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December 1989

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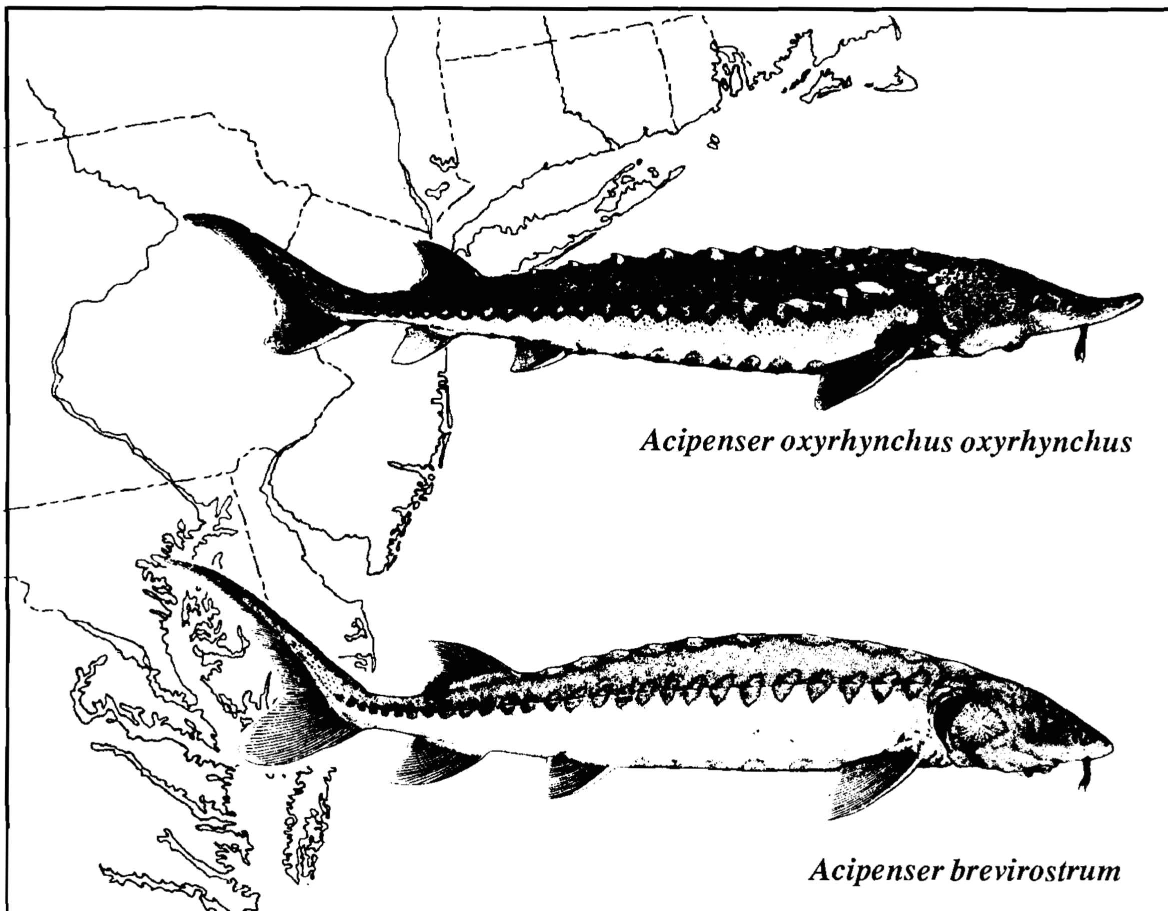

Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic Bight)

ATLANTIC AND SHORTNOSE STURGEONS

by

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Performed for
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Vicksburg, MS 39180

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PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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U.S. Army Engineer Waterways Experiment Station
Attention: WESER-C
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Vicksburg, MS 39180

CONVERSION TABLE

Metric to U.S. Customary

Multiply	*By*	*To Obtain*
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (° C)	1.8 (° C) + 32	Fahrenheit degrees

U.S. Customary to Metric

inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces	28.35	grams
pounds (lb)	0.4536	kilograms
pounds	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (° F)	0.5556 (° F - 32)	Celsius degrees

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FIGURES

ACKNOWLEDGMENTS

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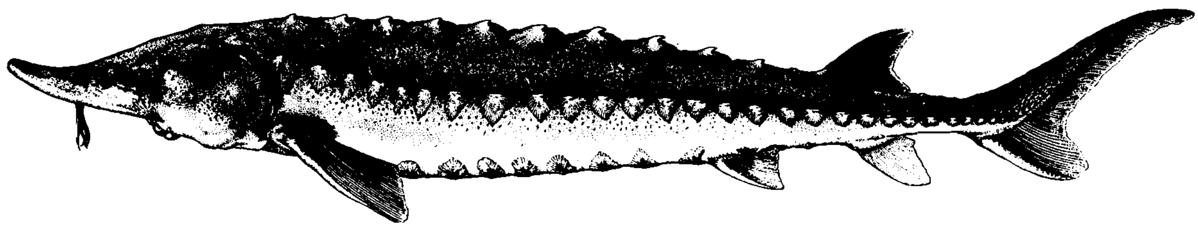

Figure 1. Atlantic sturgeon (*Acipenser oxyrhynchus oxyrhynchus*), immature male, 581 mm, from St. Lawrence River, Quebec (Vladykov and Greeley 1963).

