bean (1899)
ATLANTIC OCEAN			
Cape Henry, Va.			
to Cape Fear, N.C.	1968-71	8	Holland and Yelverton (1973)
NORTH CAROLINA			
Salmon Creek	?	1	Vladykov and Greeley (1963) (NSNM 64330)
Beaufort	1886	?	Jordan (1886)
North, New, and Neuse Rivers	1877	abundant?	Yarrow (1877)
Ashepoo River	1970	1	Anderson[23]
SOUTH CAROLINA			
Charleston	1896	1	Jordan and Evermann (1896)
South Santee River	1978	3	Marchette and Smiley (1982)[24]
South Edisto River	1978	1	
	1979	2	
Atlantic Ocean	1980	2	
Pee Dee River	1982	3	
Waccamaw River-			
Winyah Bay	1978	20	
	1979	39	
	1980	37	
	1981	39	
	1982	3	
(running-ripe male 1st wk April)			
Charlestown Harbour	1978	1	
Lake Marion-			
Wateree River	1979	11	
	1980	1	
	1981	1	
GEORGIA			
Lower Savannah River	1975	1	Smith[25]
	1979	3	Recovery Team Shad Fishery Survey 1979
	1980	1	Marchette (unpubl. data)
Lower Ogeechee River	1973	1	Smith (footnote 25)
Altamaha River	1975	?	Dahlberg (1975)
	1974-77	8	Adams[26]
	1978	16	Heidt and Gilbert (1978)[27]
	1979	18	Gilbert and Heidt (1979)
	1979	1	Recovery Team Shad Fishery Survey 1979
Ocmulgee River (16 mi from fork)	1978	3	Heidt and Gilbert (1978)
FLORIDA			
Big Lake George	1949	1	Kilby et al. (1959)
Saint Johns River			
Lake Crescent	1949	1	Moody[28]
Murphy Creek	1977	1	
Saint Johns River			
Welaka	1978	1	
Cedar Ck.	1979	1	
Clay/Putnam Co. Line	1979	1	

[1]Pottle, R., and M. J. Dadswell. 1979. Studies on larval and juvenile shortnose sturgeon. Rep. to N.E. Utilities, Hartford, Conn., 87 p.

[2]Anonymous. 1980. Studies on the early life history of the shortnose sturgeon, (*Acipenser brevirostrum*). Washburn and Gillis Assoc. Ltd., Fredericton, N.B., Canada, 119 p.

[3]Squiers, T. S., M. Smith, and L. Flagg. 1981. American shad enhancement and status of sturgeon stocks in selected Maine waters. Completion Report, Dep. Mar. Resour. Maine Proj. AFC-20, p. 20-64.

[4]Squiers, T. S. 1982. Evaluation of the 1982 spawning run of shortnose sturgeon (*Acipenser brevirostrum*) in the Androscoggin River, Maine. MS Rep., Dep. Mar. Resour., Maine, 14 p.

[5]T. S. Squiers, Fisheries Biologist, Maine Department of Marine Resources, Augusta, ME 04333, pers. commun. June 1979.

[6]E. W. Spurr, New Hampshire Fish and Game, Portsmouth, NH 03891, pers. commun. June 1977.

[7]C. L. McLaughlin, Jr., Assistant Aquatic Biologist, Massachusetts Fish and Game, Westboro, MA 01581, pers. commun.

[8]S. Rideout, Massachusetts Fish and Game, Westboro, MA 01581, pers. commun. June 1977.

[9]Texas Instruments Inc. 1975. Connecticut River ecological survey of the aquatic biology and water quality. Survey of the Montague, Massachusetts, study area. May-December 1974. Prepared for Northeast Utilities Service Co., April.

[10]B. D. Taubert, University of Massachusetts, Amherst, Mass., pers. commun. May 1979.

[11]Reed, R. J., and J. Buckley. 1978. Survey of the Connecticut River for shortnose sturgeon, *Acipenser brevirostrum*, below the Holyoke Dam, Holyoke, Massachusetts. Report to Northeast Utilities, Massachusetts Cooperative Fisheries Unit, 3 p.

[12]Hoff, T. B., R. J. Klauda, and B. S. Belding. 1977. Data on distribution and incidental catch of shortnose sturgeon (*Acipenser brevirostrum*) in the Hudson River estuary 1969 to present. Texas Instruments Inc., Buchanan, N.Y., MS Rep., 21 p.

[13]Dovel, W. L. 1978. Sturgeons of the Hudson River, New York. Final Performance Rep. for N.Y. Dep. Environ. Conserv., 181 p.

[14]Pekovitch, A. W. 1979. Distribution and some life history aspects of the shortnose sturgeon (*Acipenser brevirostrum*) in the upper Hudson River estuary. Hazelton Environ. Sci. Corp., Ill., 23 p.

[15]Dovel, W. L. 1981. The endangered shortnose sturgeon of the Hudson estuary: Its life history and vulnerability to the activities of man. The Oceanic Society. FERC Contract No. DE-AC 39-79 RC-10074.

[16]C. F. Baren, Project Leader, U.S. Fish and Wildlife Service, Delaware River Basin Anadromous Fishery Project, P.O. Box 95, Rosemount, NJ 08556, pers. commun. June 1977.

[17]Martin Marietta Corp. 1976. Monitoring fish migration in the Delaware River. Final Report. March 1976, 86 p.

[18]A. Lupine, Biologist, New Jersey Fish and Game, Rosemount, NJ 08556, pers. commun. April 1982.

[19]Hastings, R. W. 1983. A study of the shortnose sturgeon (*Acipenser brevirostrum*) population in the upper tidal Delaware River; assessment of impacts of maintenance dredging. Draft Rep. U.S. Corp. Engineers, Philadelphia Dist., 132 p.

[20]P. Miller, Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, MD 21218, pers. commun. January 1978.

[21]W. G. Saul, Collection Manager, Department of Ichthyology, The Academy of Natural Sciences, Philadelphia, PA 19103, pers. commun. July 1977.

[22]W. Hogan, Biologist, Maryland Tidewater Commission, Annapolis, Md., pers. commun. April 1981.

[23]W. D. Anderson, Grice Marine Biological Laboratory, 205 Fort Johnson, Charleston, SC 29412, pers. commun. June 1977.

[24]Marchette, D. E., and R. Smiley. 1982. Biology and life history of incidentally captured shortnose sturgeon, *Acipenser brevirostrum* in South Carolina. S.C. Wildl. Mar. Res. unpubl. ms, 57 p.

[25]L. Smith, Department of Natural Resources, Fisheries Management, Box 219, Richmond Hill, GA 31324, pers. commun. July 1977.

[26]J. G. Adams, Senior Biologist, Georgia Power Company, Atlanta, Ga., pers. commun. August 1977.

[27]Heidt, A. R., and R. J. Gilbert. 1978. The shortnose sturgeon in the Altamaha River drainage, Georgia. MS Rep., Contract 03-7-043-35-165, NMFS, 16 p.

[28]H. L. Moody, Project Leader Lower St. John's River Fishery Project, Florida Game and Freshwater Fisheries Commission, P.O. Box 1903, Eustis, FL 32726, pers. commun. May 1977.

winter. Recent experiments (Pottle and Dadswell 1979 see Table 2, footnote 1) indicate juveniles prefer a sand or gravel substratum.

In contrast, shortnose sturgeon were not found in vegetated backwater regions of the Holyoke Pool. The preferred habitat for this population was riverine and nonvegetated (Taubert 1980b). During summer, adults in the lower Connecticut River were encountered most often over sand substrates (Buckley footnote 9).

2.38 Shelter

No data.

2.39 Ice

No data.

2.310 Dissolved gases

No data.

2.311 Dissolved (inorganic) solids

Dadswell (1975, 1979) described shortnose sturgeon in the Saint John estuary, Canada, as concentrated in the 1-3 ‰ salinity zone but occurring throughout the estuary from freshwater of 70 μ ohm conductance to saltwater of 29 ‰ (Fig. 8a). Marchette and Smiley (1982 see Table 2, footnote 24) found the summer concentration zone was in the 0.5-1.0 ‰ zone of the Winyah Bay complex (Fig. 8b). In the Saint John River, Canada, an annual upstream migration of the shortnose sturgeon effectively maintains the population in the 1-3 ‰ salinity range during summer and Marchette and Smiley (1982 see Table 2, footnote 24) observed similar behavior in Winyah Bay, S.C. Shortnose sturgeon have been reported from coastal water of 27 ‰ (Wilk and Silverman 1976), 30 ‰ (Squiers and Smith footnote 7), and 30-31 ‰ (Holland and Yelverton 1973; Marchette and Smiley 1982 see Table 2, footnote 24). Taubert (1980b) described a population in the Holyoke Pool of the Connecticut River of which a majority apparently remains in and completes its entire life cycle in freshwater.

2.312 Pollutants

No data.

2.313 Vegetation

Dadswell (footnote 8, 1979) and Dovel (1978 see Table 2, footnote 13) found shortnose sturgeon adults were abundant among rooted macrophytes in 2-5 m depths during summer. Dadswell (1979) attributed this occurrence to an abundance of preferred prey (small gastropods) on the bottom and on the stems and leaves of the macrophytes. Marchette and Smiley (1982 see Table 2, footnote 24) observed shortnose sturgeon swimming upside down at night feeding off snails on the undersides of lily pads (*Nuphar luteum*).

2.314 Fauna

Appy and Dadswell (1978) and Dadswell (1979) noted that adult shortnose and juvenile Atlantic sturgeon tend to segregate themselves in the Saint John estuary, the Atlantic sturgeon dominating in more saline water. A salinity of 3 ‰ appeared to be the boundary across which the distributions of the two species diffuse. Pottle and Dadswell (1979 see Table 2, footnote 1) observed that young Atlantic sturgeon (0+–3+ yr) were intermixed with juvenile shortnose sturgeon in the upper Saint John River estuary. Marchette and Smiley (1982 see Table 2, footnote

24) found that juvenile Atlantic sturgeon were mixed with adu shortnose sturgeon but outnumbered them 2:1 in Winyah Ba S.C.

2.4 Hybridization

No natural hybrids of shortnose sturgeon with other aciper serids have been reported to date, although one suspected hybri with an Atlantic sturgeon was captured from the Saint John Rive Canada (McAllister [10]), and four suspected hybrids were capture in Winyah Bay, S.C. (Marchette [11]).

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

The species is normally heterosexual.

Atz and Smith (1976) described a shortnose sturgeon from th Hudson River with a gonad containing intermingled testicular an ovarian tissue. One ovatestis contained small, cystlike structure consisting of disorganized tissues including cartilage, bone, bloo vessels, gut epithelium, and connective tissue which was attri buted to abnormal development of a parthenogenetic or sell fertilized egg.

Sexual dimorphism

Little sexual dimorphism is exhibited by this species. Adul females are generally larger than adult males of the same age an gravid females are distinct in spring because of their swollen ap pearance (Dadswell 1979). Males and females can be reliabl distinguished externally only during the final stages before spawn ing; males by abdominal pressure which causes milt to flo (possible only during the final 2-3 d), and females because th black eggs are apparent through the abdomen (during a 3-m period, March-May in the north, January to March in the south

3.12 Maturity

Age of first maturation of males varies from south to nortl possibly occurring at 2-3 yr in Georgia, at age 3-5 yr from Soutl Carolina to New York, and increasing northward to 10 or 11 yr i the Saint John River, Canada (Table 4). Females exhibit a simila south-north trend, maturing at age 6 or younger in Georgia, ag 6-7 from South Carolina to New York, and age 13 in the Sain John River, N.B. Sexual differentiation is possible 1-2 yr younge

[10] D. E. McAllister, Curator of fishes, National Museum of Canada, Ottaw Canada K1A 0M8, pers. commun. May 1977.

[11] D. E. Marchette, Fisheries Biologist, South Carolina Wildlife and Marin Resources, Charleston, SC 29412, pers. commun. February 1982.

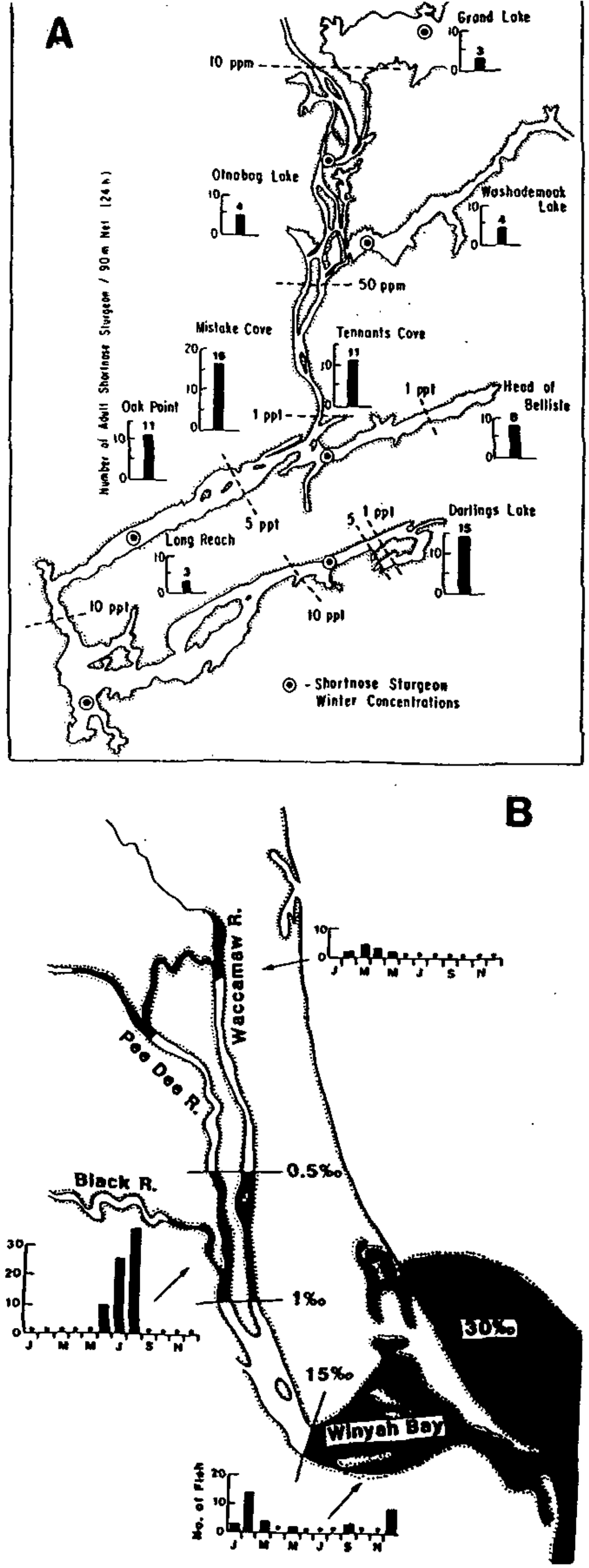

Figure 8.—A. Average June-August abundance of shortnose sturgeon in gill net catches in the Saint John estuary, Canada, as related to surface salinities. Winter concentration sites are those discovered to date. B. Location of known summer concentrations and overwintering sites in the Winyah Bay-Pee Dee River complex, S.C. Isohalines of salinity are approximate summer limits.

Table 3.—Percent, number, and mean length of shortnose sturgeon <45 cm and >45 cm in gill net catches in relation to capture site in the Saint John estuary, Canada. Mesh size range was 2.5-20.2 cm stretched. Habitat type was riverine (r) or lacustrine (l). Distance upstream is river kilometer from Saint John Harbour on the Bay of Fundy.

Locality	Type	Distance (rkm)	Depth (m)	Samples	Catch n(<45 cm)	Catch %	Mean length (cm) <45	Mean length (cm) >45
Milkish Cove	r	5	4	3	1	1.6	41.0	83.2
Westfield	r	15	5	2	3	16.6	44.0	61.7
Oak Point (June)	r	35	15	1	8	32.0	26.6	66.9
Oak Point (fall)	r	35	15	3	12	8.6	41.5	70.1
Evandale	r	45	18	3	48	91.3	37.1	50.0
Belleisle	l	45	13	2	5	9.7	39.0	82.3
Wickham	r	55	12	1	6	42.8	34.8	50.9
Washademoak	l	60	20	3	15	26.4	40.6	83.9
Gagetown	r	70	12	3	38	82.2	40.5	55.5
Oromocto[1,2]	r	90	10	1	7	58.0	31.4	49.4
Grand Lake[2]	l	90	20	4	3	21.0	24.2	60.2

[1]F. F. Meth, Biologist, Environmental Protection Service, Department of Environment, Halifax, Canada, pers. commun. August 1976.
[2]New Brunswick Fish and Game, Head Office, Fredericton, N.B., pers. commun. August 1976.

Table 4.—Age and size at first maturation and first spawning of shortnose sturgeon in various river systems.

Locality	Males Age	Males FL (cm)	Females Age	Females FL (cm)	Authority
		First maturation			
Saint John, Canada	11	50.0	13.0	58.0	Dadswell (1979)
Hudson	3-4	40.0	—	—	Greeley (1937); Pekovitch (see Table 2, footnote 14)
Delaware		50.0		58.8	Hoff (1965); Hastings (see Table 2, footnote 19)
Pee Dee	—	43.4	—	44.4	Marchette and Smiley (see Table 2, footnote 24)
Altamaha	2-3	58.6	6	72.2	Heidt and Gilbert (see Table 2, footnote 27)
		First spawning			
Saint John, Canada	11	54.0	15	66.0	Dadswell (1979)
Holyoke Poole Connecticut	8	57.0	9	52.0	Taubert (1980b)
Lower Connecticut	10		15		Buckley (1982)
Hudson	3-4	44.5	6-8	51.5	Greeley (1937)
Delaware	—	50.0	7-10	61.2	Hoff (1965); Hastings (see Table 2, footnote 19)
Pee Dee	5	53.0	7	56.5	Marchette and Smiley (see Table 2, footnote 24)
Altamaha	2-3	58.6	6	72.2	Heidt and Gilbert (see Table 2, footnote 27)

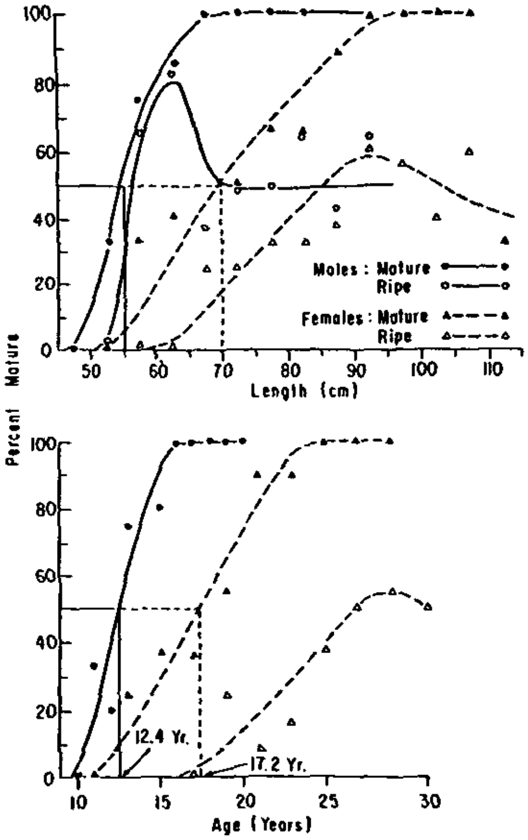

Figure 9.—Maturity ogives indicating length and age at 50% maturity for male and female shortnose sturgeon from the Saint John River, Canada, and incidence of ripening adults (stages III-V) among those mature. Length-maturity data treated in 5 cm increments for both sexes; and age-maturity in 2-yr increments for females and 1-yr increments for males.

than the above. Dadswell (1979) found 50% maturity in the Saint John River occurred at 12.4 yr for males and 17.2 yr for females (Fig. 9).

Length at maturity for this species is similar throughout its range, occurring between 45 and 55 cm FL for both males and females (Table 4).

First spawning

First spawning in males occurs 1-2 yr after maturity, but among females is delayed for up to 5 yr (Dadswell 1979; Fig. 9). Approximate female age at first spawning in the Saint John River, Canada, is 15 yr, the Hudson-Delaware Rivers 7-10 yr, and the Altamaha, 6 yr or less (Table 4). Size of males at first spawning is 44 to 55 cm FL and of females 50 to 70 cm FL. Taubert (1980b) found the first spawning of males in the Holyoke Pool was 8-12 yr old ($\bar{X} = 9.8$) and of females 9-14 yr or 52 to 67 cm FL. Marchette and Smiley (1982 see Table 2, footnote 24) found mean age of first spawning of males in South Carolina was 5-10 yr ($\bar{X} = 7.5$)

and of females 7-14 yr ($\bar{X}$ = 10.5).

3.13 Mating

Little is known of spawning behavior. Dovel (1981 see Table 2, footnote 15) found that the entire spawning population in the Hudson River moved upstream "en masse" from the overwintering site to the spawning site during the spring spawning run. Observations in the Saint John River, Canada, Connecticut River, and the Hudson River during each of 1977 through 1982 spawning periods indicated the entire spawning population was confined to a short reach of the river (1-2 km) (Taubert 1980a; Anonymous 1980 see Table 2, footnote 2). In the lower Connecticut River below Holyoke Dam (rkm 139), spawning occurred over a short period of 2-5 d in a very small area 6,000 m long (Buckley 1982). Telemetry and gill net captures indicated spawners were in the deepest available areas (6 m).

Washburn and Gillis Associates (Anonymous 1980 see Table 2, footnote 2) and Buckley and Kynard (1981) found single females captured in gill nets on the spawning grounds were often surrounded by numerous males in the same region of the net. Dadswell (1979) found that sequentially tagged shortnose sturgeon had a tendency to be recaptured together. The probability of this occurrence at random was calculated to be 1.88×10^{-24} and is highly unlikely. There is no proof, however, that this possible "pair bonding" is carried over to the spawning act, nor is it known whether the "pairs" consist of one of each sex.

3.14 Fertilization

Fertilization is probably external as in all other Acipenseridae (Ginsburg and Dettlaf 1969). Fertilization rates in nature are unknown. Meehan (1910) reported hatchery survival from fertilization to hatching on two occasions were 0.3% and 6.6%. Buckley and Kynard (1981) reported a survival of 19.3% from eggs to larvae under hatchery conditions. Whether these low survival values are due to low fertilization rates is unknown.

3.15 Gonads

Female and male shortnose sturgeon have two gonads. I females, one gonad is usually slightly larger than the other. Durin development the gonads change dramatically in color and siz Dadswell (1979) has described the stages as shown in Table 5.

Dadswell (1976) found female gonad weight during stage I averaged 10% of total body weight (Table 6). Dadswell (197 described the seasonal pattern of gonad tissue growth and foun an abrupt increase in weight during July to October with a subs quent further slow increase during winter. Between July an September, ripening females gained between 15 to 30% of the total body weight (Table 7). When fully ripe (stage V), fema gonads averaged 21-28% of total body weight (Table 6) (Dadswe 1979; Marchette and Smiley 1982 see Table 2, footnote 24 Spent (stage IV) female gonads weighed 4-6% of total bod weight.

Male shortnose sturgeon gonads are usually of equal size. The are grayish white to white throughout development (see abov and vary between 5% in stage II and 15% in stage V of total bod weight.

Fecundity

Fecundity of shortnose sturgeon in the Saint John Rive Canada, ranged from 27,000 to 208,000 eggs/fish (Table 6) ar was directly related to total body weight. The fecundity relatio ship was Log F (eggs $\times 10^3$) = 3.92 + 1.14 Log W (total weight kg) (Dadswell 1979).

Fecundity of Altamaha River shortnose sturgeon was betwe 79,000 and 90,000 eggs for fish between 75 and 87 cm FL (He and Gilbert 1978 see Table 2, footnote 27). Marchette and Smil (1982 see Table 2, footnote 24) found a 58 cm FL female from t Pee Dee River contained 30,000 eggs. Saint John River fish had mean of 11,568 eggs/kg body weight (Dadswell 1979) but He and Gilbert (1978 see Table 2, footnote 27) and Marchette a Smiley (1982 see Table 2, footnote 24) found southern shortno

Table 5.—Classification and description of maturity stages in shortnose sturgeon.

Stage	Period present	Condition of gonad	
		Female	Male
0	All year	Immature, sex macroscopically indeterminate	
I	All year	Eggs small, 0.5 mm, translucent golden brown	Almost clear ribbon, 1-2 mm in width
II	All year	Eggs 0.5 mm, bright yellow, fat body 70% by weight	Ribbon about 5 mm wide, whitish gray, large fat body 10 mm wide, yellowish gray
III	June-Oct.	Egg 1.0 mm, grayish, yellow fat body	10 mm wide, whitish gray, fat body = gonad size
IV	Sept.-Apr.	Eggs 2.0-2.5 mm, chocolate brown, gray polar globule	Testes occupy most of body cavity, white, no fat body, no milt running
V	May-June	Eggs 3.10 mm, black, gray-brown polar globule	Testes occupy most of body cavity, white, milt running
VI	May-Apr.	Spent, gonad pinkish, flaccid, blood clot-, a few aborted eggs	Spent, whitish pink, milt present in body cavity. Males regain condition II quickly, stage VI not present after July.

Table 6.—Gonad development and fecundity of shortnose sturgeon.

FL (cm)	TW (kg)	Stage	Egg diameter (mm)	Gonad wt (g)	% body wt	Number of eggs	Eggs/g gonad	Eggs/kg TW
Saint John River, N.B., Canada								
100	8.6	6	—	505	5.9	—	—	—
107	8.7	6	—	525	6.0	—	—	—
75	4.8	6	—	210	4.4	—	—	—
89	6.3	2	0.52	530	8.4	—	—	—
101	9.3	2	0.54	918	9.8	—	—	—
95	7.7	2	0.54	910	11.8	—	—	—
94	7.7	2	0.53	943	12.2	—	—	—
85	7.5	3	2.01	1,940	24.0	69,150	36	9,220
95	9.2	3-4	2.40	2,310	23.0	125,670	54	13,660
85	7.9	4	2.50	2,020	25.0	85,400	43	10,810
95	12.0	4	2.50	3,100	26.0	148,590	48	12,380
107	18.3	4	2.70	4,810	27.0	208,000	43	11,370
66	2.5	5	3.10	425	17.0	26,775	63	10,710
76	5.2	5	3.05	1,030	19.8	63,345	61.5	12,181
83	7.3	5	3.00	1,776	24.3	88,800	50.0	12,164
90	5.2	5	3.00	1,318	25.0	49,000	38	9,430
98	7.2	5	3.20	1,650	22.9	96,525	58.5	13,406
109	10.7	5	3.18	2,511	23.5	126,379	50.3	11,811
Pee Dee River, South Carolina								
58	1.8	5	3.15	518	28.0	30,000	57.9	16,216
Altamaha River, Georgia								
76	5.3	5	—	—	—	79,383	—	14,865
77	5.5	5	—	—	—	80,049	—	14,475
87	6.6	5	—	—	—	90,361	—	13,608

sturgeon to have about 14,000-16,000 eggs/kg body weight. Egg size in the examined South Carolina fish was the same as the northern population which may indicate southern shortnose sturgeon produce more eggs at a given size. This is consistent with other fish species having a wide north to south range of spawning populations (Jones 1976).

3.16 *Spawning*

Shortnose sturgeon spawn once a year during spring but among adults in northern populations and perhaps in southern ones also, spawning is not a yearly event for each individual. Dadswell (1979) found the spent/recovering condition persisted up to 10 mo after spawning and stage II females were present all year. Only 30% of adult females examined during the August to March ripening period were found to be developing sexually as were 50% of the males. The evidence suggests females probably spawn at a maximum of once every 3 yr and males every other year in the Saint John River, Canada. In addition, check zones (a series of closely grouped yearly annuli) of the pectoral ray, which can be interpreted as leading up to spawning (Roussow 1957), may indicate a duration of as long as 5-11 yr between spawnings (Dadswell 1979).

Taubert (1980b) described a similar situation in the Holyoke Pool, Connecticut River. Using check zones, he found male shortnose sturgeon spawned for the first time at a mean of 9.8 yr and a second time at a mean of 18.2 yr. Range in years between first and second spawnings was 4-12 ($\bar{X} = 8.4$ yr). Taubert (1980b) did not identify any females spawning for the second time. Also of 193 sturgeon aged, 51 had spawned once (8-14 yr; $\bar{X} = 10$) and 12 had spawned a second time (14-20 yr; $\bar{X} = 17.9$). In the Hudson River, tagged males returned to the spawning grounds in each of two successive years (Dovel 1981 see Table 2, footnote 15). Marchette and Smiley (1982 see Table 2, footnote 24), also using check zones, identified a 3-yr spawning periodicity for one male and two females from the Pee Dee River, S.C.

Table 7.—Average percent weight gain ($\overline{WG}$) and time at large ($\overline{\Delta T}$) of mature, adult, shortnose sturgeon (+70 cm) between successive captures June-September in the same year in the Saint John estuary, Canada.

Month of capture and recapture	Reproductive females N	$\overline{WG}$ (%)	$\overline{\Delta T}$ (d)	Nonreproductive adults N	$\overline{WG}$ (%)	$\overline{\Delta T}$ (d)
June-July	7	9.3	41.4	14	5.8	33.3
June-August	5	14.5	59.6	6	2.3	59.0
June-September	8	18.0	84.4	11	8.0	60.3
July-August	4	15.0	43.8	15	3.7	30.1
July-September	5	19.5	63.6	8	3.8	57.7
August-September	4	17.7	47.5	7	2.8	29.8

Spawning period and location

Spawning occurs between February and May depending on latitude. Ripe and spent females were present in the Altamaha River, Ga., during February (Heidt and Gilbert 1978 see Table 2, footnote 27), and during January to April in the Savannah, Santee, and Pee Dee Rivers, S.C. (Marchette and Smiley 1982 see Table 2, footnote 24). Ripe and running-ripe females occur during the middle 2 wk of April in the Delaware (Meehan 1910; Hoff 1965), the last week of April and first week of May in the Hudson (Greeley 1937; Pekovitch 1979 see Table 2, footnote 14), the first 2 wk of May in the Connecticut (Taubert 1980a; Buckley 1982) and the Androscoggin (Squiers 1982 see Table 2, footnote 4), and the middle 2 wk of May in the Saint John River, Canada (Dadswell 1979; Anonymous 1980 see Table 2, footnote 2).

Temperature is probably the major factor governing spawning. Meehan (1910), Heidt and Gilbert (1978 see Table 2, footnote 27), Taubert (1980a), Dadswell (1979), and Buckley and Kynard (1981) all reported shortnose sturgeon spawning to occur between 9° and 12°C. Other apparent factors influencing spawning are the occurrence of freshets and substrate character. Taubert (1980a), Dadswell (1979), Buckley (1982), and Squiers (1982 see Table 2, footnote 4) indicated spawning occurs during or soon after peak flows in the spring. Spawning grounds examined to date in the north are in regions of fast flow (40-60 cm/s) with gravel or rubble bottoms (Taubert 1980a; Pekovitch 1979 see Table 2, footnote 14; Anonymous 1980 see Table 2, footnote 2; Buckley 1982). Locations are generally well upriver of the summer foraging and nursery grounds (rkm 100-200). In South Carolina, on the other hand, spawning occurs in flooded, hardwood swamps along inland portions of the rivers (Savannah, Pee Dee; Marchette, unpubl. data).

Ratio and distribution of sexes on spawning grounds

Pekovitch (1979 see Table 2, footnote 14) found a ratio of 2.5:1 males to females on the spawning grounds between rkm 135 and 140 on the Hudson River during 1979. Taubert (1980b) found a ratio of 3.5:1 males to females on the Holyoke Pool spawning grounds over two spawning seasons.

There appeared to be no tendency for sexes to segregate on the spawning grounds. There is some evidence to suggest males migrate to the spawning ground first (Dovel 1981 see Table 2, footnote 15).

3.17 Spawn

Shortnose sturgeon eggs are dark brown to black with a light-gray polar body (Meehan 1910; Dadswell 1979). Egg development in the gonad is illustrated in Figure 10. Size change is marked during late summer and early fall (Dadswell 1979). Ripe eggs have a diameter of 3.00-3.20 mm (Table 6; Dadswell 1979) and size does not change after fertilization or water hardening (Reed;[12] Buckley and Kynard 1981). In the Saint John River, Canada, shortnose sturgeon eggs are often parasitized by *Polypodium* sp. (≅ 50% of females) but the number of parasitized eggs per female has never been observed to exceed 1%. The egg is enlarged, light gray in color (Fig. 11; Hoffman et al. 1974), and is most evident in stage IV and V females.

The eggs are separate when spawned but become adhesive within 20 min of fertilization. Adhesiveness is probably due to

[12]R. J. Reed, Professor, Massachusetts Cooperative Fishery Research Unit, Department of Forestry and Wildlife, University of Massachusetts, Amherst, MA 01002, pers. commun. June 1975.

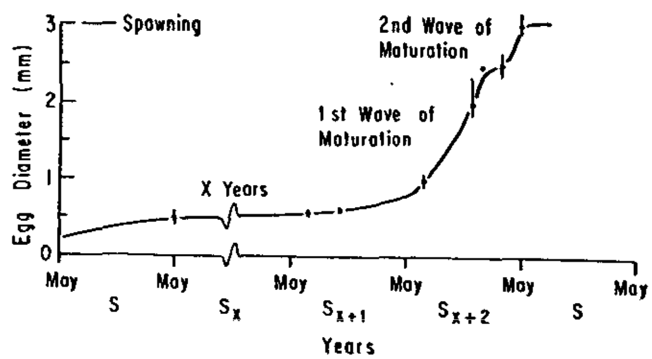

Figure 10.—Duration of ripening conditions and change in mean egg diameter during gonad development between spawning of female shortnose sturgeon. Bars are range of egg diameter.

Figure 11.—Shortnose sturgeon stage V egg (left) and egg parasitized by *Polypodium* sp. (right). Enlarged eggs average 4 mm in diameter.

surface protuberances like the spokes of "iron jackstr (Meehan 1910; Markov 1978). Sinking rates of unfertilized fertilized eggs are 5.2 ± 0.8 and 5.2 ± 0.2 cm/s, respecti (Anonymous 1980 see Table 2, footnote 2).

3.2 Preadult phase

3.21 Embryonic phase

Little is known about embryonic development of short sturgeon but it is probably very similar to other specie *Acipenser* (Ryder 1890; Ginsburg and Dettlaf 1969). Me (1910) gave the following description: During development t was little change in the hue (i.e., brown for about two-thirds cumference, grayish white on the other), between 8° and 12°C eggs hatched 13 d after fertilization, eyes appeared first on d and were light colored, on day 8-9 they darkened, fish shape distinguishable on day 10. At 17°C, hatching occurs in 8 d bu development period is similar if converted to degree-days (13 143) (Buckley and Kynard 1981). Near time of hatching, may become clear and amber and emergence is tail (Anonymous 1980 see Table 2, footnote 2).

Mortality

No data on natural egg mortality are available.

Meehan (1910) reported a fertilization to hatching surviv 0.3% and 6.6% for two attempts under artificial condit Buckley and Kynard (1981) reported hatching survival of 19

3.22 Larval phase

In Meehan's (1910) hatching experiments, no swim-up o red and the larvae remained for several days at the bottom c jar, but Buckley and Kynard (1981) found larvae to be activ photopositive during the first 2 d. Larvae of approxim 10-d-old attempt to remain on the bottom or placed thems under any available cover in aquaria (Pottle and Dadswell see Table 2, footnote 1; Anonymous 1980 see Table 2, foo 2). Buckley and Kynard (1981) found week-old larvae t photonegative and form aggregations with other larvae in con ment.

Hatching size is 7.3-11.3 mm (Taubert 1980a; Anony 1980 see Table 2, footnote 2; Buckley and Kynard 1981). H lings < 8.0 mm did not survive (Anonymous 1980 see Tal footnote 2). Taubert and Dadswell (1980), Pekovitch (197 Table 2, footnote 14), and Bath et al. (1981) have described tured or reared larvae (Table 8).

At hatching, the larvae are tadpolelike and dark gray, w large yolk sac, the head is closely attached to the yolk sa mouth is unopened, and pectoral and pelvic fins are undeve (Fig. 12). At 14 mm TL, approximately 10 d after hatchin barbels are formed, the mouth is large and distinctly *breviros* like but has teeth (9-12 upper, 8-11 in lower jaw), pectoral b pelvic fins are present, eye size averages 0.70 mm, the anl the dorsal fin is present, and the yolk sac is gone (Fig (Taubert and Dadswell 1980). By 16.3 mm pelvic fins are pi (Fig. 14) and by 20 mm scutes, nose shape, and dorsal and fins are characteristic of the species (Fig. 14) (Pekovitch 197 Table 2, footnote 14; Anonymous 1980 see Table 2, footno

Table 8.—Morphological and meristic parameters of shortnose sturgeon larvae from Pekovitch (see Table 2, footnote 14), Taubert and Dadswell (1980), Anonymous (see Table 2, footnote 2), and Bath et al. (1981). Larvae are from (a) Saint John River, Canada; (b) Connecticut River; (c) Hudson River and their status is (1) reared from egg or (2) captured in drift sampling nets.

Locality and status	Total length (mm)	Preanal myomeres	Postanal myomeres	Total	Snout to vent length % TL	Eye diameter	Yolk sac length % TL	Head width (mm)	Mouth width (mm)	MW/HW %	Upper teeth	Lower teeth	Dorsal fin rays	Dorsal scutes	Probable or known age (d)
a, 1	7.3	34	24	58	68	—	—	1.0	—	—	—	—	—	—	<1
a, 1	7.9	35	23	58	68	—	36	0.9	—	—	—	—	—	—	<1
a, 1	8.1	33	24	57	63	—	—	0.9	—	—	—	—	—	—	<1
a, 1	8.6	33	19+	52+	70	0.43	34	1.0	0.28	28	—	—	—	—	<1
b, 2	9.1	34	22	56	69	0.30	31	—	—	—	—	—	—	—	<1
a, 1	9.5	34	24	58	70	0.64	37	1.1	0.34	31	—	—	—	—	1
a, 1	9.6	35	24	59	67	0.64	34	1.1	0.42	38	—	—	—	—	1
b, 2	10.0	34	20	54	70	0.32	32	—	—	—	—	—	—	—	<1
a, 1	10.1	36	24	60	63	0.57	32	1.1	0.45	41	—	—	—	—	1
b, 2	11.0	33-36	20-21	53-57	67	0.32	—	—	—	—	—	—	—	—	<1
b, 2	11.1	34	22	56	65	—	—	—	—	—	—	—	—	—	1?
b, 2	11.3	33-34	22-23	55-57	68	0.34	—	—	—	—	—	—	—	—	<1
b, 2	12.5	33	22	55	66	—	—	—	—	—	—	—	—	—	1?
a, 2	13.0	34	22	56	61	0.79	—	2.0	1.50	75	—	—	—	—	8
a, 2	14.7	34	22	56	61	0.79	—	2.1	1.50	71	12	11	14	—	8
c, 2	15.3	—	—	—	59	0.70	—	2.0	1.50	75	—	—	—	—	10?
c, 2	15.5	—	—	—	61	0.70	—	2.0	1.50	75	—	—	—	—	10?
c, 2	15.6	—	—	—	58	0.70	—	2.0	1.50	75	—	—	—	—	10?
c, 2	16.0	—	—	—	55	0.70	—	2.3	1.50	65	—	—	—	—	10?
a, 1	16.2	35	26	61	62	0.86	—	2.5	2.07	83	9	10	15	—	10
c, 2	16.3	37	21	58	54	—	—	—	—	—	—	—	16	—	10
a, 1	17.1	35	24	59	58	1.00	—	2.6	2.28	87	11	8	14	—	13
a, 1	17.2	—	—	—	61	0.85	—	2.8	2.00	71	—	—	16	—	13
c, 2	17.5	36	22	58	57	—	—	—	1.80	—	—	—	16	—	15?
c, 2	18.0	37	22	59	58	—	—	—	1.80	—	—	—	17	—	15?
c, 2	18.2	37	22	59	58	—	—	—	1.60	—	—	—	15	—	15?
a, 1	20.4	—	—	—	59	1.07	—	3.1	2.85	92	10	6	17	8	28

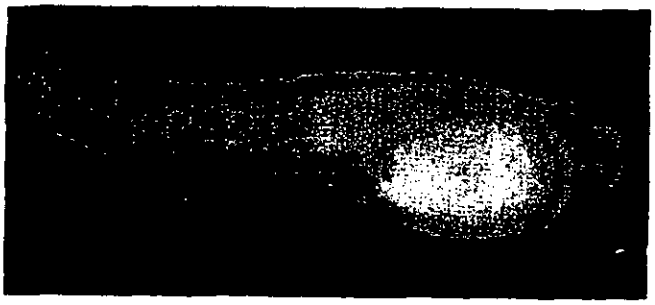

Figure 12.—One- or 2-d old, 10 mm TL shortnose sturgeon protolarvae from the Holyoke Pool, Connecticut River. Note large yolk sac, continuous fin fold, lack of barbels, and no lateral fins (courtesy of B. Taubert, Univ. of Mass.).

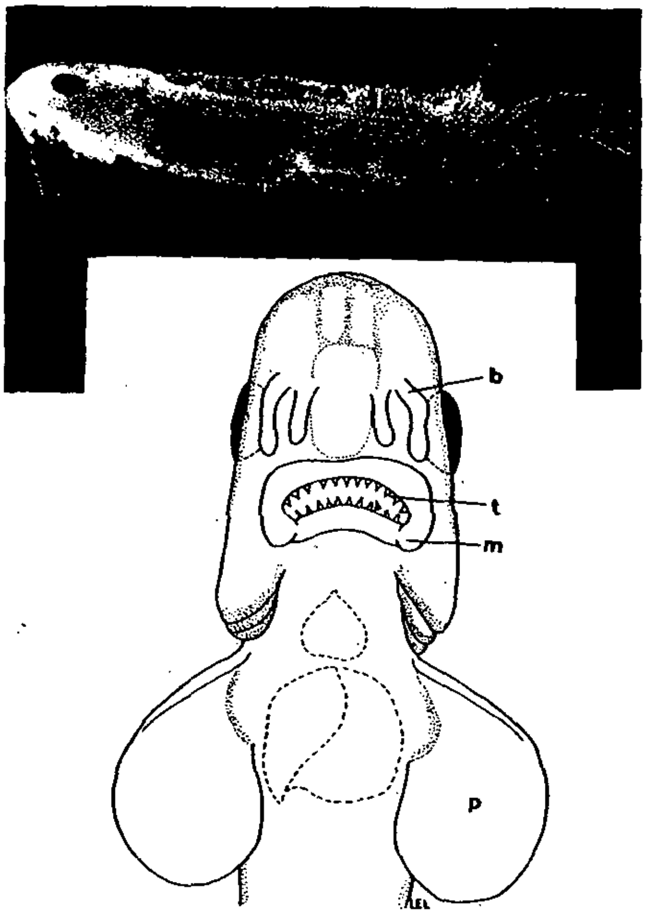

Figure 13.—Upper. Approximately 10-d-old, 14.7 mm TL shortnose sturgeon mesolarvae from the Saint John River, Canada. Note: barbel (b) just anterior to eye on ventral surface and anlage (a) dorsal fin. Lower. Ventral view of head of 14.7 mm TL mesolarvae illustrating mouth (m), teeth (t), barbels (b), and pectoral fins (p).

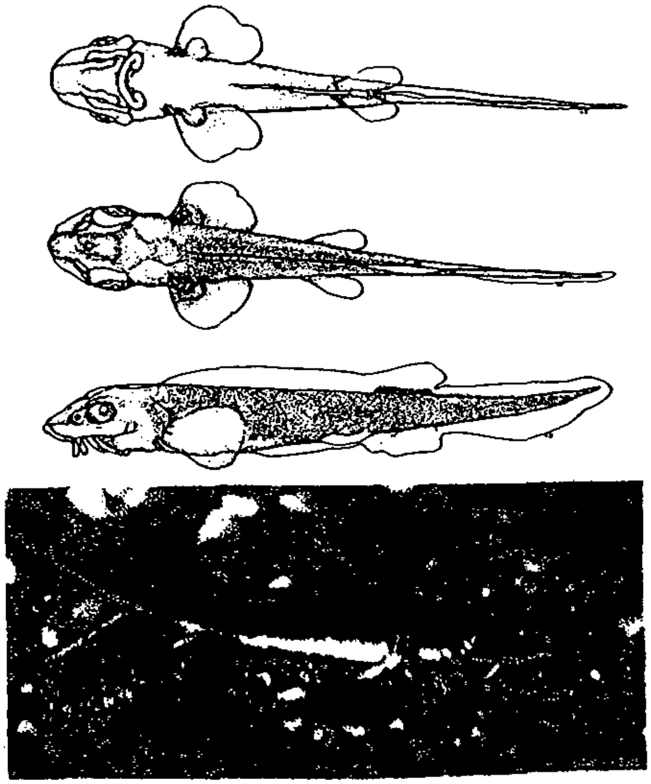

Figure 14.—Upper. Ventral, dorsal, and lateral views of 16.3 mm TL shortnose sturgeon from the upper Hudson River (after Pekovitch 1979 see Table 2, footnote 14). Lower. Lateral view of 20 mm shortnose sturgeon reared in captivity from Connecticut River stock (courtesy of Buckley, Univ. Mass).