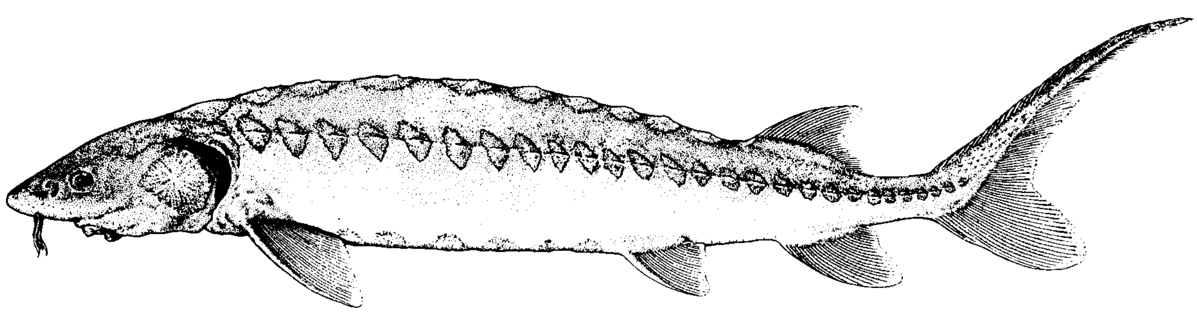

Figure 2. Shortnose sturgeon (*Acipenser brevirostrum*), spawning female, 580 mm, from Hudson River, New York (Vladykov and Greeley 1963).

ATLANTIC AND SHORTNOSE STURGEONS

NOMENCLATURE/TAXONOMY/RANGE

Scientific name .... *Acipenser oxyrhynchus* Mitchill; divisible into two distinct, geographically separate subspecies, one (*A. o. oxyrhynchus*) living in the Atlantic Ocean and the other (*A. o. desotoi*) confined to the Gulf of Mexico.

Preferred common name ...... Atlantic sturgeon (Figure 1).

Other common names .... Sea sturgeon; common sturgeon; big sturgeon (adults,

Hudson River); sharpnose sturgeon (young, Hudson River); pelican (young, Hudson River); esturgeon noir (adults, Quebec); esturgeon d'eau sallée (adults, Quebec); escargot (young, Quebec); escaille (young, Quebec) (*A. o. oxyrhynchus*); common sturgeon; Gulf of Mexico sturgeon; Gulf sturgeon (*A. o. desotoi*).

Scientific name .... *Acipenser brevirostrum* Lesueur.
Preferred common name ..... Shortnose sturgeon (Figure 2).
Other common names .... Shortnosed sturgeon; pinkster (young, New York); esturgeon á museau court (Quebec); little sturgeon (St. John River, New Brunswick); roundnoser (Hudson River); bottlenose (Delaware River); mammose (Delaware River); salmon sturgeon (North and South Carolina); soft-shell (Altamaha River, Georgia); lake sturgeon (Altamaha River, Georgia).

Class .... Osteichthyes
Order .... Acipenseriformes
Family .... Acipenseridae

Geographic ranges: Atlantic sturgeon: *A. o. oxyrhynchus*, Atlantic Ocean, from Hamilton River, Labrador, and George River, Ungava Bay, Labrador, south to St. Johns River, Florida, and ranging south in winter to Port Canaveral and Hutchison Island, Florida (Gruchy and Parker 1980b; Wooley 1985) (Figure 3); *A. o. desotoi*, Gulf of Mexico, from lower Mississippi River east to Suwannee River, Florida, and occasionally south to Charlotte Harbor, on lower west coast of Florida (Wooley 1985); two old records from Bermuda (Beebe and Tee-Van 1933) and a doubtful record from French Guiana (Duméril 1867) have tentatively been considered to be based on *A. o. desotoi* (Vladykov and Greeley 1963), but substantiating data are lacking. The doubtful occurrence in northern South America apparently is responsible for erroneous inclusion of Central America in geographic range (van den Avyle 1984).

Shortnose sturgeon: St. John River, New Brunswick, south to St. Johns River, Florida (Gruchy and Parker 1980a) (Figure 4); an old record from Indian River, Florida (Evermann and Bean 1898) is probably valid but requires confirmation. Populations may be semi-disjunct, inasmuch as there are no confirmed records from extensive sections of intervening coast.

MORPHOLOGY/IDENTIFICATION AIDS

Adults

Sturgeons are heavy, subcylindrical fishes with an elongated, hard snout and a distinctly ventral, protrusible mouth. A row of four barbels, which extends across most of the width of the snout, is situated midway between the mouth and tip of the snout. Sturgeons are also distinguished by a strongly heterocercal tail in which the upper lobe (which contains the extended vertebral column) is distinctly longer than the lower lobe. The head is covered by bony plates, and the remainder of the body has five rows of large, bony scutes: one dorsal row running along the midline of the back; two lateral rows, one on each mid-side of body; and two ventrolateral rows, one on each lower side of the body between the pectoral and pelvic fins. The scutes are sharp and obvious in the young, becoming smoother and less distinct with age. The rest of the body surface appears naked but has small patches of denticles. The dorsal and anal fins are approximately opposite from each other and situated far back on the body.