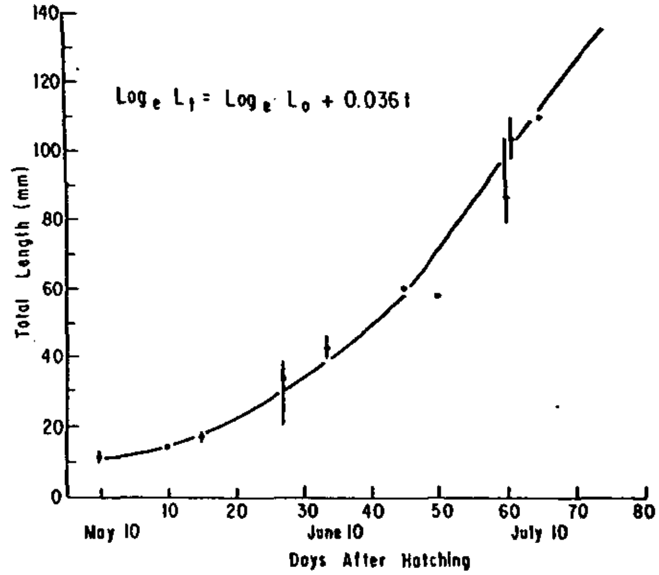

Figure 15.—Larval growth of shortnose sturgeon. Figure is composite of data from the Saint John River, Canada, the Connecticut River (Taubert 1980a), and the Hudson River (Pekovitch 1979 see Table 2, footnote 14). May 10th was selected as mean hatching date in all three river systems.

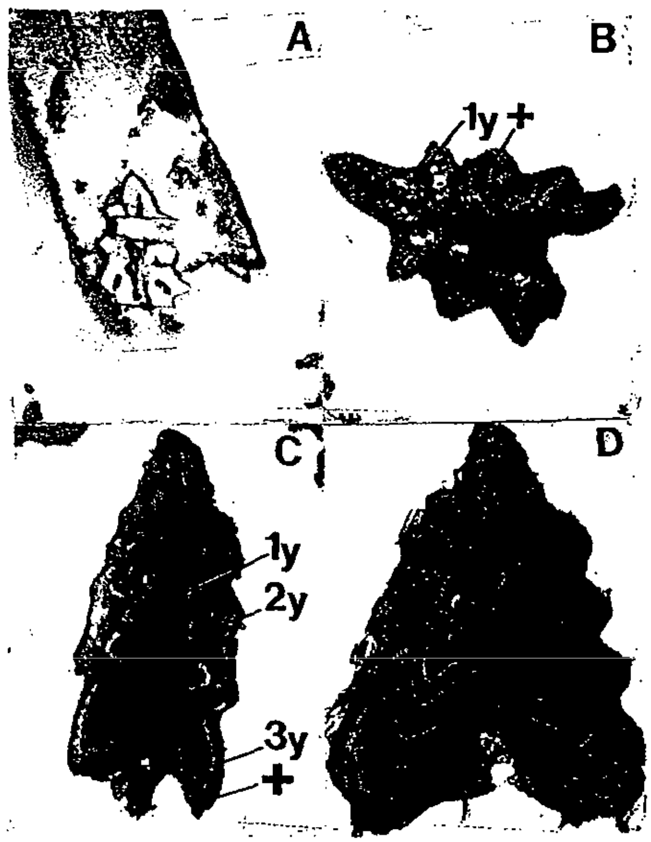

Figure 16.—Transverse sections of the marginal ray of the pectoral fin of shortnose sturgeon showing annuli. Dark zones are summer-formed dense bone; translucent zones, winter bone. (A) 14.7 cm, captured 20 May 1979, 1 yr. (B) 19.2 cm, 1 August 1979, 1 + yr. (C) 29 cm, 11 July 1979, 3 + yr. (D) 45 cm, 9 yr (Pottle and Dadswell 1979 see Table 2, footnote 1).

Growth of fry

Early growth of shortnose sturgeon is rapid (Fig. 15). This species attains between 14 and 30 cm by the end of its first growing season, depending on latitude. Juveniles are between 15 and 19 cm during July of their second summer season in the Saint John River (Fig. 16) (Dadswell 1979). Evidence from the Hudson River suggests the juveniles may reach 25.0 cm by the end of their first growing season (Pekovitch 1979 see Table 2, footnote 14) and growth averages 3.0 mm every 10 d (Fig. 15). Growth may be even more rapid in the southern United States (Heidt and Gilbert 1978 see Table 2, footnote 27).

A growth equation for shortnose larvae using data from the Hudson, Connecticut, and Saint John Rivers was derived as follows:

$$\mathrm{Log_e}\, L_t = \mathrm{Log_e}\, L_0 + 0.036\, t$$

where L_0 = 10.7 mm and t is time in days from hatching date (chosen as 10 May). In the Saint John River, Canada, shortnose sturgeon exhibit a two-phase growth curve (Fig. 17) with a slow growing "parr" stage between ages 1 and 9 (Pottle and Dadswell 1979 see Table 2, footnote 1). Similar growth patterns are known for Russian sturgeon species (Pavlov 1971).

Survival

No information on natural survival rates of shortnose sturgeon larvae and juveniles is available.

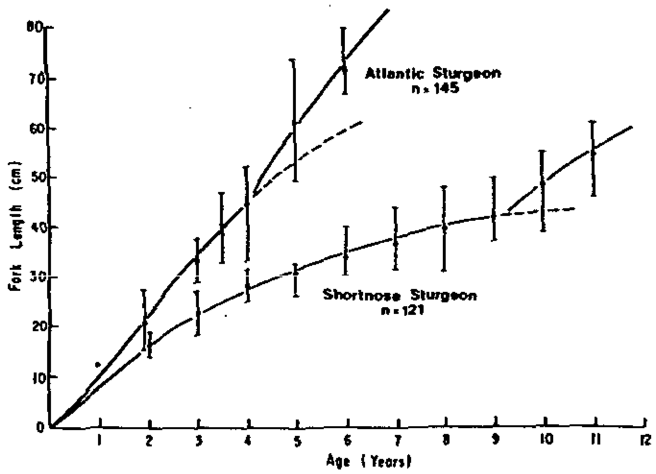

Figure 17.—Juvenile growth of shortnose sturgeon from age 1 to 11 in the Saint John River, Canada (Pottle and Dadswell 1979 see Table 2, footnote 1). Bars represent range of length at age and open dots are mean size.

Predators

The only record of predation on larval or juvenile shortnose sturgeon is the occurrence of 24 juveniles approximately 5 cm FL found in perch (*Perca flavescens*) stomachs from the Androscoggin River, Maine (Squiers[13]).

3.23 Adolescent phase

Young shortnose sturgeon begin to resemble adults by the time they are 20-30 mm in length (Fig. 18), but they remain juveniles until 45-55 cm FL or from 3 to 10 yr of age, depending on latitude.

[13]T. S. Squiers, Fisheries Biologist, Maine Department of Marine Resources, Augusta, ME 04333, pers. commun. October 1976.

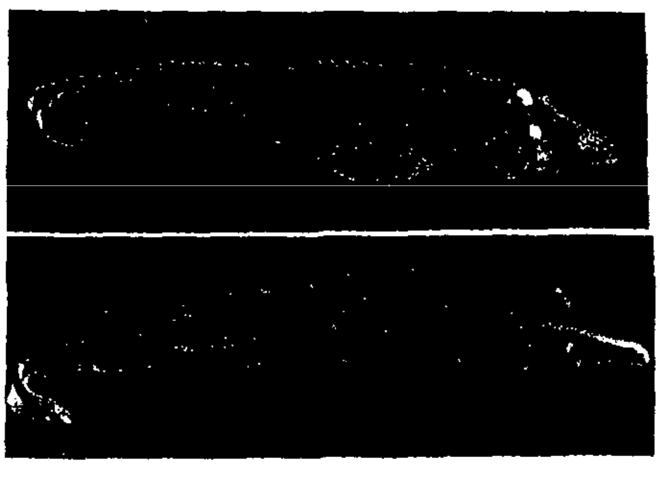

Figure 18.—Dorsal and ventral views of 5 cm TL, young-of-the-year shortnose sturgeon taken from the stomach of a perch captured in the Androscoggin River, Maine.

3.3 Adult phase (mature fish)

3.31 Longevity

The oldest shortnose sturgeon determined to date was a 67-yr-old female from the Saint John River, Canada; the oldest male examined, also from the Saint John River, was 32 yr (Dadswel 1979). Maximum ages determined to date for other river system are less but may be a reflection of smaller sample size. They are Kennebec, 40 yr (Squiers[14]); Connecticut, 34 yr (Taubert 1980b) Hudson, 37 yr (Dovel 1981 see Table 2, footnote 15); Pee Dee, 2(yr (Marchette and Smiley 1982 see Table 2, footnote 24) Altamaha, 10 yr (Heidt and Gilbert 1978 see Table 2, footnote 27), but based on a small female (89 cm FL). In general, northern populations of shortnose sturgeon have a life span similar to other *Acipenser*, but southern populations may be relatively short-lived.

3.32 Hardiness

No research has been done on the physiological hardiness of shortnose sturgeon.

Shortnose sturgeon have been captured in the Altamaha River in 34°C water but Dadswell (unpubl. data) found young from the Saint John River, Canada, to experience distress and/or rapid mortality at temperatures over 25°C.

Shortnose sturgeon are known to live in salinities up to 30 ‰ (Holland and Yelverton 1973; Marchette and Smiley 1982 see Table 2, footnote 24).

Dovel (1981 see Table 2, footnote 15) found that shortnose sturgeon from the Hudson estuary have severe cases of fin rot and body sores, presumably from industrial pollutants, but are reasonably healthy otherwise (i.e., weight-length relation normal; Fig. 19).

3.33 Competitors

Shortnose sturgeon probably have no other competitors for spawning area since they utilize the habitat early in the spring and

[14]T. S. Squiers, Fisheries Biologist, Maine Department of Marine Resources, Augusta, ME 04333, pers. commun. November 1981.

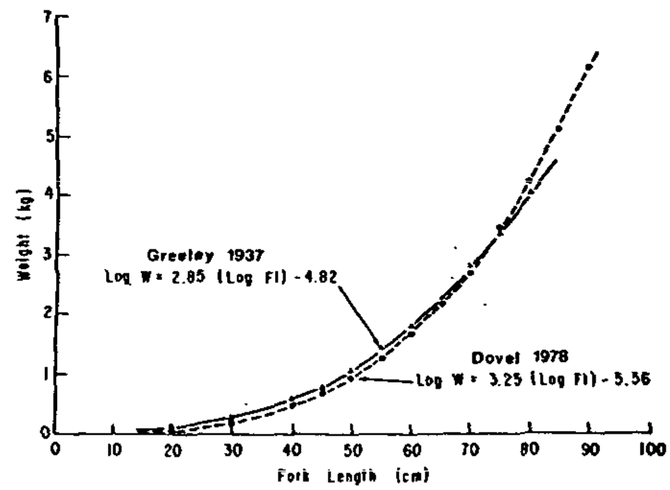

Figure 19.—Weight-length relationships of shortnose sturgeon from the Hudson River, N.Y. There was a 40-yr interval between the two studies.

temporally avoid the spawning of Atlantic sturgeon. Other possible competitors could be walleye, *Stizostedium vitreum*, and/or spring-spawning rainbow trout, *Salmo gairdneri*.

Shortnose sturgeon compete for food with most other benthic feeders, particularly those which exploit molluscs. In the Saint John River, Canada, juveniles apparently avoid competition with suckers (*Catostomus*) and Atlantic sturgeon, *Acipenser oxyrhynchus*, by spatial separation, i.e., juveniles occupy the deep, freshwater channels; the suckers, the shallows; the Atlantics the deeper saline parts of the estuary (Dadswell 1979). A large degree of habitat overlap occurs but darkness and/or turbidity may enhance the success of the sturgeon because of the presence of barbels.

In the Saint John River, Canada, shortnose sturgeon and whitefish, *Coregonus clupeaformis*, compete for gastropods in the upper estuary and shortnose sturgeon and winter flounder, *Pseudopleuronectes americanus*, for *Mya arenaria* in the lower estuary. Competition with the whitefish, however, is limited because the two fish populations are segregated by temperature (Fig. 20) and there appears to be some resource partitioning between the two (Fig. 21). The sturgeon utilize the gastropods during summer, the whitefish, during the cooler period of the year; the sturgeon select the smaller *Amnicola* and *Valvata*, the whitefish, the larger *Lymnaea* and *Physa*.

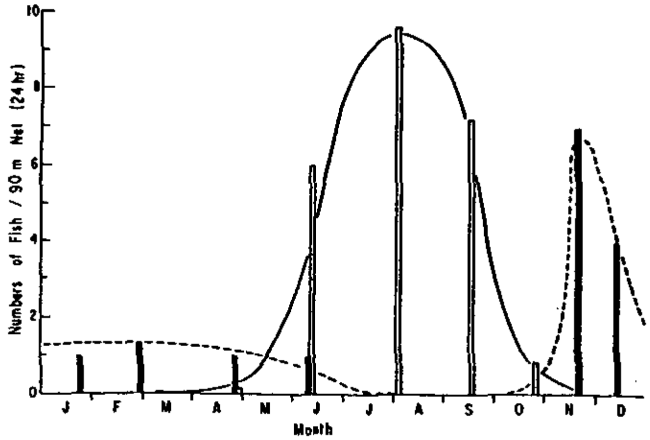

Figure 20.—Utilization of the same feeding site in the Saint John River, Canada, by whitefish (dark bars) and shortnose sturgeon (open bars) on a seasonal basis.

Competition with other fish species for food resources in central and southern Atlantic coast estuaries has not been studied. More intense competition would, however, be expected because of the large and complex fish communities present in the region.

Adult shortnose sturgeon may compete for space with similar sized juvenile Atlantic sturgeon. In the Saint John River, Canada, the two rarely occupy the same habitat and the separation seems to be based on a salinity relationship. Large Atlantic sturgeon juveniles predominate in water > 3 ‰ and shortnose adults in < 3 ‰ (Appy and Dadswell 1978; Dadswell 1979). In the saline water of Winyah Bay, S.C., Atlantic sturgeon outnumber shortnose sturgeon 2 to 1 (Marchette and Smiley 1982 see Table 2, footnote 24) and may compete with them.

3.34 Predators

Adult shortnose sturgeon may have few predators. In general, they are one of the larger fish occurring in their freshwater

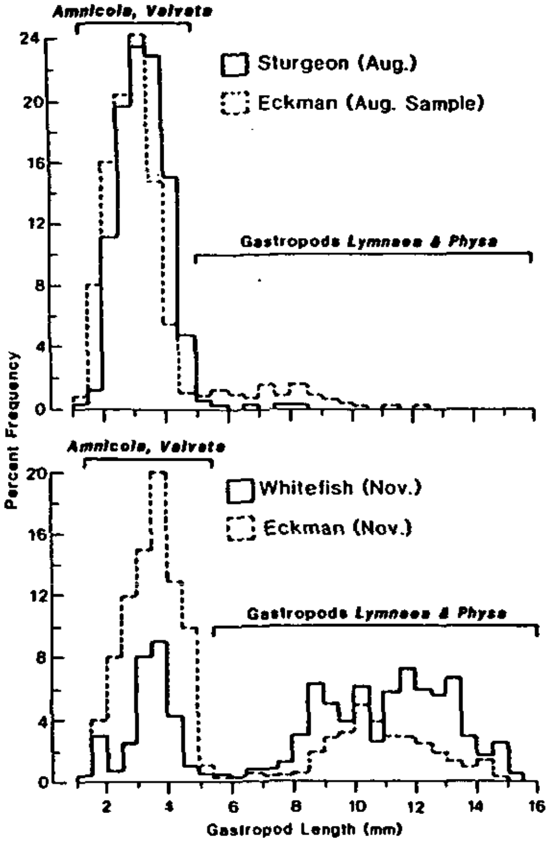

Figure 21.—Size and frequency of gastropods found in stomachs of shortnose sturgeon and lake whitefish feeding on the same resource but at different times of the year.

habitat. In the south, alligators; gars; and striped bass, *Morore saxatilis*; may be suspected as predators. In marine habitats, they could be preyed upon by sharks or seals but the only evidence for this may be the occasional specimen lacking a tail (see section 3.35).

3.35 Parasites, diseases, injuries, and abnormalities

A checklist of parasites recorded from shortnose sturgeon is given in Table 9. Intensity of infestation is low in most cases except for *Capillospirura*. None appear harmful to the sturgeon.

No diseases have been recorded from shortnose sturgeon.

Abnormalities and healed injuries appear to be a common occurrence among shortnose sturgeon. Fried and McCleave (1974) described two shortnose sturgeon from Montsweag Bay, Maine, one with only one barbel and one with forked barbels. They also observed a bilaterally blind specimen. Table 10 summarizes the numerous abnormalities and healed injuries observed during 6 yr of sampling in the Saint John estuary, Canada (Dadswell, unpubl. data). One blind specimen was observed with the eyes completely overgrown by flesh, another had no suggestion of an eye on its right side. The first fish was large and otherwise in excellent condition and was completely black in color, both dorsally and ventrally. Figure 22 illustrates two other findings: No nasal septum (3 specimens); no tail (observed twice). Dovel (1981 see Table 2, footnote 15) found that many adult shortnose sturgeon from the Hudson River have severe cases of fin rot and abdominal sores. Both problems were thought related to industrial pollution. Pekovitch (1979 see Table 2, footnote 14)

Table 9.—Parasites recorded from shortnose sturgeon.

Group and species	Parasite location	Capture locality	Authority
Coelenterata			
Polypodium sp.	Eggs	Saint John River[1]	Hoffman et al. (1974)
Diclybothrium armatum	Gills	Saint John River[1]	Appy and Dadswell (1978)
Spirochis sp.	Mesenteric blood vessels	Saint John River[1]	Appy and Dadswell (1978)
Nitzschia sturionis	Gills	N.Y. Aquarium (may be unnatural infection)	MacCallum (1921)
Nematoda			
Capillospirura pseudoargumentosus	Gizzard	Saint John River[1]	Appy and Dadswell (1978)
Acanthocephala			
Fessesentis friedi	Spiral valve	Saint John River[1]	Appy and Dadswell (1978)
Echinorhynchus attenuatus	?	Woods Hole	Sumner et al. (1911)
Hirundinea			
Calliobdella vivida	External	Connecticut River	Smith and Taubert (1980)
Piscicola milneri	External	Connecticut River	Smith and Taubert (1980)
Piscicola punctata	External	Connecticut River	Smith and Taubert (1980)
Arthropoda			
Argulus alosa	External	Saint John River[1]	Appy and Dadswell (1978)
Pisces			
Petromyzon marinus	External	Saint John River[1]	Dadswell (pers. obs.)

[1]Saint John River, N.B., Canada.

Table 10.—Abnormalities and healed injuries found among shortnose sturgeon from the Saint John River, Canada, and the Hudson River, N.Y.

Condition	Times observed	Remarks
Total blindness (no eyes)	1	Birth defect, entire sturgeon melanistic
One eye blind	1	Eye completely missing
Lacking nasal septum	3	Birth defect
Bent backbone, shortened caudal peduncle	4	Birth defect?
Lateral spine curvature (scoliosis)	1	Birth defect?
Extra pelvic fin	2	Birth defect
Loss of pelvic or pectoral fin	3	Healed injury
No tail	2	Healed injury, extra long rays in dorsal and anal fin
Extreme blunt nose	8	Healed injury Sometimes nose cleft
U-shaped snout	21	Genetic (Hudson only)
Fin rot	76% of population	Hudson River only

described a physical deformity involving a U-shaped section missing from the snout of shortnose sturgeon in the Hudson River. A total of 21 specimens, one as large as 87 mm TL, had the deformity and he thought the trait was probably inherited.

3.36 Physiology and biochemistry

No data available.

3.4 Nutrition and growth

3.41 Feeding

Time of day

Dadswell (pers. obs.) found shortnose sturgeon were most active (most readily captured) during night or on windy days when water

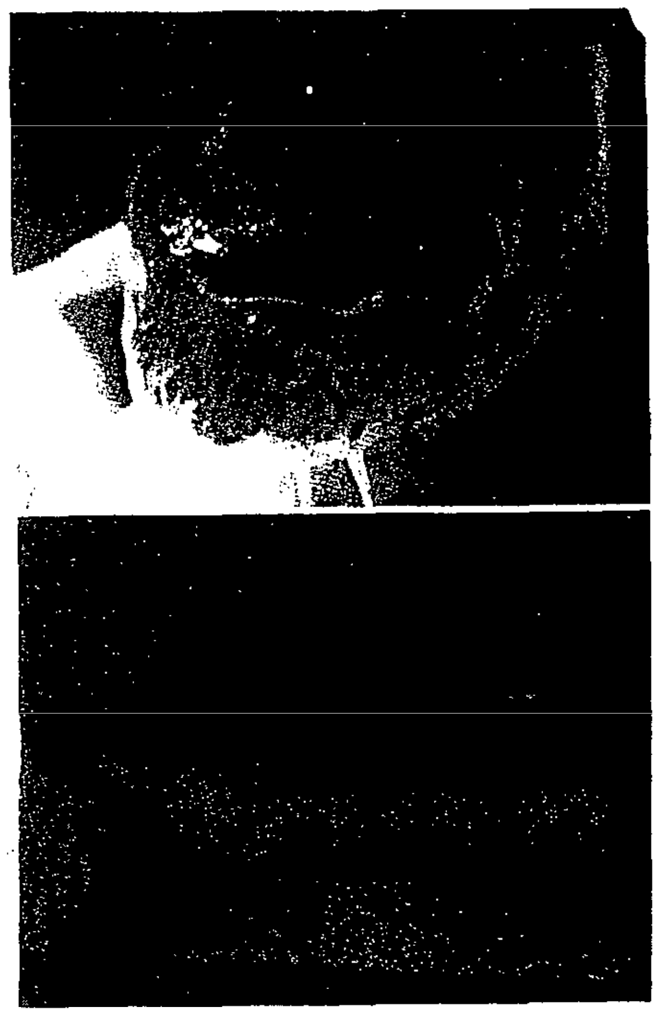

Figure 22.—Defects and/or injuries of shortnose sturgeon: top, no nasal septum; bottom, caudal fin missing.

turbidity was high. Gill net catches were large during these periods and sampled fish always contained full gastrointestinal tracts. Dovel (1978 see Table 2, footnote 13) described Hudson River shortnose sturgeon as moving into shallows during the night, presumably to feed. Marchette and Smiley (1982 see Table 2, footnote 24) observed shortnose sturgeon feeding at night on molluscs off the undersides of lily pads.

Place

All feeding of shortnose sturgeon seems to be either benthic or off plant surfaces. In freshwater portions of the Saint John estuary, Canada, adult shortnose sturgeon foraged in weedy backwaters or along the river banks over mud bottoms in depths of 1-5 m (Dadswell 1979). During late summer, feeding areas tended to be in deeper water (5-10 m), perhaps in response to higher temperatures in the shallows. What little feeding occurred in freshwater during the fall and winter took place in deep water (15-25 m). Juvenile shortnose sturgeon feed primarily in the deep channels (10-20 m) over sandy-mud or gravel-mud bottoms (Pottle and Dadswell 1979 see Table 2, footnote 1).

In saline water of the lower Saint John estuary, adult shortnose sturgeon feed over sandy-mud or mud bottoms in 5-10 m depths, both in summer and winter. McCleave et al. (1977) found shortnose sturgeon in Montsweag Bay (salinity 18-25 $^{o}/_{oo}$) were feeding over mud-tide flats, mostly in 1-5 m depths. Townes (1937) described the shortnose sturgeon as feeding in coves along the Hudson River over mud bottoms in 4-10 m of water. Marchette and Smiley (1982 see Table 2, footnote 24) found the summer feeding habitat was characterized by shallow water with sandy bottoms and emergent macrophytes and the winter feeding habitat with deeper water and mud bottom.

Manner of feeding

The shortnose sturgeon, particularly the young, may simply use its protuberant mouth to vacuum the bottom extracting substrate as well as animals. Curran and Ries (1937) described shortnose sturgeon stomachs from Hudson River fish as having 85-95% mud intermingled with plant and animal debris. During winter in South Carolina, sturgeon stomachs contained 90% by volume nonfood matter (Marchette and Smiley 1982 see Table 2, footnote 24). Dadswell (1979) found a similar situation among juvenile shortnose sturgeon from the Saint John River implying they employed random suctorial feeding.

The stomach contents of many adults from the Saint John River, Canada, and Winyah Bay, S.C., contained little or no nonfood matter. In most adults examined from freshwater portions of the estuary, crop contents were solely food organisms, implying either efficient separation of food and bottom debris between mouth and crop (possibly with ejection of debris out through the gills), or feeding was precisely oriented and took place off vegetative surfaces rather than off mud (Marchette, pers. obs.). The latter possibility is likely a normal occurrence since major shortnose sturgeon prey such as the small gastropods *Annicola limnosa* and *Valvata* spp. (Dadswell 1979), live mainly on the leaves and stems of submerged macrophytes. Stomach contents of adults feeding in saltwater on *Mya arenaria* or *Corbicula manilensis* however, often had a high portion of mud and bottom debris (30-60%), implying that in the situation of partially buried food, they probably vacuumed the bottom.

Regular spatial dispersion of foraging shortnose sturgeon captured in gill nets suggests they feed individually (Dadswell, pers. obs.).

Frequency

Feeding frequency of individual adult shortnose sturgeon is unknown but completely filled gastrointestinal tracts at all times of daily capture during summer in the Saint John River, Canada, suggest feeding is continuous.

Variation of feeding with availability, season, age, size, sex, and physiological condition

The ventral, protrusible mouth and barbels of the shortnose sturgeon are adaptations for a diet of small, live, benthic animals. Adult shortnose sturgeon (+50 cm) generally feed on whatever mollusc is readily available. In the Saint John River, Canada, Dadswell (1979) found shortnose sturgeon fed on *Mya arenaria* in saline water, *Macoma balthica* where it was dominant in brackish water, *Amnicola limnosa* and *Valvata* spp. in freshwater of high chloride content (100-1,000 ppm), and *Pisidium* spp. and *Elliptio complanata* in permanent freshwater regions. Marchette and Smiley (1982 see Table 2, footnote 24) found molluscs were abundant in the sturgeon's diet in freshwater and polychaetes in saltwater. Juvenile shortnose sturgeon feed primarily on benthic insects and crustaceans and their diet is dominated by crustaceans where they are most available and insects where they are most abundant (Townes 1937; Currand and Ries 1937; Dadswell 1979).

Feeding in freshwater portions of the Saint John River, Canada, and Winyah Bay, S.C., is largely confined to periods when water temperature exceeds 10°C (Table 11; Dadswell 1979; Marchette and Smiley 1982 see Table 2, footnote 24). During the warmwater season, gastrointestinal tracts of New Brunswick sturgeon were crammed with prey but in South Carolina many fish were empty. Feeding in freshwater was minimal during winter. At most, a few shortnose sturgeon were found to contain 1-5 small amphipods or isopods. Shortnose sturgeon captured in saline water, however, were found to feed all year but food volume in the gut during winter was about half the summer level (Table 11; Dadswell 1979; Marchette and Smiley 1982 see Table 2, footnote 24). Reduced feeding activity during winter was probably a result of low water temperature.

Dadswell (1979) found that female shortnose sturgeon ceased feeding about 8 mo before spawning. The stomachs of all females examined with stage III or more developed gonads after the beginning of August through to when spawning occurred were empty. Developing males, on the other hand, feed during fall and winter if they are in saline water. Immediately after spawning males and females fed heavily.

3.42 Food

Juvenile shortnose sturgeon eat available benthic crustaceans or insects (Table 12). Townes (1937), Curran and Ries (1937), Dadswell (1979), Pottle and Dadswell (1979 see Table 2, footnote 1), and Taubert (1980b) all found *Hexagenia* sp., *Chaoborus* sp., *Chironomus* sp., *Gammarus* sp., *Asellus* sp., and *Cyathura polita* to be important prey items. Pottle and Dadswell (1979 see Table 2, footnote 1) found young shortnose sturgeon (20-30 cm FL) often feed extensively on Cladocerans. Adult shortnose sturgeon from

Table 11.—Incidence, mean volume, mean dry weight, and fullness of food in stomachs of adult shortnose sturgeon captured in freshwater (<3 ‰) and saline (>3 ‰) portions of the estuary, Saint John River, Canada (N.B.), and Winyah Bay, S.C. (S.C.), in relation to month. Fullness is Blegvard's index ($W \times 10{,}000$) / W_f where W = weight of ration and W_f = weight of fish.

Month	Sample size N.B.	Sample size S.C.	Number empty N.B.	Number empty S.C.	Incidence (%) N.B.	Incidence (%) S.C.	Volume (ml) N.B.	Volume (ml) S.C.	Dry weight (g)	Index of fullness N.B.	Index of fullness S.C.
Freshwater											
January	8	0	8	0	0.0	—	0.0	—	0.00	0.0	—
February	10	0	9	0	10.0	—	0.6	—	0.28	0.7	—
March	8	0	8	0	0.0	—	0.0	—	0.00	0.0	—
April	7	6	5	4	28.6	33.3	2.0	32.0	0.19	2.5	21.2
May	9	3	3	2	66.6	33.3	16.0	2.5	7.32	12.1	2.5
June	12	8	1	7	91.6	12.5	21.9	35.5	9.56	15.7	22.2
July	16	13	4	6	75.0	53.8	30.1	28.2	9.73	22.4	16.3
August	24	16	4	12	83.3	25	40.7	40.5	12.52	25.6	27.1
September	10	0	1	0	90.0	—	40.2	—	17.83	24.8	—
October	3	0	2	0	33.3	—	20.1	—	7.88	12.4	—
November	4	0	3	0	25.0	—	1.4		0.31	3.8	—
December	5	0	4	0	20.0	—	0.5	—	0.18	1.0	—
Saline water											
September	16	0	2	0	87.5	—	37.4	—	10.85	24.5	—
December	—	6	—	1	—	83.0	—	—	12.1		
February	8	6	2	5	75.0	16.7	21.0	0.5	8.20	16.5	0.1
March	—	1	—	1	—	0.0	—	0.0	—	—	0.0
April	2	—	0	—	100.0	—	19.6	—	1.49	2.5	—

the Saint John River, Canada, eat mostly molluscs (Dadswell 1979). Marchette and Smiley (1982 see Table 2, footnote 24) found *Physa* sp. (53%), *Heliosoma* sp. (47%), and *Corbicula manilensis* (33.3%) to be the most commonly occurring items in stomachs of fish captured in freshwater in South Carolina (Table 13). Curran and Ries (1937) combined adult and juvenile food data, making it impossible to interpret their findings beyond the fact that molluscs constituted 25-53% by volume of the gut contents of all their sampled fish. Benthic crustaceans and insects appear to be relatively more important in the diet of adult shortnose sturgeon from the upper Connecticut River (Taubert 1980b; 4,000+ mayflies in one stomach) and the Hudson River (Curran and Ries 1937), but these findings may be a reflection of food availability rather than a preference change. Dadswell (1979) and Marchette and Smiley (1982 see Table 2, footnote 24) found that electivity of shortnose sturgeon for preferred prey was marked and it is possible the occurrence of nonpreferred prey in the gut is a byproduct of the suctorial feeding method. McCleave et al. (1977) found adult shortnose sturgeon in Montsweag Bay (salinity 18-24 ‰) were feeding on *Mya arenaria*, *Crangon septemspinosa*, and small flounder, Dadswell (1979) found *Mya arenaria* dominated the diet in the lower Saint John estuary (20 ‰), and Marchette and Smiley (1982 see Table 2, footnote 24) found mollusc-shell fragments as well as polychaetes in all sampled shortnose sturgeon.

3.43 Growth rate

Growth in length and weight of shortnose sturgeon has been reported from the Saint John River, Canada (Dadswell 1979), the Kennebec River (Squiers and Smith footnote 7), the Connecticut River (Taubert 1980b; Buckley 1982), the Hudson River (Greeley 1937; Pekovitch 1979 see Table 2, footnote 14; Dovel 1981 see Table 2, footnote 15), the Pee Dee-Winyah Bay region (Marchette and Smiley 1982 see Table 2, footnote 24), and the Altamaha River (Heidt and Gilbert 1978 see Table 2, footnote 27). Because of the slow growth of this species, ageing, which is best done by cross-sectioning a pectoral ray, can be difficult (Fig. 23). The first year's growth (Fig. 16) is often lost by sectioning too far from the body or by subsequent growth processes (Fig. 23). Tight belts of annuli, thought to be caused by slow growth during gonad ripening (Roussow 1957), also make interpretation difficult. Recently, Stone et al. (1981)[15] have developed a method for Giemsa staining of decalcified ray cross sections which improves readability.

Figure 24 shows the known growth rates in length of shortnose sturgeon for its latitudinal range and Figures 25, 26, 27, 28, and 29 illustrate length and weight growth for shortnose sturgeon of different age and sex in the Saint John River, Canada (Dadswell 1979), and the Pee Dee-Winyah system, S.C. (Marchette and Smiley 1982 see Table 2, footnote 24).

Shortnose sturgeon grow fastest in the southern portion of their range but apparently attain smaller maximum size than in the north (Fig. 29; Table 14). The von Bertalanffy growth parameter K varies from 0.044 to 0.149 over the north to south latitudinal range of the species. Juvenile growth is rapid in the south and shortnose sturgeon reach 50 cm after only 2-4 yr (Fig. 24). Growth of juveniles is very similar for the three populations so far studied in the central portion of the range. The Holyoke Pool of the Connecticut River has the slowest growing adults known to date (Fig. 24). This slow growth is probably a reflection of early maturity, and the limited food resources available in the freshwater portion of the river to which the population is confined (Taubert 1980b). The maturity inflection (depression of growth rate) of the length-growth curve is very obvious for the Holyoke Pool population (Fig. 24). Growth of juveniles is slowest in the

[15]Stone, W. B., A. M. Narahara, and W. L. Dovel. 1981. Giemsa stained sections of pectoral fin rays for determining the age of sturgeons. Unpubl. ms., 4 p. N.Y. Dep. Environ. Conserv.

Table 12.—Percent occurrence (%) and mean percent volume (%V) of prey in stomachs of juvenile (<50 cm) and adult (>50 cm) shortnose sturgeon from fresh (<3 ‰) and saline (>3 ‰) portions of the Saint John River estuary, Canada.

	Juveniles				Adults			
	Fresh (n=49)		Saline (n=8)		Fresh (n=50)		Saline (n=26)	
	%	%V	%	%V	%	%V	%	%V
ANNELIDA: total	0		0		8		23	
Polychaeta: total	0		0		4	1	23	
Scoleolepides viridis	—		0		—	—	23	13
Hirundinea	0		—		4	1	—	
CRUSTACEA: total	50		100		25		16	
Cladocera								
Eurycercus glacialis	8		—		—	—	—	—
Latona setifera	15		—		—	—	—	—
Ostracoda	20	10	—		0	0	—	
Isopoda: total	30		75		6		12	
Cyathura polita	30	61	75	60	6	4	12	8
Amphipoda: total	30		50		12		0	
Hyalella azteca	0		—	—	12	2	—	
Gammarus tigrinus	30	67	50	45	4	1	0	
Mysidacea: total	10		13		0		0	
Neomysis americana	10	2	13	5	0		0	
Decapoda								
Crangon septemspinosa	—	—	0		—	—	4	2
INSECTA: total	70		63		26		12	
Ephemeroptera	40		—		4		—	
Hexagenia sp.	40	57	—		4	2	—	
Trichoptera	30	38	—		8	2	—	
Diptera	60	63			25		12	
Chironomidae	60	35	63	40	25	3	12	2
Chaoborus punctipennis	20	5	—	—	0	0	—	—
Culicoides sp.	31	—	—	—	—	—	—	—
MOLLUSCA: total	10		13		100		95	
Gastropoda: total	10		13		94		23	
Heliosoma anceps	0		—		66	8	—	
Gyraulus deflectus	0		—		26	2	—	
Physa ancillaria	0		1		14	2	—	
Lymnaea elodes	0		—		60	10	—	
Valvata tricarinata	0		—		62	16	—	
Valvata sincera	0		0		56	5	4	1
Amnicola limnosa	10	15	13	10	88	64	19	5
Pelecypoda: total	0		0		52		95	
Elliptio complanata	0		—		1	1	—	
Sphaerium sp.	0		—		30	18	—	
Pisidium sp.	0		—		12	2	—	
Macoma baltica	—		0		—		38	40
Mya arenaria	—		0		—		81	85
Pisces	0		0		2		4	
Anguilla rostrata (larvae)	0		0		2	10	4	5

Table 13.—Percent occurrence (%) and mean percent volume (% V) of prey in stomachs of adult shortnose sturgeon from fresh (<3 ‰) and saline (>3 ‰) portions of the Winyah Bay estuary, S.C.

	Fresh (n = 15)		Saline (n = 6)	
	%	% V	%	% V
Annelida				
Polychaeta	—	—	—	—
Crustacea				
Amphipoda	26.6	0.9	16.7	0.5
Isopoda	20.0	0.25	—	—
Insecta				
Euphemeroptera				
Hexagenia sp.	13.3	51.4	—	—
Diptera				
Chironomidae	6.6	0.2	—	—
Mollusca				
Corbicula manilensis	33.3	64.3	33.3	0.75
Heliosoma sp.	46.6	12.3	—	—
Physa sp.	53.3	85.9	—	—
Shell fragments	6.6	16.0	100.0	89.7
Vegetative matter	20.0	3.5	—	—
Detritus	6.6	40.0	33.3	15.0
Sand	13.3	80.0	—	—

Saint John River, Canada, but adult growth is sustained throughout life, resulting in a larger maximum size in this population. Figure 25 illustrates the different growth rates between adult and juvenile shortnose sturgeon in the Saint John River. The maturity inflection which begins between ages 7 and 10 is overridden when the juveniles migrate to the inshore regions of the lower estuary and a richer food base, resulting in subsequent growth increment increase (Fig. 30; Dadswell 1979). A similar behavior pattern and growth change occurs in South Carolina (Fig. 30; Marchette and Smiley 1982 see Table 2, footnote 24). Most of the Holyoke population is apparently unable to carry out such a migration (Taubert 1980b) and slow adult growth rates may be the result. The smaller L_∞ of adults in the Kennebec and Hudson Rivers, as compared with the Saint John may be due to stress caused by pollution. In other southern populations, smaller L_∞ is probably an expression of younger maturity and more frequent gonad ripening because of faster juvenile growth and warmer water temperatures. This phenomenon is common to fishes with distinct populations over a south-north latitudinal range (Jones 1976). The weight-age relationship of shortnose sturgeon from four studied populations is illustrated in Figure 31. Weights of stage V females from Altamaha River (Heidt and Gilbert 1978 see Table 2, footnote 27) were adjusted to reflect stage II condition (× 0.80). Weight gain is rapid in the south, slower but sustained in the north, and least during the freshwater stage or for solely freshwater populations (Holyoke). The weight-age relationship for the entire life span of shortnose sturgeon in the Saint John River, Canada, is illustrated in Figure 26. The von Bertalanffy growth equation for this population is $W_t = W_\infty\,(1-e^{-0.047(t-2.061)})^3$.

Average length and weight gain/year in various populations are: 5 cm/yr and 400 g/yr, Altamaha River; 2.0 cm/yr and 260 g/yr, Kennebec River; 1.3 cm/yr and 167 g/yr, Holyoke Pool; 1.5 cm/yr and 300 g/yr, Saint John River, Canada. Dadswell (1979) found in a capture-recapture study over a 4-yr period in the Saint John River that observed average length and weight gain among recaptured shortnose sturgeon was 0.72 cm/yr and 490 g/yr (Table 15). Taubert (1980b) found growth of recaptured fish was 1.8 cm/yr. Buckley (1982) found ripe adults massed below the spawning site in the Connecticut River lost an average 15% of body weight during winter before spawning.

In the Saint John River, Canada, Dadswell (1979) found male and female shortnose sturgeon had different growth relationships (Figs. 27, 28). Males grew more rapidly until mature but growth rate as adults decelerated at a greater rate than females. A similar growth pattern occurs in males and females from South Carolina (Fig. 29; Marchette and Smiley 1982 see Table 2, footnote 24). More frequent ripening of gonads among males may be the cause of this type of growth relationship.

3.44 Weight-length relationships, condition factors

The weight-length relationship for shortnose sturgeon from the Saint John River is illustrated in Figure 32 (Dadswell 1979). It is essentially similar to weight-length relationships of other sturgeon species. Weight gain is slow for the first years of life, then increases for most of the remainder of the life span.

The weight-length relationships for shortnose sturgeon populations studied to date are given in Table 16. Some were calculated from preliminary data provided by various workers. In general, the relationships are similar. Calculated condition factors were lowest for the Kennebec River (Squiers and Smith footnote 7) and the Holyoke Pool populations (Taubert 1980b). Both these populations are somewhat stressed, the Kennebec by pollution (Squiers et al. 1981 see Table 2, footnote 3), the Holyoke by confinement to freshwater. Figure 19 compares the weight-length relationship of the Hudson River population for studies 40 yr apart; capture gear differences aside, the two relationships are remarkably similar. Dadswell (1979) found no statistical difference (paired t-tests) between the weight-length relationships of various spawning stage and sexes of shortnose sturgeon from the Saint John River, Canada (Fig. 33).

Condition factor ($k = W/L^3$) of shortnose sturgeon in the Saint John estuary varied through the year, reaching a peak in late winter as gonads of ripe fish reached their maximum size, and declining to the lowest level in May after spawning (Table 17). Average summer condition of shortnose sturgeon was 0.87 and recovery to this level occurred soon after spawning, probably because of the increased feeding observed at this time (Dadswell 1979).

3.45 Metabolism

No data are available on the metabolism of shortnose sturgeon.

3.5 Behavior

3.51 Migrations and local movements

Extent of movements

In estuarine and riverine environments where shortnose sturgeon have been tagged and recaptured, they are known to move considerable distances. In the Saint John estuary, the mean minimum distance travelled by those shortnose sturgeon which moved more than 1 km between recaptures was 22.9 ± 6.7 km. The maximum channel distance travelled between tagging and recapture was 160 km (Dadswell 1979). The mean minimum rate of upstream movement of 11 shortnose sturgeon in the Saint John River between June and August was 4.0 ± 1.5 km/d (Fig. 34). In the Altamaha River, Ga., a shortnose sturgeon moved 193 km

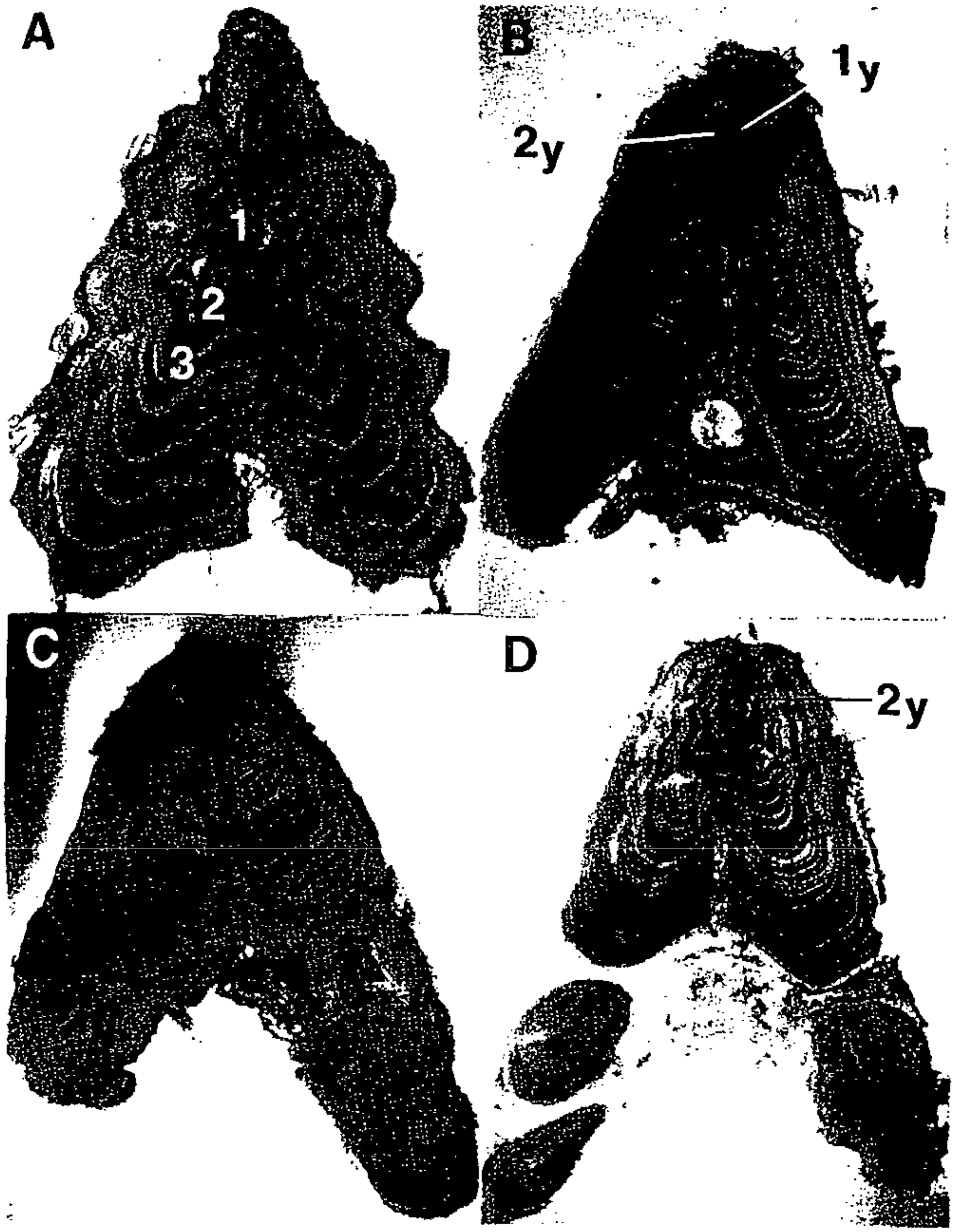

Figure 23.—Transverse sections of the marginal ray of the pectoral fin of shortnose sturgeon showing annuli. Dark zones are summer-formed dense bone; translucent zones, winter period. (A) Juvenile: 45 cm, 0.8 kg; 9 yr (×18). (B) Male: 97 cm, 9.4 kg; 27 yr (×8) (annuli 17 and 19 each have a false annulus associated; year 1 is almost obscured, arrow). (C) Female: 112 cm, 12.5 kg; 40 yr (×5). Matured age 11, spawned at 21, 26, 32, 37 yr. (D) Female: 86 cm, 6.1 kg; 23 yr (×5). Matured at 10, spawned at 16, but no later spawning checks discernible.

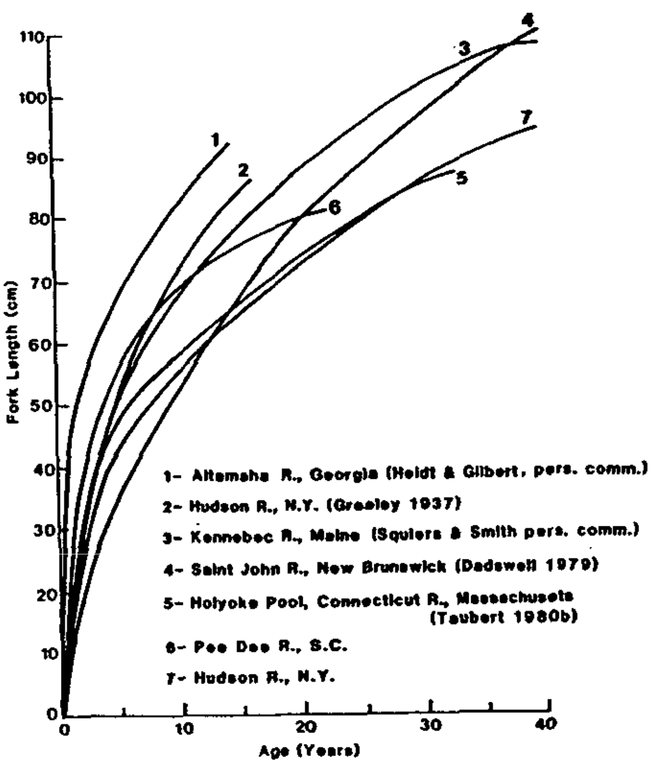

Figure 24.—Growth of shortnose sturgeon in various rivers within the species range. (Sexes combined.)

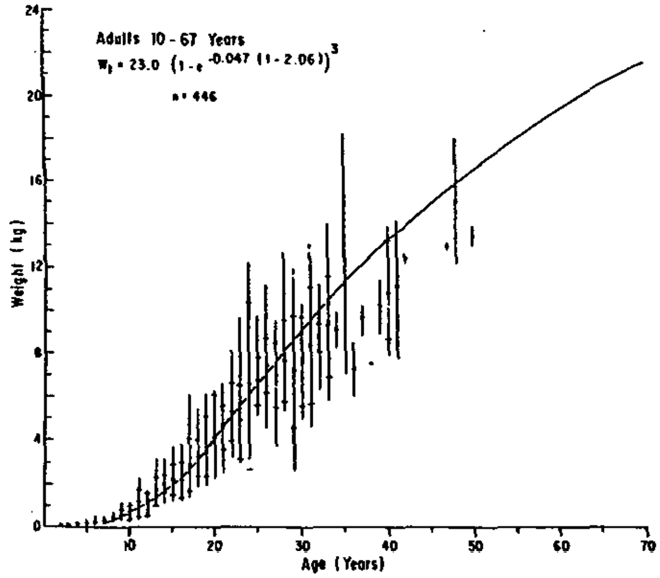

Figure 26.—Weight-age relationship for shortnose sturgeon from the Saint John River, Canada.

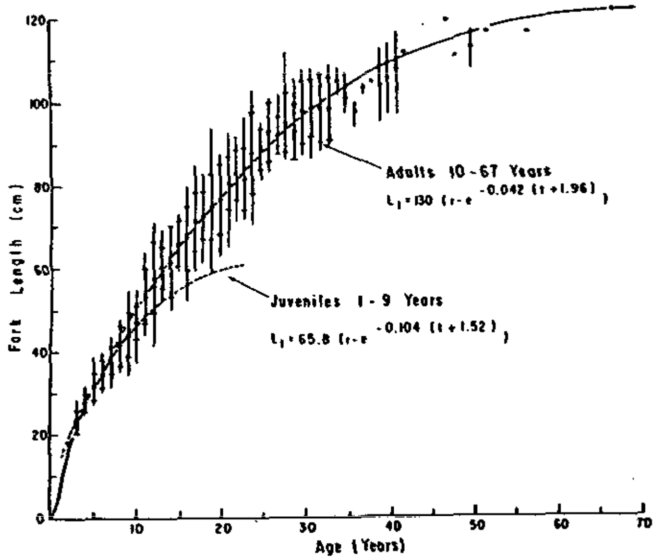

Figure 25.—Growth of juvenile and adult shortnose sturgeon from the Saint John River, Canada. Bars represent range and crossbars 95% confidence limits of year sample. Note sharp change in growth pattern at age 9-10.

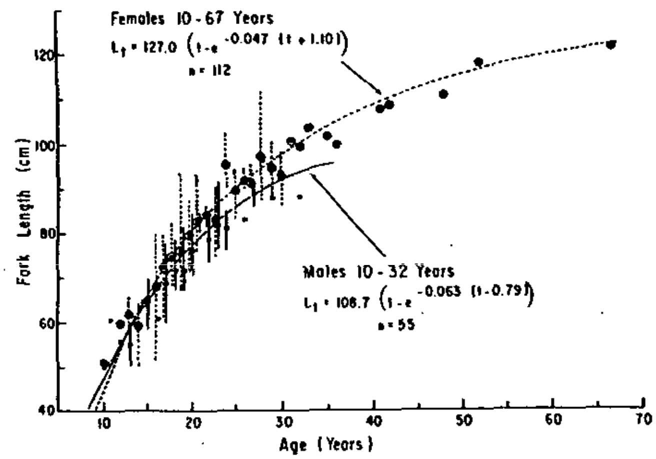

Figure 27.—Growth of male and female shortnose sturgeon from the Saint John River, Canada, fork length versus age.

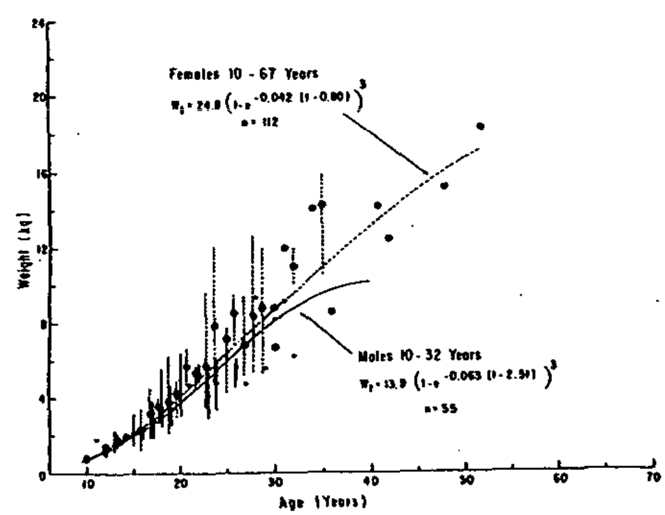

Figure 28.—Growth of male and female shortnose sturgeon from the Saint John River, Canada, weight versus age.

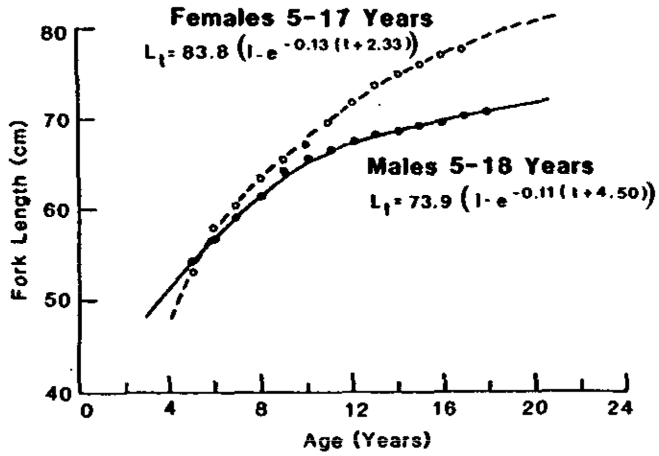

Figure 29.—Growth of male and female shortnose sturgeon from the Pee Dee-Winyah system, S.C.

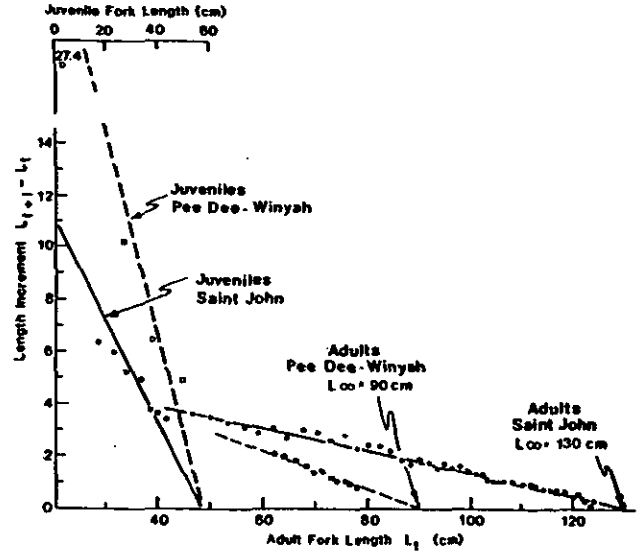

Figure 30.—Yearly length-increment change during growth of shortn sturgeon from the Saint John estuary, Canada, and the Pee Dee-Wiay estuary, S.C. Growth increments of < 50 cm (open circles) and > 50 cm (se circles).

Table 14.—Von Bertalanffy growth parameters for length relationships of shortnose sturgeon populations of eastern North America.

Locality	Latitude	L_∞ (FL)	K	t	Source
Altamaha R., Georgia	32°N	97.0	0.149	−3.15	Heidt and Gilbert[1]
Pee Dee-Winyah, S.C.	34°N				
Females		83.8	0.133	−2.33	Marchette and
Males		73.9	0.114	−4.50	Smiley (see
Combined		87.0	0.093	−6.02	Table 2, footnote 24)[1]
Hudson R., N.Y.	42°N				
Females		102.6	0.079	−3.17	Greeley (1937)[1]
Males		57.9	0.305	−1.80	
Combined		106.4	0.044	6.39	Dovel (see Table 2, footnote 15)[1]
Connecticut R.	43°N				
Lower		100.0	0.073	−2.73	Buckley (unpubl. data)[1]
Holyoke Pool, Mass.		87.8	0.084	−2.64	Taubert (1980b)
Kennebec R.,	44°N	[2]93.8	0.098	−3.89	Squiers and Smith (see text footnote 7)
Saint John R., Canada	45°N				
Females		127.0	0.047	−1.10	Dadswell (1979)
Males		108.7	0.063	0.79	
Combined		130.0	0.042	−1.96	

[1]Calculated from original data by Dadswell.
[2]Sturgeon longer than this were observed.

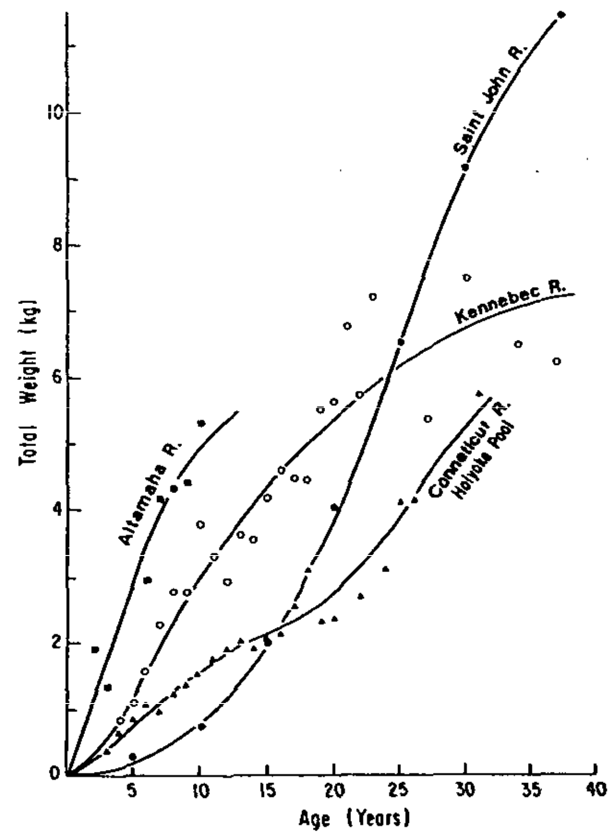

Figure 31.—Weight-age relationship of shortnose sturgeon from four rivers spanning the range of the species.

Table 15.—Observed mean length ($\Delta\bar{L}$) and mean weight ($\Delta\bar{W}$) change of tagged shortnose sturgeon during 1 to 4 yr at large in the Saint John estuary, Canada. Obvious large 1-yr weight increases due to female gonad maturation were excluded from data.

Period at large	ΔT (yr)	N	$\Delta\bar{L}$ (cm)	$\Delta\bar{W}$ (kg)	$\Delta\bar{L}/\Delta T$	$\Delta\bar{W}/\Delta T$
1973-74	1	32	0.8	0.2	0.8	0.2
1974-75	1	19	0.7	0.1	0.7	0.1
			mean $\Delta\bar{L}/\Delta T$=0.75 $\Delta\bar{W}/\Delta T$=0.15			
1973-75	2	15	1.3	0.5	0.65	0.25
1974-76	2	19	1.4	1.5	0.70	0.75
1975-77	2	4	2.2	1.2	1.1	0.60
			mean $\Delta\bar{L}/\Delta T$=0.82 $\Delta\bar{W}/\Delta T$=0.53			
1973-76	3	2	0.0	2.8	0.0	0.93
1974-77	3	11	3.7	2.4	1.23	0.80
			mean $\Delta\bar{L}/\Delta T$=0.62 $\Delta\bar{W}/\Delta T$=0.86			
1973-77	4	4	2.2	1.2	0.55	0.30
		All data mean $\Delta\bar{L}/\Delta T$=0.72 $\Delta\bar{W}/\Delta T$ =0.49				

Table 16.—Weight-length relationships for shortnose sturgeon populatio from the east coast of North America.

Locality	Relationship	Source
Altamaha R., Georgia	[1]LogW = 2.95(LogFL)−5.01	Heidt and Gilbert[2]
Pee Dee R., S.C.	LogW = 3.06(LogFL)−5.29	Marchette and Smile (see Table 2, footn 24)
Delaware R., N.J.	[1]LogW = 3.11(LogFL)−4.25	Hastings (see Table 2 footnote 19)[2]
Hudson R., N.Y.	[1]LogW = 2.85(LogFL)−4.82	Greeley (1937)[2]
Hudson R., N.Y.	[1]LogW = 3.25(LogFL)−5.56	Dovel (see Table 2, footnote 13)[2]
Hudson R., N.Y.	[3]LogW = 2.73(LogTL)−10.12	Pekovitch (see Table footnote 14)
Holyoke Pool Connecticut R., Mass.	[1]LogW = 3.03(LogFL)−5.23	Taubert (1980b)
Lower Connecticut R.	LogW = 2.98(LogFL)−5.08	Buckley (unpubl. dat
Kennebec R., Maine	[1]LogW = 3.10(LogFL)−4.90	Squiers and Smith (s text footnote 7)
Saint John R., Canada	[1]LogW = 3.20(LogFL)−5.45	Dadswell (1979)

[1]W in kg, FL in cm.
[2]Calculated by Dadswell.
[3]W in g, TL in mm.

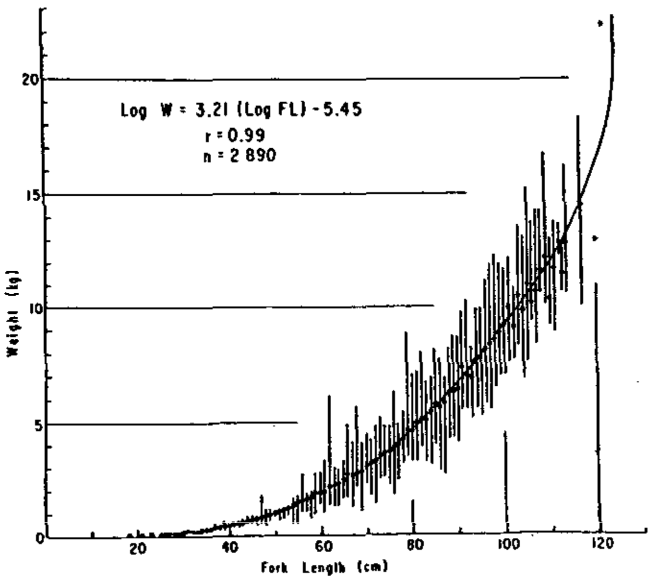

Figure 32.—Weight-length relationship for shortnose sturgeon from the Saint John River, Canada. Circles are mean weight for 1 cm length increments, bars are range of weight.

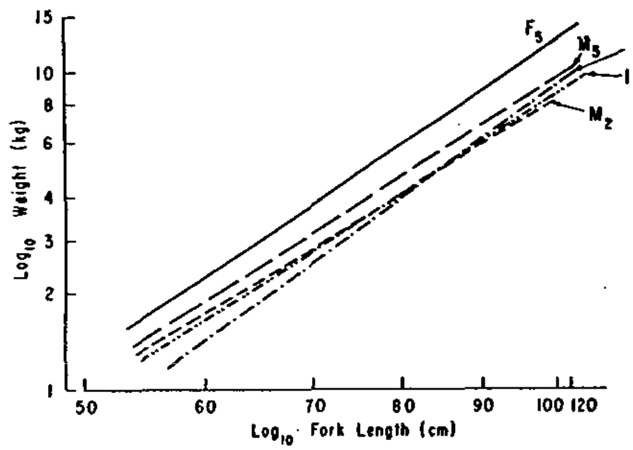

Figure 33.—Log-log regressions of weight-length relationships for stage II, a V male and stage II, V, and VI female shortnose sturgeon from the Saint Jo River, Canada.

downstream in 11 d (Heidt and Gilbert 1978 see Table 2, footnote 27) and in the Connecticut River one radio-tagged shortnose sturgeon moved 60 km in 2 d (Buckley, unpubl. data). McCleave et al. (1977), using sonic tags, documented a mean daily rate of shortnose sturgeon movement of about 20 km in Montsweag Bay, Maine. Shortnose sturgeon movement during the Montsweag study appeared to be predominately nondirected, random feeding movements, often into very shallow water.

On the other hand, Taubert (1980b), using radio tags, found that for the landlocked population of shortnose sturgeon in the Holyoke Pool, Connecticut River, individuals had small home ranges which they inhabited year around unless they migrated upstream in spring to spawn. No general migration of the population to spawning or overwintering sites was observed, but it may have gone unnoticed because of small population size. It appeared that the tagged sturgeon had the ability to leave their home area

Table 17.—Mean condition factor (K = [W × 10] / L^3) by month for shortnose sturgeon in the Saint John estuary, Canada.

Month	K	Month	K
January	0.85	July	0.82
February	1.12	August	0.86
March	1.28	September	0.91
April	0.91	October	1.11
May	0.73	November	1.19
June	0.88		

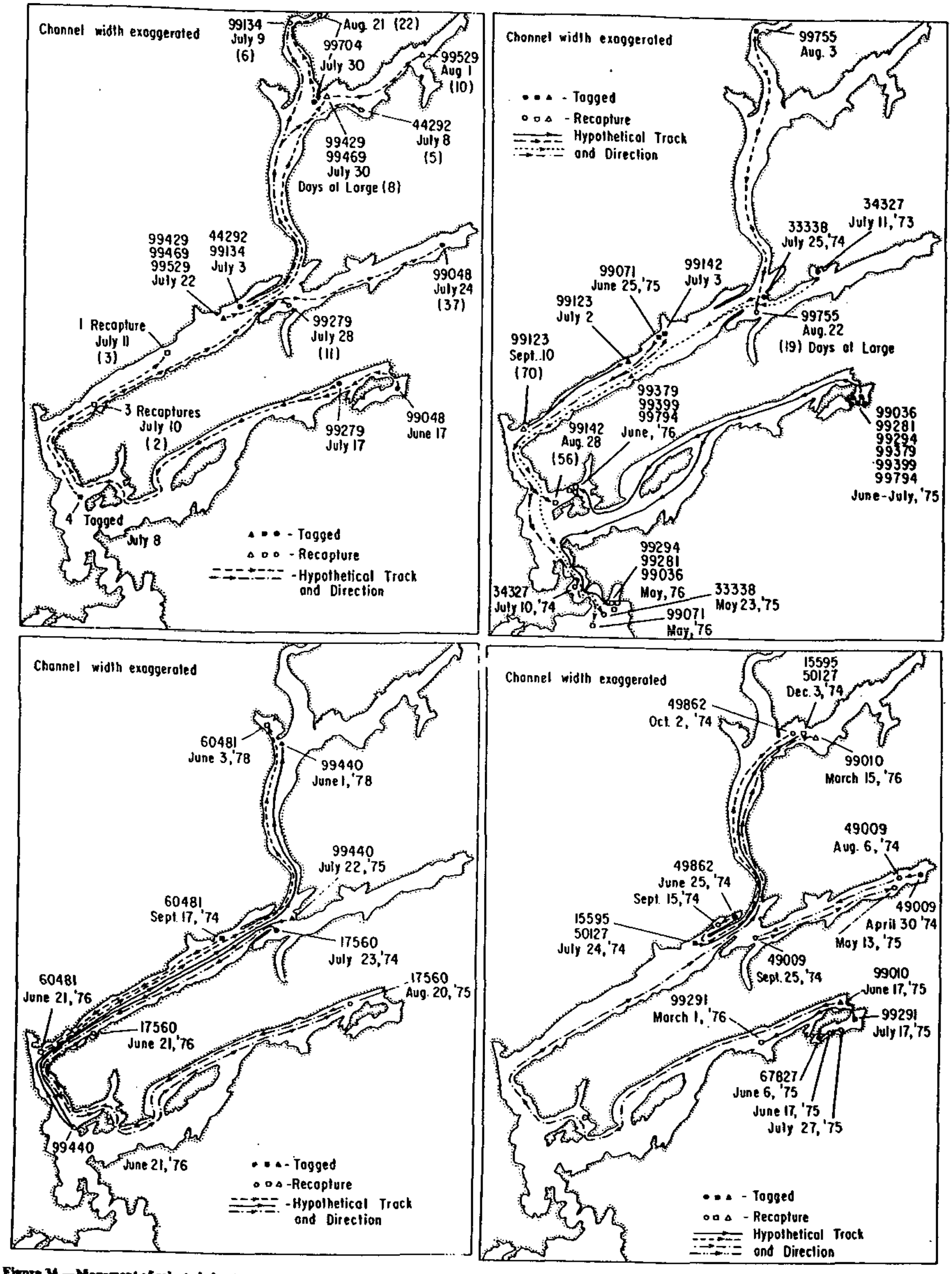

Figure 34.—Movement of selected shortnose sturgeon in the Saint John estuary, Canada: Top left, short-term movement, July-August, movement predominantly upstream; top right, movement between late summer to early spring, generally downstream; bottom left, long-term migratory movement; bottom right, residential behavior during summer and movement to winter concentration sites. Numbers in parentheses under dates in top figures indicate number of days at large between capture and recapture.

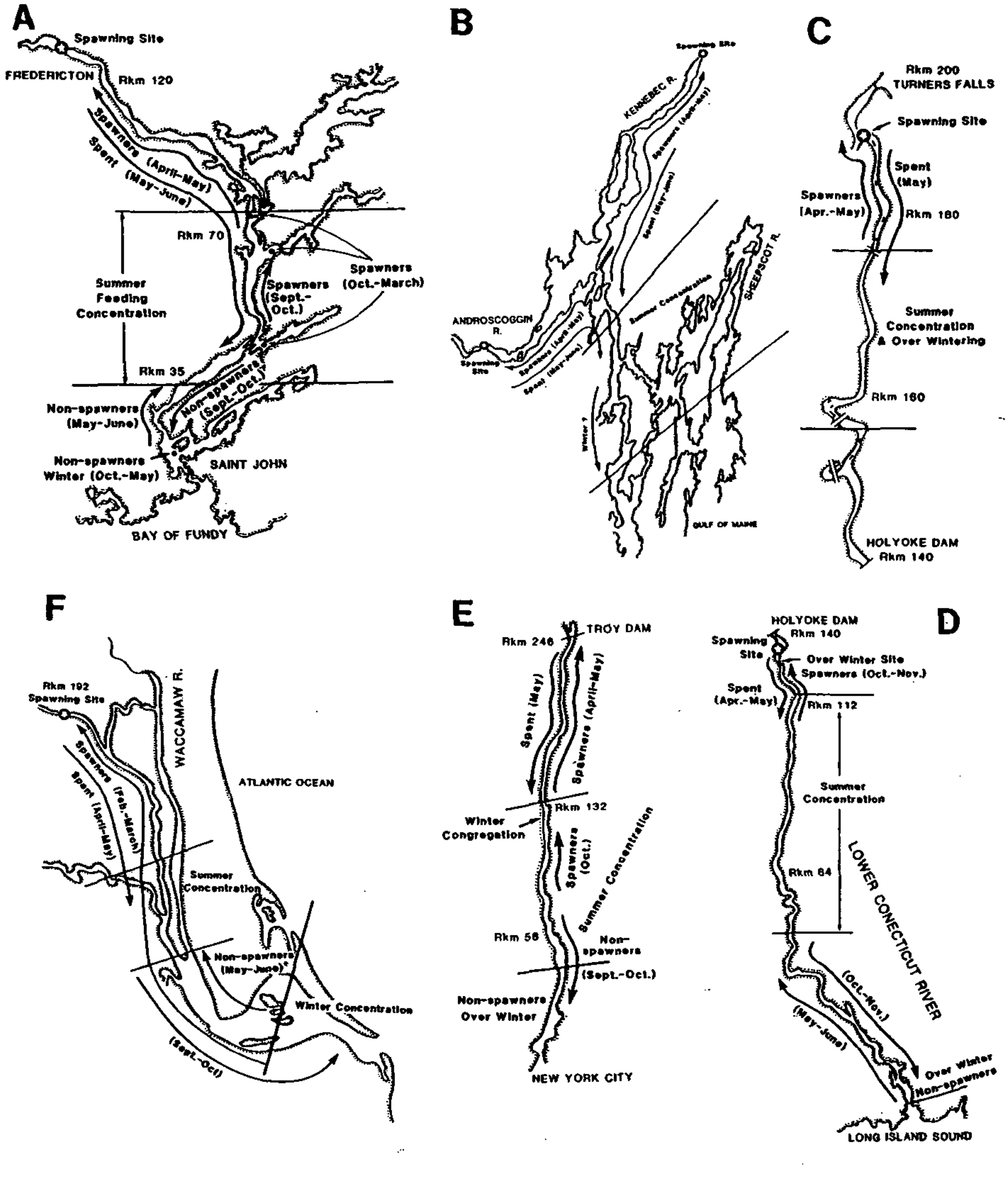

Figure 35.—Migration patterns of various life stages of shortnose sturgeon in river systems studied to date. A) Saint John River, Canada; B) Kennebec River, Maine; C) Holyoke Pool, Connecticut River, Mass.; D) Lower Connecticut River; E) Hudson River, N.Y.; F) Pee Dee-Winyah Bay system, S.C.

and return after long-distance movements. Buckley (1982) found that radio-tagged shortnose sturgeon in the lower Connecticut River also tended to stay in localized areas during summer but migrations occurred in spring and fall similar to those in other rivers (Fig. 35). He found the mean daily rate of migration against the current, from feeding grounds to spawning grounds, was 0.82 ± 0.47 km/d.

To date shortnose sturgeon have not been shown to move in the sea away from the influence of their home river system (Fig. 7). As recent studies suggest, continued research may reveal that marine movements of this species are extensive (Wilk and Silverman 1976; Holland and Yelverton 1973; Marchette and Smiley 1982 see Table 2, footnote 24).

Direction and mode of migratory movements

The normal pattern of migration in shortnose sturgeon conforms to the simple model of Harden Jones (1968) in which, during life, fish move between feeding, wintering, and spawning areas (Fig. 35).

Seasonal gill net catch data from discrete estuarine localities in the Saint John River demonstrated bimodal abundance peaks in the mid-estuary and a unimodal peak in the upper estuary (Fig. 36; Dadswell 1979). Recaptures of tagged shortnose sturgeon in the Saint John River indicate changing abundance patterns which represent annual migration upriver in spring-summer and downriver in fall by most of the nonripening portion of the population (Fig. 34). Some ripening males carried out a similar migration but

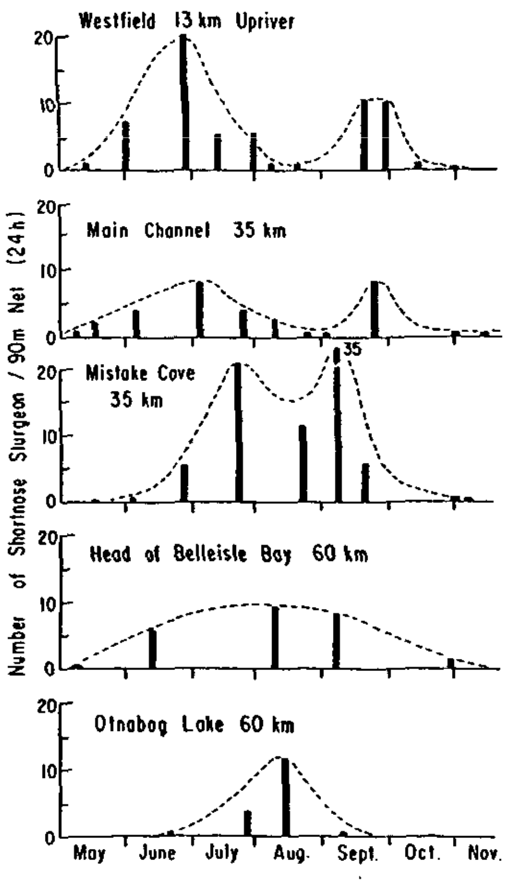

Figure 36.—Number of shortnose sturgeon captured per standard gill net set in various localities of the Saint John River, Canada, during May to November.

many ripening males and females either migrated farther upriver in the fall or remained at upriver locations over winter (Fig. 34; Dadswell 1979; Buckley 1982). Abundance peaks during downstream migration were of shorter duration, suggesting this migratory phase was more rapid.

Squiers and Smith (footnote 7) reported similar behavior of shortnose sturgeon in the Kennebec River. Recaptures of tagged shortnose sturgeon during July occurred upstream of June tagging sites and downstream sites had bimodal abundance peaks, while upstream sites had unimodal peaks.

Heidt and Gilbert (1978 see Table 2, footnote 27) and Gilbert and Heidt (1979), however, observed a different migration pattern in the Altamaha River, Ga. There, shortnose sturgeon were found upstream during February and March while spawning but during the remainder of the year were taken only in the first few kilometers of the river within tidal influence. Marchette and Smiley (1982 see Table 2, footnote 24; Fig. 8b) reported a similar migration pattern in the tributaries of Winyah Bay, S.C., with adults spending the winter in the estuary or the sea within 5,000 m of shore. Documentation of shortnose sturgeon movements in the Hudson River is still in progress but current information suggests a combination of patterns occur. There is a spawning run in spring to the upper reaches of the estuary (rkm 130-150; Dovel 1981 see Table 2, footnote 15; Pekovitch 1979 see Table 2, footnote 14; Greeley 1937), many actively feeding adults occur in the river during summer (Curran and Ries 1937; Dovel 1978 see Table 2, footnote 13), and adults are also captured in the sea during summer about the mouth of the river (Schaefer 1967; Wilk and Silverman 1976). In the Holyoke Pool of the Connecticut River, shortnose sturgeon were found to move only short distances except during upstream spawning migration (Taubert 1980b). In the lower Connecticut River, movement patterns are similar to those in the Saint John River (Kynard et al. 1982;[16] Buckley 1982; Fig. 35). Dadswell (1979) found that a portion of the Saint John River shortnose sturgeon population migrated to the Bay of Fundy but remained close to the river mouth.

In contrast with the migratory behavior of the adults, juvenile shortnose sturgeon are nonmigratory and largely confined to the inland riverine portion of estuaries upstream of the salt wedge (Pottle and Dadswell 1979 see Table 2, footnote 1). In the Saint John River, juveniles are only captured seaward of the normal salt-wedge excursion region during flood periods (Dadswell 1979). The mean length of shortnose sturgeon in the under 45 cm size group was least in upriver portions of the estuary and the length difference between size classes with a mean length of < 45 cm and > 45 cm was greatest in downstream and lacustrine regions (Table 3). These data suggest there is a gradual downstream movement of juveniles as they become older. Recent work has shown that the major juvenile concentration is just inland of the salt wedge and they move in the estuary according to salt-wedge perturbations (Pottle and Dadswell 1979 see Table 2, footnote 1). Dovel (1978 see Table 2, footnote 13) found a similar distributional relationship for juvenile shortnose sturgeon in the Hudson River.

Time or season of migration

Spawning migrations to the upstream spawning grounds occur in spring or fall. Spring movement onto the spawning grounds ap-

[16]Kynard, B., J. Buckley, and W. Gabriel. 1982. Shortnose sturgeon biology below Holyoke Dam. Mass. Coop. Fish. Res. Unit, Univ. Mass., Amherst, 8 p.

pears to be initiated by water temperatures rising above 8°C (Pekovitch 1979 see Table 2, footnote 14; Taubert 1980a; Anonymous 1980 see Table 2, footnote 2). Limited available data suggest males migrate upstream in the fall to winter holding areas before females and perhaps occupy the spawning grounds first (Pekovitch 1979 see Table 2, footnote 14; Anonymous 1980 see Table 2, footnote 2). However, sampling of overwintering fish on the spawning grounds below Holyoke Dam on the Connecticut River revealed the ratio of males to females was 1:1 (Buckley 1982).

Feeding migrations occur immediately after spawning. Spent fish in the Saint John and Connecticut Rivers migrate back downstream rapidly and join the slower, general upstream movement of the remainder of the population (Fig. 35; Dadswell 1979; Buckley 1982). Upstream migration during summer in the Saint John River, Canada, and Kennebec River may be the adaptational response of a warmwater species to environmental conditions at the northern end of its range. However, in both the Saint John and Winyah systems, the abundance of shortnose sturgeon on foraging grounds was highest in mid-estuary where salinities averaged 1 ‰ (Fig. 8; Dadswell 1979; Marchette and Smiley 1982 see Table 2, footnote 24). During summers of high river flow (i.e., reduced estuarine salinity) summer abundance peaks in the Saint John River were displaced seaward. The opposite situation occurred during summers with reduced flows (i.e., increased estuarine salinity). In addition, interspecific competition with juvenile Atlantic sturgeon may influence distribution of shortnose sturgeon. Dadswell (1979) found that juvenile Atlantic sturgeon dominated catches in higher salinities (> 3 ‰) and adult shortnose sturgeon dominated catches in freshwater. Rapid downstream migration, which occurs in early fall in the Saint John and Pee Dee Rivers, was probably in response to seasonal cooling (Figs. 8, 34). Salinity relationships during this period seemed of little consequence as large numbers of shortnose sturgeon occupied lower estuary foraging grounds in salinities over 20 ‰ (Dadswell 1979; Marchette and Smiley 1982 see Table 2, footnote 24). Squiers and Smith (footnote 7) noted a similar occurrence in the Kennebec estuary.

Wintering migrations occur in autumn, specifically during the last few weeks of September in the Saint John River, Canada (Dadswell 1979). Wintering sites are discrete (Fig. 8) and generally occur in deep areas of lakes and river channels or in halocline regions of the lower estuary (Dadswell 1979). Overwintering sites in the lower Saint John estuary are characterized by salinities averaging 20 ‰ and temperatures of 2°-13°C. They are usually occupied by nonripening adults, stage IV males and large juveniles. Freshwater overwintering sites were characterized by depths in excess of 10 m, moderate tidal currents, and cold water (0°-2°C) and were occupied mainly by juveniles and stage IV females (Dadswell 1979).

Buckley (1982) found one overwintering site for ripe adults in the Connecticut River was a discrete 1,500 m section below the Holyoke Dam. Other shortnose sturgeon moved to the estuary for the winter.

Dovel (1979,[17] 1981 see Table 2, footnote 15) and Pekovitch (1979 see Table 2, footnote 14) found a similar wintering behavior of shortnose sturgeon in the Hudson River. Concentration of shortnose sturgeon occurred in deep parts of the estuary in both fresh and brackish water from Kingston to the George Washington Bridge (rkm 94-12). Greeley (1935) reported a ripe, female, shortnose sturgeon captured at Albany during the winter of 1934.

In the Pee Dee-Winyah system, S.C., a temperature decline of 2°-3°C stimulated downriver migration in September to overwintering sites. Overwintering sites were in the lower estuary in channels leading into shallow estuarine lakes, in the estuary proper, and in the ocean within 5,000 m of the beach (Marchette and Smiley 1982 see Table 2, footnote 24). Overwintering sites had surface water temperatures of 5°-10°C and salinities of 18-30 ‰.

Changes in pattern with age and condition

See juveniles and spawning migrations above.

3.52 Shoaling

Shoaling or schooling of shortnose sturgeon has not been reported for young-of-the-year or juveniles, although it is known to occur in other sturgeon species (Scott and Crossman 1973). Most workers report that capture of shortnose sturgeon in gill nets suggests the adults space themselves evenly over the foraging area with no suggestion of shoaling.

Dadswell (1979), however, found that although there was a general upriver movement of the entire population during summer, multiple recaptures of individual shortnose sturgeon within confined areas during July-September suggested that once reaching a certain locality a portion of the population became resident there (Fig. 34). Additionally, the incidence of recapture of individuals in a particular locality from year to year was high (Table 18). Either sampling merely intercepted the movement pattern at the same time and place annually, which suggests a regular, cohort-type migration, or segments of the population "homed" to foraging areas. Both Taubert (1980b) and Buckley (1982) have observed similar behavior in the Connecticut River. There, radio-tagged sturgeon occupied small home ranges to which they returned after migration.

A further striking feature about shortnose sturgeon recaptures in the Saint John River, Canada, and the Connecticut River was their tendency to be grouped (Dadswell 1979; Buckley 1982). Shortnose sturgeon which had been captured and tagged in the same locality on the same day one year were recaptured together in the same or a different locality after a 1-yr or more interval. On the Saint John River, nine shortnose sturgeon tagged in a single day were recaptured together after periods at liberty of 1 yr or more. Also, on seven occasions in the Saint John River shortnose sturgeon tagged in sequence were recaptured together, often side by side, after 1- to 3-yr intervals. The probability of the latter event occuring at random is 1.88×10^{-24} and is highly unlikely.

3.53 Responses to stimuli

Environmental stimuli

No research on shortnose sturgeon has been carried out in this field.

Artificial stimuli

While transporting adult shortnose sturgeon, Dadswell (pers. obs.) found they tolerated light and temperature variations well but were very susceptible to mechanical shock. A small accident

[17] Dovel, W. L. 1979. Atlantic and shortnose sturgeon in the Hudson River estuary. Rep. for U.S. Environ. Prot. Agency, The Oceanic Soc., Conn., 26 p.

Table 18.—Numbers of shortnose sturgeon in the Saint John River, Canada, recaptured during July and August in the same site during the year of initial tagging and in subsequent years in the same or a different site. Site defined as area within 1 km radius of original capture site.

	Recaptures								
	Same site and year[1]			After 1 yr		After 2 yr		After 3 yr	
Tagging site	1X	2X	3X	Same[2]	Diff.	Same	Diff.	Same	Diff.
Mistake Cove[3]	47	4	1	48	12	4	2	1	2
Belleisle Bay	27	2	1	6	7	1	1	1	0
Darlings Lake	24	3	1	No sampling subsequent years					
Tennants Cove	4	0	0	10	4	5	6	0	3
Otnabog Lake	3	0	0	4	0	3	2	2	0
Total	105	9	3	[4]68	23	13	11	4	5

[1]Recapture efforts at a minimum of 4-wk intervals.

[2]Total effort in alternate sites 4X effort in any one original tagging site except Mistake Cove where alternate effort only 2X more.

[3]Total initial tagging effort in Mistake Cove was twice that of other sites.

[4]Incidence of "Homing" 1st yr 68/91 = 0.75, 2nd yr 13/24 = 0.59, 3rd yr 4/9 = 0.44.

on the highway in which the shortnose sturgeon were knocked about in their transport tank, but during which no water spilled, resulted in instantaneous, complete mortality of nine specimens of all sizes. Before and after that accident, large numbers of shortnose sturgeon have been transported in both New Brunswick and South Carolina for up to 15 h, held in tanks for 15 d, and handled during experiments for periods up to 1.5 yr with no mortality.

4 POPULATION

4.1 Structure

4.11 Sex ratio

Among adult shortnose sturgeon from the Saint John River, the ratio of females to males in the general population was 2:1 (Dadswell 1979); in the Pee Dee River it was 1:1 (Marchette and Smiley 1982 see Table 2, footnote 24). In both studies, adults were either randomly selected from the daily catch and sacrificed or were net mortalities and, since sex can not be determined prior to dissection, observed sex ratio was likely a true representation of the adult population. At younger ages, the ratio of females to males was 1:1, but among shortnose sturgeon over 20 yr old in the Saint John River, Canada, and 10 yr old in the Pee Dee River, S.C., females were more numerous (Table 19). The observed population structure was thought an expression of a shorter life span for males (Dadswell 1979). Greeley (1937) found a ratio of 1.42:1 females to males among Hudson River shortnose sturgeon. Meehan (1910) found that among a sample of over 100 shortnose sturgeon from the Delaware River, taken at random from commercial fishermen catches, females represented more than 50%. Gilbert and Heidt (1979) captured four females and three males from the spawning run in the Altamaha River, but their sampling was limited and the sex ratio is probably not representative.

During 1977 and 1978 Taubert and Reed (1978)[18] captured 14 males and 4 females on the spawning grounds in the Holyoke Pool and Pekovitch (1979 see Table 2, footnote 14) captured 157 males and 63 females on the spawning grounds in the Hudson River. The preponderance of males to females during the spawning runs is a common occurrence among *Acipenser* species (Vladykov and Greeley 1963; Cuerrier 1966; Magnin 1966), and among fish in general, and without adequate sampling cannot be regarded as representative of the population as a whole.

Table 19.—Sex ratio of shortnose sturgeon from the Saint John River, Canada, and the Pee Dee River, S.C., as related to age.

Saint John, Canada			Pee Dee, S.C.		
Age	Number	% female	Age	Number	% female
5-9	—	—	5-7	4	30.8
10-14	17	47.1	5-10	12	40.0
15-19	60	55.0	11-13	11	78.6
20-24	42	76.0	13-15	5	83.3
25-29	31	81.0	16-18	4	80.0
30-34	16	81.2	Total	36	$\bar{X}$ = 62.5
35-70	5	100.0			
Total	171	$\bar{X}$ = 70.6			

4.12 Age composition

Shortnose sturgeon may not exhibit strong year-to-year variation in year class strengths due to their long life span. Dadswell (1979) found that among a relatively nonbiased sample (ages 15-50) there was a regular decrease in year class size with age and no particular abundance of any one year class (Fig. 37).

Perhaps among southern populations, which have shorter life spans, year class strength will be observable.

4.13 Size composition

Figure 38 illustrates the size composition of captured shortnose sturgeon during 3 yr sampling on the Saint John River. In the size range adequately sampled by the gear (60-120 cm), no predominance or stratification of sizes was observed. The relatively greater catches of large shortnose sturgeon during 1974 was attributed to the greater selectivity of the large mesh gill nets (Fig. 39). When selectivity and effort were adjusted for, no size class dominance was observed (Table 20) (Dadswell 1979).

[18]Taubert, B. D., and R. J. Reed. 1978. Observations of shortnose sturgeon (*Acipenser brevirostrum*) in the Holyoke Pool, Connecticut River, Massachusetts. Rep. to Northeast Utilities Service Co., Hartford, Conn., 24 p.

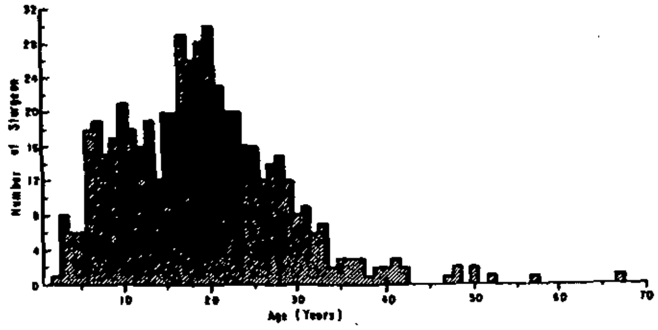

Figure 37.—Age composition of shortnose sturgeon sampled from the Saint John River, Canada. Predominance of fish around age 20 is an artifact of gill net selectivity for that size of sturgeon. Fewer shortnose sturgeon of younger age reflects small amount of effort with nets selective for that size and the differential distribution of juveniles and adults (Dadswell 1979).

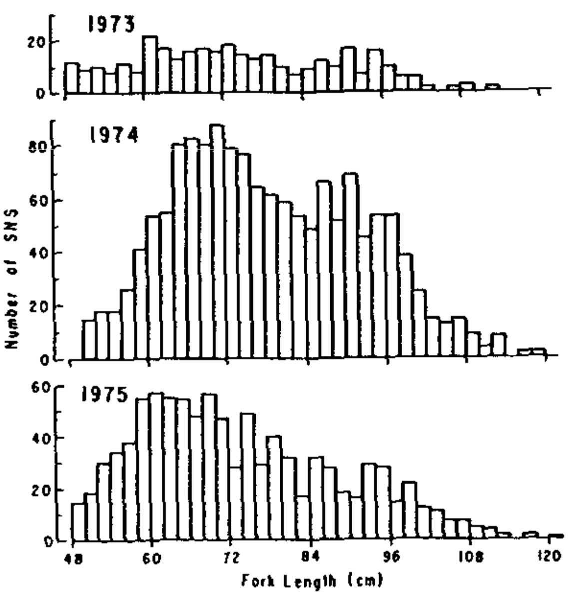

Figure 38.—Size composition of gill net catches of shortnose sturgeon from the Saint John River, Canada, during each of 3 yr.

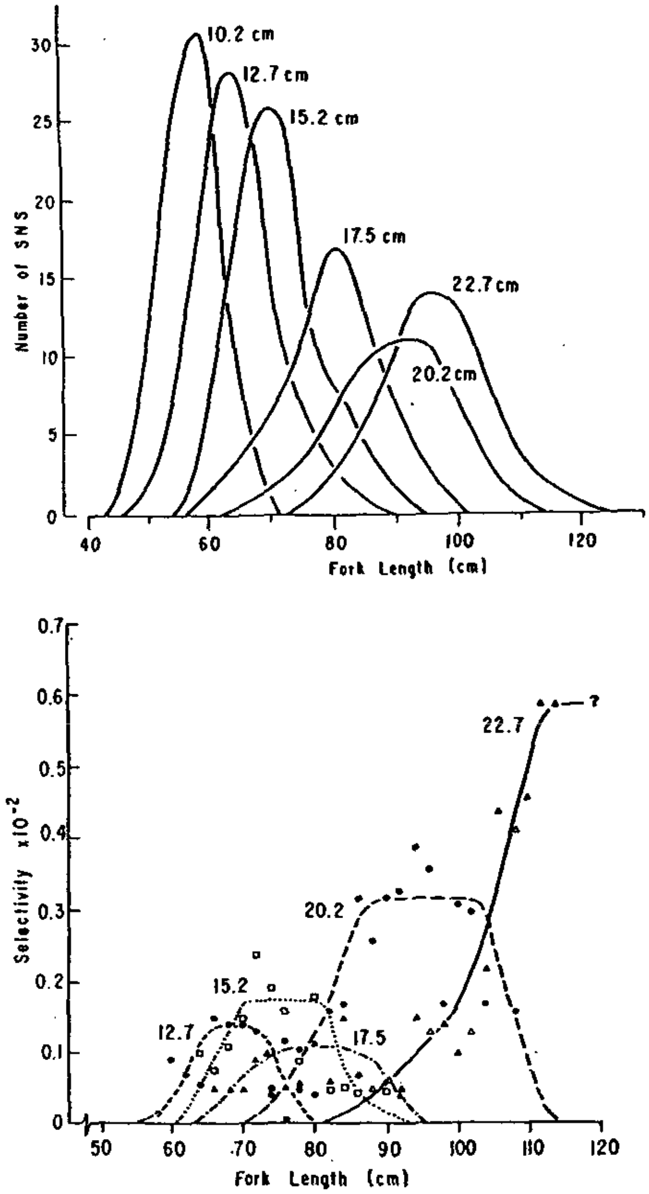

Figure 39.—Indirect selectivity (top) and direct selectivity (bottom) of #12 monofilament gill net of various stretched-mesh sizes for shortnose sturgeon. Note the greater efficiency of large mesh size nets.

Maximum size

The maximum known size for shortnose sturgeon is a 122 cm FL, 143 cm TL female captured in the Saint John estuary (Dadswell 1979). Total weight of this sexually resting (stage II) individual was 23.6 kg (52 lb.) The specimen is deposited at the Royal Ontario Museum, Toronto, Canada (Cat. No. ROM 34310). Shortnose sturgeon longer than 100 cm FL and weighing more than 10 kg are common in the Saint John River (Gorham and McAllister 1974). The largest male on record is a 97.0 cm FL, 108 cm TL, 9.4 kg specimen from the Saint John estuary (Dadswell 1979).

Maximum size among shortnose sturgeon populations varies over the north to south range of the species (Table 21) with larger maximum sizes known from northern populations. Larger maximum sizes may be found in southern populations after more sampling with large mesh gill nets (20 cm stretched mesh).

Length and weight relationships

See section 3.44.

4.14 Subpopulations

Data collected so far suggest that within each river along the Atlantic seaboard there is one shortnose sturgeon population, except perhaps in the Connecticut River where populations are physically separated by the Holyoke Dam. Whether each river population is a distinct entity from others awaits future chemical or genetic population discrimination studies. Southern populations may mix in the sea. Northern populations appear confined to their separate drainage systems.

Table 20.—Catch by size class and assigned mean age, actual (C_{ac}) and adjusted (C_{ad}) total catches of shortnose sturgeon for various mesh gill nets during 1974 and July-August 1975 in the Saint John River, Canada. Effort by mesh size was: 1974, 15.2 cm = 143 net-nights, 20.2 = 162 net-nights; 1975, all meshes = 24 net-nights. Total adjusted catch $\Sigma C_{ad} = \Sigma C_{ac} / \hat{S}_i X_1 / X_2$ where X_1 is effort/mesh and X_2 is total effort of overlapping catch curves. Selectivities used were smoothed estimates from Figure 39. Underlined counts are from selectivity plateau of each mesh-size curve and were used to calculate total instantaneous mortality.

		1974				1975						
Length (cm)	Age (yr)	15.2	20.6	ΣC_{ac}	ΣC_{ad}	12.7	15.2	17.5	20.2	22.7	ΣC_{ac}	ΣC_{ad}
61-63	14	46	—	46	1,608	39	19	0	—	—	58	2,093
64-66	15	87	—	87	761	34	29	5	—	—	68	1,188
67-69	16	78	2	80	333	28	29	6	2	—	65	754
70-72	17	78	3	81	253	22	40	10	2	—	74	747
73-74	18	47	3	50	127	7	12	7	2	—	28	288
75-76	19	50	6	56	134	9	23	13	4	—	49	487
77-78	20	35	6	41	93	6	10	10	4	1	31	410
79-80	21	37	7	44	94	5	9	17	6	3	40	528
81-82	22	22	15	37	78	2	2	14	8	3	29	508
83-84	23	15	24	39	97	1	3	7	4	2	17	297
85-86	24	14	19	33	118	0	6	14	5	7	32	531
87-88	25	11	33	44	161	1	4	8	8	7	28	439
89-90	26	4	34	38	102	—	1	4	11	2	18	224
91-92	27	2	41	43	109	—	0	2	9	6	17	212
93-94	28	1	38	39	73	—	1	3	8	14	26	324
95-96	29	2	35	37	67	—	—	1	11	14	26	335
97-98	30	—	36	36	69	—	—	0	7	6	13	129
99	31	—	14	14	27	—	—	1	5	6	12	102
100	32	—	15	15	29	—	—	0	2	8	10	105
101	33	—	11	11	21	—	—	0	2	3	5	41
102	34	—	10	10	19	—	—	—	3	4	7	57
103	35	—	5	5	10	—	—	—	1	4	5	36
104	36	—	8	8	15	—	—	—	3	3	6	42
105	37	—	8	8	21	—	—	—	0	2	2	12
106	38	—	5	5	13	—	—	—	1	4	5	33
107	39	—	7	7	27	—	—	—	0	3	3	15
108	40	—	7	7	27	—	—	—	2	4	6	45
109	41	—	4	4	25	—	—	—	1	1	2	25
110	42	—	3	3	18	—	—	—	1	1	2	25
111	44	—	0	0	0	—	—	—	0	3	3	21
112	45	—	1	1	15	—	—	—	—	1	1	7
113	47	—	0	0	0	—	—	—	—	1	1	7
114	48	—	0	0	0	—	—	—	—	0	—	—
115	50	—	—	—	—	—	—	—	—	0	—	0
116	51	—	—	—	—	—	—	—	—	0	—	0
117	53	—	—	—	—	—	—	—	—	1	1	7
118	55	—	—	—	—	—	—	—	—	1	1	7
119	58	—	—	—	—	—	—	—	—	0	—	0
120	61	—	—	—	—	—	—	—	—	1	1	7
Z		0.19	0.14	—	0.12	0.22	0.37	0.15	0.13	0.06	—	0.15

4.2 Abundance and density (of population)

4.21 Average abundance—estimation of population size

Adequate estimation of the population size of shortnose sturgeon in most river systems requires the use of multiple-census population models because of the size of the systems and the different behavior of various age and spawning groups (Dadswell 1979).

Using gill net mark-recapture data over a 4-yr period, Dadswell (1979) estimated the adult population in the Saint John estuary with a Seber-Jolly population model as 18,000 ± 30% (Table 22). Back calculating through the use of the mortality curve for this population suggests there are about 100,000 shortnose sturgeon in the Saint John estuary.

Estimates of other shortnose sturgeon population sizes have been made for the Kennebec River (Squiers et al. 1981 see Table 2, footnote 3), the Holyoke Pool (Taubert 1980b), the lower Connecticut River (Buckley, unpubl. data), the Hudson River (Dovel 1981 see Table 2, footnote 15), and the Delaware R. (Dadswell, from Hastings 1983 see Table 2, footnote 22) (Table 22). Estimates were largely made by single and/or multiple Peterson types (Schnabel), and recapture levels have met the Peterson validity requirements of $mc > 4N$ (Robson and Regier 1964). All estimates are biased by gear use (gill nets only); nonetheless, population sizes obtained to date are probably good first estimates for the various river systems. Population sizes of shortnose sturgeon in other river systems are unknown to date but the accumulation rate of new captures is similar for both well- and poorly studied populations (Fig. 40). The number of actual, observed shortnose sturgeon in all populations since 1970 is ap-

Table 21.—Maximum known sizes among shortnose sturgeon populations along the Atlantic coast. Lengths are in centimeters, weights in kilograms.

Locality	Sample size	Female TL	Female FL	Female Wt	Male TL	Male FL	Male Wt	Unsexed TL	Unsexed FL	Unsexed Wt	Source
Saint John R., Canada	4,500	143.0	122.0	23.6	108.0	97.0	9.4				Dadswell (1979)
Kennebec R., Maine	18	118.1	107.4	8.5	80.7	72.1	2.6				Fried and McCleave (1973)
Kennebec R., Maine	728							120.5	111.0	12.3	Squiers et al. (see Table 2, footnote 3)
Holyoke Pool, Connecticut R., Mass.	270	—	95.1	7.2	87.9	79.2	4.1				Taubert (1980b)
Lower Connecticut R.	360	107.0	97.0	9.2	93.1	83.9	—				Buckley and Kynard (1981)
Hudson R., N.Y.	3,000	105.0	94.5	7.2	99.0	89.0	5.3				Dovel (see Table 2, footnote 15)
Delaware R., N.J.	282	86.4	77.7	5.1	74.0	66.0	2.0	107.0	98.3	8.3	Hastings (see Table 2, footnote 19)
Pee Dee R., S.C.	135	92.7	—	4.3	84.0	—	3.1				Marchette and Smiley (see Table 2, footnote 24)
Lake Marion, S.C.	13							77.5	66.0	2.4	Marchette and Smiley (see Table 2, footnote 24)
Altamaha R., Georgia	37	99.5	87.5	6.6	69.4	58.6	1.9				Heidt and Gilbert (see Table 2, footnote 27)
Saint Johns R., Florida	2	73.5	—	—	—	—	—				Vladykov and Greeley (1963)

Table 22.—Estimates of adult (+50 cm) shortnose sturgeon populations of North American Atlantic coast.

Locality and estimate type	Marked m	Captured c	Recaptured r	Population estimate N (95% conf. limits)	$mc/4\hat{N}$	Source
Saint John R., N.B.						
Seber-Jolly 1973-77	3,705	4,082	343	18,000 ± 30%	>1	Dadswell (1979)
Kennebec R., Maine						
Modified Peterson 1977-80	381	322	7	15,423 ± 66%	>1	Squiers et al. (see Table 2, footnote 3)
Modified Peterson 1977-82	917	233	19	10,741 (6,960-17,038)	>1	From Androscoggin spawners only
Modified Schnabel 1977-80	381	322	13	11,646 (6,998-20,639)		From Androscoggin spawners only
Modified Schnabel 1977-81	703	272	56	7,222 (5,046-10,765)		For total river population
Connecticut R., Conn.						
Holyoke Pool						
Simple Peterson 1976-77	51	162	16	516 (317-898)	>1	Taubert (1980b)
Simple Peterson 1976-78	51	56	4	714 (280-2,856)	>1	Taubert (1980b)
Simple Peterson 1977-78	119	56	18	370 (235-623)	>1	Taubert (1980b)
Simple Peterson 1976-77-78	170	56	24	297 (267-618)	>1	
Lower Connecticut R.						
Schnabel 1977-82	—	—	—	186 (106-359)		Rkm 110-139 Buckley (unpubl. data)
Schnabel 1981	—	—	—	28 (10-55)		Holyoke spawners only (Buckley, unpubl. data)
Schnabel 1982	—	—	—	38 (25-59)		Holyoke spawners only (Buckley, unpubl. data)
Schnabel 1977-82	—	—	—	800		[1]Rkm 04139
Hudson R., N.Y.						
Modified Peterson 1979	350	544	7	[2]23,911 (1,322-68,000)	>1	Calculated Dadswell (total)
Modified Peterson 1979	548	899	38	12,669 (9,080-17,735)	>1	Dovel (see Table 2, footnote 15) (spawners only)
Modified Peterson 1980	811	698	40	13,844 (10,014-19,224)	>1	Dovel (see Table 2, footnote 15) (spawners only)
Modified Peterson 1980	—	—	—	30,311		Dovel (see Table 2, footnote 15) (total population: based on extrapolation of population mortality relationship)
Delaware R.						
Modified Peterson 1981-83	464	99	7	[3]6,452 (3,584-18,434)	>1	Hastings (see Table 2, footnote 19) (Philadelphia to Trenton)

[1]Calculated by Dadswell.
[2]After Pekovitch (see Table 2, footnote 14), sturgeon tagged 1977 and 1978, recaptured 1979.
[3]Sturgeon tagged 1981-Oct. 1982, recaptured Nov. 1982-March 1983.

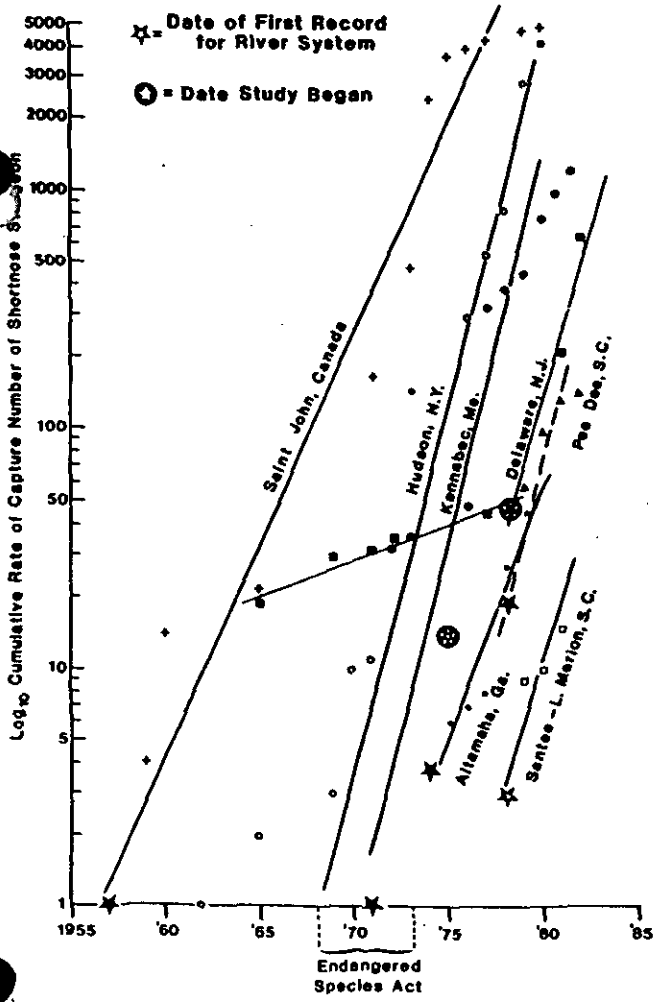

Figure 40.—Log_{10} cumulative total captures for individual known shortnose sturgeon populations in eastern North America.

proximately 11,500 individuals and most are or were tagged with individually numbered tags. The total estimated adult population size for the best known rivers now stands at about 70,000 (Table 22).

4.22 Changes in abundance

Since the size of shortnose sturgeon populations was unknown before the last few years, changes in abundance cannot be accurately determined.

The presence of shortnose sturgeon in the Saint John River, Canada; the Kennebec River, Maine; the Winyah-Pee Dee and Lake Marion systems, S.C.; and the Altamaha River, Ga.; were unknown until the last two decades, but these apparently are some of the larger populations. Ryder (1890) described himself as fortunate when he obtained five shortnose sturgeon from the Delaware River and said the species had not been seen since LeSueur's day, but the Geological Survey of New Jersey (1890) reported a 5:1 ratio of shortnose to Atlantic sturgeon and Meehan (1910) obtained over 100 shortnose sturgeon from the Delaware River in 1908 with relative ease. Since 1969, incidental catches in the lower Delaware have amounted to at least 40 shortnose sturgeon (Table 2; Brundage and Meadows 1982) as well as another 20 observed (Hoff 1965), and recently Hastings (1983 see Table 2, footnote 19), using proper sampling gear in the upper estuary, captured over 600 in 2 yr. Whether the Delaware population changed in abundance between these periods, or fishing effort with proper gear and subsequent reporting varied, can probably never be determined. Beck (1973) described the disappearance of Atlantic sturgeon from the Delaware by 1900 and subsequent decline in fishing effort until the 1950's. But as late as 1909 (Meehan 1910) and 1914 (Smith 1915) shortnose sturgeon were commonly caught by shad fishermen.

Greeley (1937) observed over 100 shortnose sturgeon incidently captured in the Hudson River shad fishery during 1936 but stated the species was rare. Similarly, Dovel (1978 see Table 2, footnote 13) observed about 100 shortnose sturgeon a year as incidental catch in the same fishery during 1976 and 1977. These observations suggest the shortnose sturgeon population in the Hudson River may have been stable during the 40-yr period between the two studies but casts no light on what actual population levels were, especially since the sampling gear (drift gill nets) are inappropriate for shortnose sturgeon. However, when Pekovitch (1979 see Table 2, footnote 14) and Dovel (1981 see Table 2, footnote 15) employed appropriate gear and were able to locate the shortnose sturgeon spawning run in the Hudson River, they captured almost 1,500 during each of the 1-mo periods in 1979 and 1980.

Conversely, McCabe (1942) stated that up to 100 sturgeon/d were caught in commercial gill nets below Holyoke Dam during 1940-42. McCabe reported these as Atlantic sturgeon but some may have been shortnose sturgeon. Neither Taubert (1980b) or Buckley (1982) ever achieved such a catch rate for either species, which may signify a decline. Also, Yarrow (1877) stated that shortnose sturgeon were common in North Carolina rivers, but recently Schwartz and Link (1976) described them as extirpated in the state.

4.23 Average density

Average density of shortnose sturgeon in the environment has only been determined for the Saint John estuary (Dadswell 1976). Population estimates from three or four recapture cycles at 4-wk intervals were made in areas of feeding concentrations during the June-September peak feeding period (Table 23). Average standing crop or density was 5.2 shortnose sturgeon/ha or 1.66 g/m². Concurrent benthos studies at these sites determined the average standing crop of benthic molluscs, which constitute the shortnose sturgeon diet, was 24 g/m² or a ratio of shortnose sturgeon standing crop to mollusc standing crop of 1:15. Since conversion between mollusc and shortnose sturgeon is direct and the energy transfer found was within the normal range for a one-step conver-

Table 23.—Schnabel population and standing crop estimates of adult shortnose sturgeon for four discrete regions of the Saint John estuary, Canada. Standing crop estimates in g/m² were determined using 3.21 kg as the average weight of adult shortnose sturgeon in this population.

Locality	Area (ha)	Recapture attempts	$\hat{N}$	Standing crop SNS/ha	Standing crop g/m²
Mistake Cove	225	4	1,161	5.16	1.65
Tennants Cove	182	3	1,969	10.81	3.47
Belleisle Bay	387	3	838	2.16	0.69
Darlings Lake	419	4	1,102	2.63	0.84
Mean	303		1,267	5.19	1.66

sion (Odum 1959), density estimates of the shortnose sturgeon, when concentrated on their feeding grounds, appear near the carrying capacity.

Average densities for the whole adult population are possible to calculate for the Saint John, Kennebec, Holyoke Pool and lower Connecticut River, Hudson, and Delaware Rivers (Table 24). Densities range between 0.04 and 0.9 adult shortnose sturgeon/ha. Density estimates are very similar except for the Delaware River where neither the population's size or its estuarine-riverine limits are well known. Population size projections, for rivers with poorly known populations, that use densities calculated for feeding concentrations rather than average densities, such as was done by Masnik and Wilson (1980), are inappropriate.

4.24 Changes in density

See section 3.51 for effects of migration on density. In optimum habitat of the middle Saint John estuary, Canada, peaks occur during early summer and early fall (Fig. 26). At inland estuary habitat a peak occurs in July-August. Wintering site densities peak between October and May. Similar density/abundance changes have been reported for the Kennebec estuary (Squiers and Smith footnote 7), the lower Connecticut (Buckley 1982), the Hudson estuary (Dovel 1978 see Table 2, footnote 13, 1981 see Table 2, footnote 15), and the Pee Dee-Winyah system, S.C. (Marchette and Smiley 1982 see Table 2, footnote 24).

4.3 Natality and recruitment

4.31 Reproduction rates

Annual egg production

Annual egg production estimates for a shortnose sturgeon population have not been done. One problem with any such estimate is determination of what percentage of females in a population spawn each year. Dadswell (1979) estimated one-third of the Saint John shortnose sturgeon female population spawned per year based on the proportion of ripening females present during the preceding summer. If one-third do spawn each year and there are about 12,000 adult females in the Saint John population (two-thirds of total 18,000 since sex ratio 2:1♀:♂), then approximately 4,000 females spawn each year in that river system. Mean fecundity of 21 females sampled was 94,000 which means total egg deposition could be about a maximum of $4,000 \times 94,000 = 376 \times 10^6$ eggs/yr in the Saint John River, Canada.

Survival rates

Nothing is known about survival of eggs, larvae, or young-of-the-year shortnose sturgeon in the wild. Survival under hatchery conditions is usually poor due to fungus infections of eggs and death of larvae after yolk sac absorption because of lack of required food (Anonymous 1980 see Table 2, footnote 2; Buckley and Kynard 1981; Dovel 1981 see Table 2, footnote 15).

4.32 Factors affecting reproduction

Density dependent factors

No research has been done which indicates density factors affect reproduction. Shortnose sturgeon are usually found concentrated in a short stretch of their river during the spawning period (Pekovitch 1979 see Table 2, footnote 14; Taubert 1980a; Buckley 1982).

Dadswell (unpubl. data) found one small female (75 cm FL) was resorbing her eggs in September, and because the body cavity contained stage V eggs, it was thought she had not spawned during the spring for unknown reasons.

Physical factors

Shortnose sturgeon spawning grounds are found in the upper reaches of rivers (Taubert 1980a), below dams (Buckley and Kynard 1981; Squiers et al. 1981 see Table 2, footnote 3), in flooded cypress-tupelo swamps (Marchette, pers. obs.), and in riverine regions just above tidal influence (Dadswell 1979; Anonymous 1980 see Table 2, footnote 2; Dovel 1981 see Table 2, footnote 15). Known sites in the north have gravel or rubble substrate, medium to strong current speeds (0.3-0.8 m/s), and are 1-10 m in depth (Taubert 1980a; Anonymous 1980 see Table 2, footnote 2; Buckley 1982; Squiers et al. 1981 see Table 2, footnote 3). They are usually in or near areas of deeper water (Taubert 1980a; Squiers et al. 1981 see Table 2, footnote 3). Some southern sites (Pee Dee and Savannah Rivers) are in backwaters, with little current and 1-3 m in depth (Marchette, pers. obs.).

4.33 Recruitment

Because there are no commercial fisheries for shortnose sturgeon, no recruitment information is available. Dadswell (1976) estimated a possible recruitment of 1,100 15-yr-old shortnose sturgeon to a commercial fishery using a 20 cm stretch mesh,

Table 24.—Average densities for adult shortnose sturgeon populations from rivers in eastern North America.

System	Boundary		Surface area (ha)	Adult population estimate $\tilde{N}$	Density SNS/ha
	Lower	Upper			
Saint John R., N.B.	Reversing Falls	Fredericton	5.0×10^4	18,000	0.36
Kennebec R., Maine	Popham Beach	Augusta	1.1×10^4	10,000	0.90
Holyoke Pool, Connecticut R., Mass.	Holyoke Dam	Turner's Falls	1.6×10^3	400	0.25
Lower Connecticut R., Conn.	Enfield Dam	Holyoke Dam	0.8×10^3	186	0.23
	Long Island Sound	Holyoke Dam	3.6×10^3	800	0.22
Hudson R., N.Y.	Battery	Troy Dam	2.9×10^4	27,000	0.93
Delaware R., N.J.	Cape May	Scudders Falls	1.9×10^5	10,000	0.05
	C & D Canal	Lambertville	2.4×10^4	10,000	0.42

gill net if such a fishery was permitted in the Saint John River, Canada.

4.4 Mortality and morbidity

4.41 Mortality rates

Mortality rate has been determined for the Saint John River, Canada, population (Dadswell 1979), the Holyoke Pool population (Taubert 1980b), and the Pee Dee-Winyah population (Marchette and Smiley 1982 see Table 2, footnote 24). In all studies catches were adjusted for gill net selectivity and effort. Total instantaneous mortality rate (Z) for ages 14 through 55 was 0.12 for 1974 and 0.15 for 1975 in the Saint John River (Fig. 41). Mortality was relatively high among younger shortnose sturgeon but declined with age (Dadswell 1979). In the Holyoke Pool, Z was 0.12 for adjusted catches and 0.14 for all catches (Taubert 1980b). Marchette and Smiley (1982 see Table 2, footnote 24) estimated an instantaneous mortality in the Pee Dee-Winyah between 0.08 and 0.12.

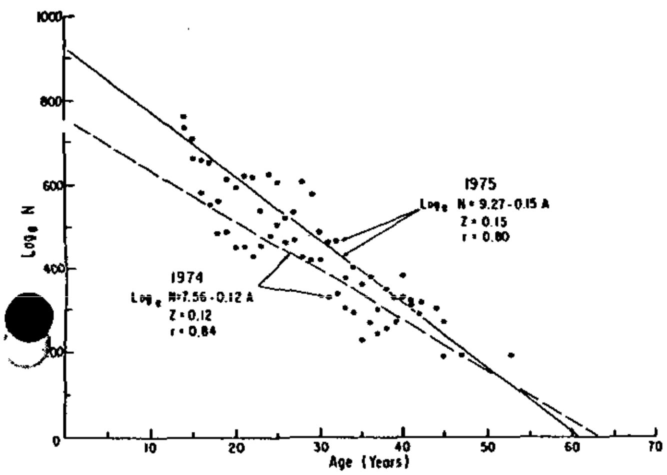

Figure 41.—Mortality [log$_e$ of year class abundance adjusted for gill net selectivity (Table 19)] of shortnose sturgeon captured in the Saint John River, Canada, during 1974 and 1975.

4.42 Factors causing or affecting mortality

Predators

See sections 3.34 and 3.35. Young are known to be eaten by yellow perch and adults may possibly be attacked by seals, sharks, gar, or alligators.

Physical factors

Dadswell (pers. obs.) observed a small kill of shortnose sturgeon during the first week of August 1974. The sturgeon were found dying or dead (four specimens) in an intensely eutrophic region of the Saint John estuary that was choked with vegetation. It was assumed that the heavy plant concentration caused an oxygen depletion in the area during the night. Other species of fish (suckers, perch) were killed at the same time.

Dovel (1981 see Table 2, footnote 15) observed that 78% of adult shortnose sturgeon in the Hudson River were affected by fin rot. Whether this has contributed to mortality is unknown.

Impingement of shortnose sturgeon on intake screens of power stations may result in some mortality, but the cause of impingement may be from events or injury elsewhere (netting, natural death). Hoff et al. (1977 see Table 2, footnote 12) reported that three shortnose sturgeon were found dead on the intake screens of Indian Point Power Plant, Hudson River, during 1978 and W. Kirk[19] stated mortalities of two, two, and one shortnose sturgeon were recorded at Indian Point in 1972, 1973, and 1979, respectively. Hoff and Klauda (1979 see Table 1, footnote 1) reported 39 shortnose sturgeon impinged on intake screens of power plants along the Hudson River between 1969 and 1979. Three shortnose sturgeon were impinged on the intake screens of the Salem Nuclear Station on the Delaware River in 1978 (Masnick and Wilson 1980), one in 1981 (Brundage[20]), and one at the Delaware Station in Philadelphia in 1975 (Brundage and Meadows 1982). Two shortnose sturgeon have been impinged at the Connecticut Yankee Nuclear Power Station. The most recent was in 1979 (Klattenberg[21]). Two shortnose sturgeon recovered dead were impinged on the trash racks of the Maine Yankee Nuclear Power Plant in 1980 (Squiers[22]).

Fishing

Besides natural mortality, fishing mortality caused by incidental catch in nets set for other species (mainly shad) is probably the main cause of mortality of shortnose sturgeon. Dadswell (1979) estimated the annual fishing mortality for shortnose sturgeon in the Saint John River as 1% or approximately 200 adult sturgeon a year. Many fishermen return sturgeon to the water alive but others do not. Either they are killed and discarded as a nuisance (Leland 1968; Cobb 1900) or they are marketed locally (Bean 1893; McCabe 1942). Incidental fishing mortality may be a major reason for the disappearance of this species from the shallow estuaries of Chesapeake Bay (Shortnose Sturgeon Recovery Team[23]) and is a suspected major factor of mortality in South Carolina (Marchette[24]).

4.5 Dynamics of population (as a whole)

No studies on shortnose sturgeon population dynamics have been done to date.

4.6 The population in the community and the ecosystem

4.61 Physical features of the biotype of the community

The shortnose sturgeon inhabits riverine, estuarine, and nearshore marine waters. It is most commonly found in productive

[19]W. Kirk, Research Scientist, Texas Instruments Inc., P.O. Box 237, Buchanan, NY 10511, pers. commun. March 1979.

[20]H. M. Brundage III, Ichthyological Associates Inc., 100 South Cass Street, Middleton, DE 19709, pers. commun. April 1983.

[21]R. Klattenberg, Northeast Utilities, P.O. Box 270, Hartford, Conn., 06101, pers. commun. July 1981.

[22]T. S. Squiers, Fisheries Biologist, Maine Department of Marine Resources, Augusta, ME 04333, pers. commun. June 1981.

[23]Shortnose sturgeon recovery team, National Marine Fisheries Service, State Pier, Gloucester, MA 01930, pers. commun. March 1978.

[24]D. E. Marchette, Fisheries Biologist, South Carolina Wildlife and Marine Resources, Charleston, SC 29412, pers. commun. August 1982.

mesohaline environments with salinities between 1 and 20 $^{0}/_{00}$, usually in and around the salt-wedge portion of estuaries (Squiers and Smith footnote 7; Dadswell 1979; Marchette and Smiley 1982 see Table 2, footnote 24). Freshwater habitats are characterized as deep river channels or in shallow regions with soft bottoms and abundant macrophytes. Habitats in higher salinity are usually over sand-mud bottoms in and around the *Mya-Macoma* zone. Populations may require access to a gravel-boulder section of riverine habitat for spawning (Taubert 1980b; Buckley 1982). The habitat of the shortnose sturgeon while in nearshore marine situations is undescribed, but shortnose sturgeon may occur in shallow water a few miles from shore associated with mixed sediments containing *Mya arenaria*, *Corbicula manilensis*, or other similar molluscs.

4.62 Species composition of the community

Juvenile shortnose sturgeon share the deep river channels with few other species. In the Saint John River only juvenile Atlantic sturgeon and ling, *Lota lota*, occur in this habitat. Adult shortnose sturgeon in the Saint John River were found in company with American eels, *Anguilla rostrata*; ling, *Lota lota*; suckers (*Catostomus* spp.); and whitefish, *Coregonus clupeiformis*, in freshwater and Atlantic sturgeon, *A. oxyrhynchus*; flounders (*Pseudopleuronectes americanus*); hake, *Urophycis tenuis*; and tomcod, *Microgadus tomcod*; in saline water (Dadswell, pers. obs.). In the Connecticut River, adult shortnose sturgeon associated with channel catfish, *Ictalurus punctatus*, walleye, *Stizostedion vitreum*, carp, *Cyprinus carpio*, and northern pike, *Esox lucius* (Taubert, pers. obs.; Buckley, pers. obs.).

Community relationships of shortnose sturgeon populations in other rivers are undescribed at present.

4.63 Interrelations within the community

Dadswell (1976) considered shortnose sturgeon and Atlantic sturgeon to competitively exclude each other depending on the salinity of the habitat. In the Saint John River, Canada, shortnose sturgeon compete with flounder and whitefish for the same food resource (see section 3.33).

5. EXPLOITATION

5.1 Fishing equipment

Shortnose sturgeon were captured with gill nets and traps. Gill nets were either drifted or fixed (Ryder 1890; Greeley 1937; McCabe 1942). Most shortnose sturgeon were (Meehan 1910; Greeley 1937), and are presently caught in shad drift and set gill nets (Dovel 1979, see Fig. 4 legend; Dadswell 1979; Shortnose Sturgeon Recovery Team footnote 23). In the Saint John River, Canada, many shortnose sturgeon are captured in commercial alewife trapnets. Some of these shortnose sturgeon are processed along with the alewife into fish meal. A few shortnose sturgeon are captured by ocean trawlers (Brundage and Meadows 1982).

5.2 Fishing areas

Commercial shortnose sturgeon fishing areas were typically the middle and upper reaches of the estuaries of large rivers. McCabe (1942) described a sturgeon fishery below the Holyoke Dam in the Connecticut River that may have principally utilized shortnose sturgeon.

5.21 General geographic distribution

Throughout its range shortnose sturgeon have entered the commercial fishery (see section 2.1) (Bean 1893; Greeley 1937). Caviar from this species formerly commanded a higher price than Atlantic sturgeon caviar (Vladykov and Greeley 1963).

5.22 Geographic ranges

See section 2.1.

5.23 Depth ranges

Adult shortnose sturgeon are usually captured in shallow water. Depth of capture seldom exceeds 10 m but this is mainly because of the commercial fishing gear used.

5.3 Fishing seasons

5.31 General pattern of seasons

Since the shortnose sturgeon is listed as endangered in the United States, there is no open season for this species. Formerly, a few fishermen in the Delaware and Hudson Rivers set nets for the purpose of capturing this species during the few weeks (late April) before the shad season (Greeley 1937).

In the Saint John River, Canada, the sturgeon season is open all year except the month of June, but sturgeon are actively sought only during July-August. If a season for shortnose sturgeon were established in the Saint John River, Dadswell (1975) recommended it be confined to winter and early spring (January-April). This would provide caviar in peak condition and flesh untainted by a muddy flavor which becomes prevalent in late summer in this river.

5.32 Dates of beginning, peak and end of season

See section 5.31.

5.33 Variation in date or duration of season

See section 5.31.

5.4 Fishing operations and results

5.41 Effort

At present there is no directed effort for shortnose sturgeon in the United States because of its endangered status. Effort for sturgeon in the Saint John River, Canada, amounts to 1 or 2 mo of gillnetting per year, depending on the market. About 5% of the sturgeon catch in the Saint John River is shortnose sturgeon (Dadswell, unpubl. data).

5.42 Selectivity

Figure 39 illustrates the indirect and direct selectivity of various size monofilament gill nets for shortnose sturgeon. Each direct selectivity mode has a broad plateau because of the multiple ways a shortnose sturgeon can mesh (Dadswell 1979). Larger mesh sizes are more efficient in capturing shortnose sturgeon than small mesh sizes. Dadswell (unpubl. data) found that monofilament nets were about twice as efficient as multifilament nets unless multifilament twine size was very fine. The direct selectivity relationship for the commercial, multifilament nylon, shad gill net (5 in or 12.7 cm stretched mesh) is illustrated in Figure 42. Confidence limits of the selectivity curve indicate 95% of incidental shortnose sturgeon catch is concentrated between 57 and 90 cm fork length ($\bar{X} = 73.6$, SE = 8.1) which is the size range of adult shortnose sturgeon in most U.S. rivers.

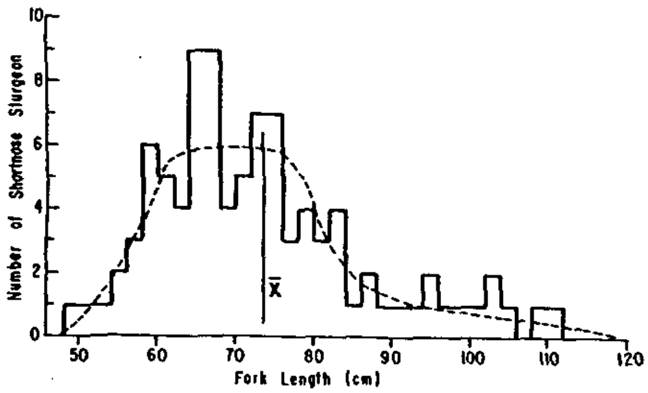

Figure 42.—Direct selectivity of 15.2 cm (5 in) stretched mesh, 210/3 multifilament nylon, commercial shad net for shortnose sturgeon in the Saint John River, Canada. Data from tag returns of shortnose sturgeon captured by commercial fishermen.

5.43 Catches

Total annual yield

The annual, incidental, shortnose sturgeon catch in most U.S. rivers, except perhaps the Hudson, may not exceed 10 or 20 fish per river (Shortnose Sturgeon Recovery Team shad fishery bycatch survey). Annual yield of shortnose sturgeon before the advent of endangered species status is unknown since fishery statistics data were listed as "sturgeon" only, thereby combining the two Atlantic coast species (Hoff 1979). For landing statistics of "sturgeon" on the east coast of the United States see Murawski and Pacheco (1977).

In the Saint John River, Canada, about three or four legal size shortnose sturgeon (total length 4 ft [122 cm TL] or more) are captured each year (Gorham[25]). As many as 200 sublegal shortnose sturgeon may be harvested each year as a bycatch from the shad gill net or alewife trapnet fisheries as determined by limited local markets (Dadswell, pers. obs.). Additionally, an unknown amount of shortnose sturgeon captured with alewives in the trapnet fishery become fish meal (Dadswell, unpubl. data). Dadswell (1975) used a yield/recruit model based on a 20 cm gill net catch curve (Fig. 43) to estimate a sustainable annual yield of approximately 2,000 kg or 350 adult shortnose sturgeon/yr could be removed from the Saint John River, Canada, over and above the present incidental catch.

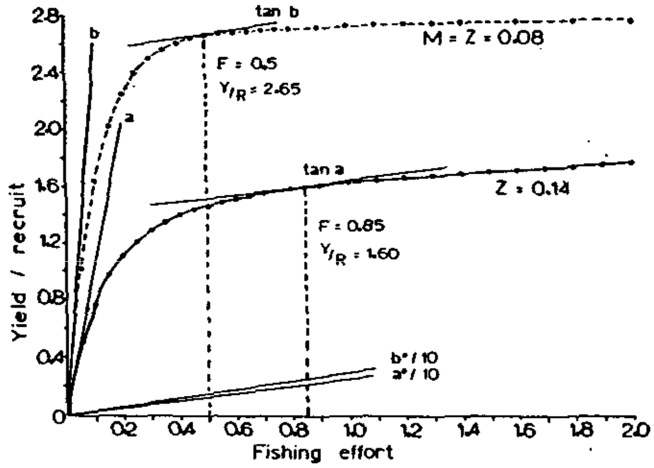

Figure 43.—Theoretical yield/recruit relationship for a 20 cm (8 in) stretched mesh gill net fishery for the shortnose sturgeon population in the Saint John River, Canada, at two levels of instantaneous total mortality.

6. PROTECTION AND MANAGEMENT

6.1 Regulatory (legislative) measures

6.11 Limitation or reduction of total catch

Since passage of the Endangered Species Act of 1973, as amended, it has been unlawful to "take" (hunt, harass, capture, or kill) shortnose sturgeon in the United States.

6.12 Protection of portions of population

At present all portions of the shortnose sturgeon population in the United States are protected. In Canada, all sturgeon under 122 cm (4 ft) total length are protected.

6.2 Control or alteration of the physical features of the environment

Not presently used for promotion of shortnose sturgeon stocks but some alterations of fish-lift schemes or bypass systems are now under consideration to assist natural populations (Klattenberg[26]). However, any other proposed alteration of the environment that may adversely affect shortnose sturgeon populations is closely reviewed in the United States under the Endangered Species Act. Any proposed action that might jeopardize the continued existence of a population will be modified to reduce these adverse effects.

6.3 Control or alteration of the chemical features of the environment

None used for the promotion of shortnose sturgeon stocks. See section 6.2 for proposed alterations.

[25] S. W. Gorham, Curator of vertebrates, New Brunswick Museum, Saint John, N.B., pers. commun. August 1975.

[26] R. Klattenberg, Northeast Utilities, P.O. Box 270, Hartford, Conn. 06101, pers. commun. March 1981.

6.4 Control or alteration of the biological features of the environment

None used for the promotion of shortnose sturgeon.

6.5 Artificial stocking

6.51 Maintenance stocking

None has been attempted.

6.52 Transplantation, introduction

None has been attempted.

7. POND FISH CULTURE

Shortnose sturgeon have never been cultured. Meehan (1910) described one successful and one unsuccessful attempt to overwinter shortnose sturgeon in catfish ponds near Philadelphia. These fish were kept for the purpose of stripping eggs and milt when ripe and not for growth experiments. Marchette (footnote 24) kept 12 shortnose sturgeon in hatchery ponds in South Carolina for over a year, and work is now underway in South Carolina to culture this species.

7.1 Procurement of stocks

Stocks appear to be available if enhancement or reintroduction is attempted.

7.2 Genetic selection of stocks

None attempted to date.

7.3 Spawning

Artificial spawning has been successful for this species (Anonymous 1980 see Table 2, footnote 2; Buckley and Kynard 1981; Dovel 1981 see Table 2, footnote 15), but only from naturally ripe specimens. Hormonal inducement has been unsuccessful so far (Pottle and Dadswell 1979 see Table 2, footnote 1; Anonymous 1980 see Table 2, footnote 2).

7.4 Rearing

Artificially spawned shortnose sturgeon have been reared only to an age of 40-60 d (Anonymous 1980 see Table 2, footnote 2; Buckley and Kynard 1981). Most larvae in hatchery conditions have died just after yolk sac absorption, probably because offered natural or artificial diets were not correct.

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