There is little sexual dimorphism, although females reach a larger size than males. The sex of an individual can be determined externally only during spawning time.

Atlantic Sturgeon

Snout longer and more sharply pointed in smaller individuals, becoming relatively shorter and less pointed in larger individuals; snout longer than postorbital distance (posterior margin of orbit to posterior margin of opercle) in fish shorter than 95 cm (37.5 inches) total

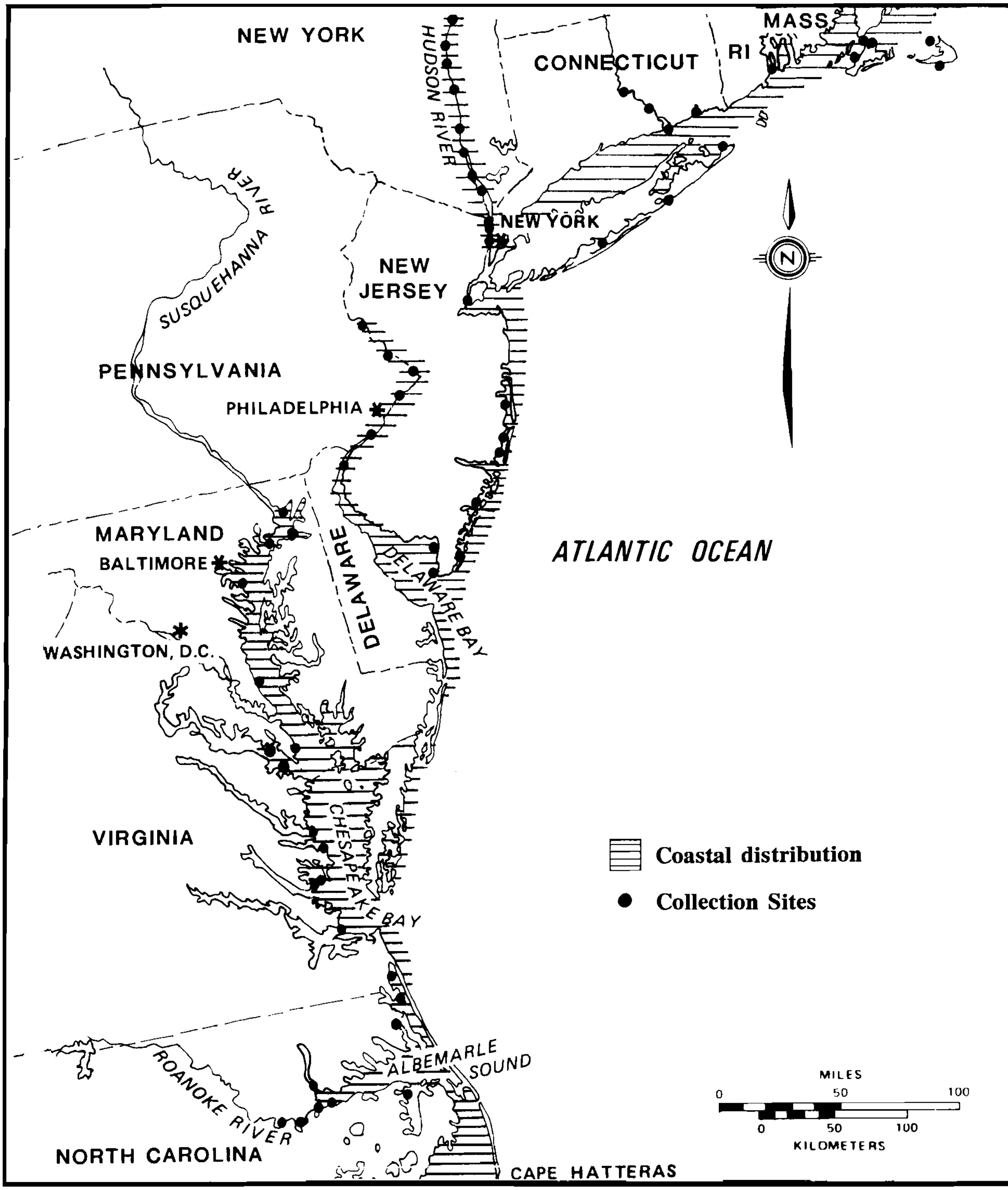

Figure 3. Coastal distribution of Atlantic sturgeon in the Mid-Atlantic Bight. Although there are no published records from the outer part of the Delmarva Peninsula or from Long Island Sound, the species obviously occurs there, based on tag returns. It probably once ranged farther up the Roanoke and Susquehanna Rivers, but upstream movement is now blocked by the presence of dams. Data from Gruchy and Parker (1980b) and C. Smith (1985).

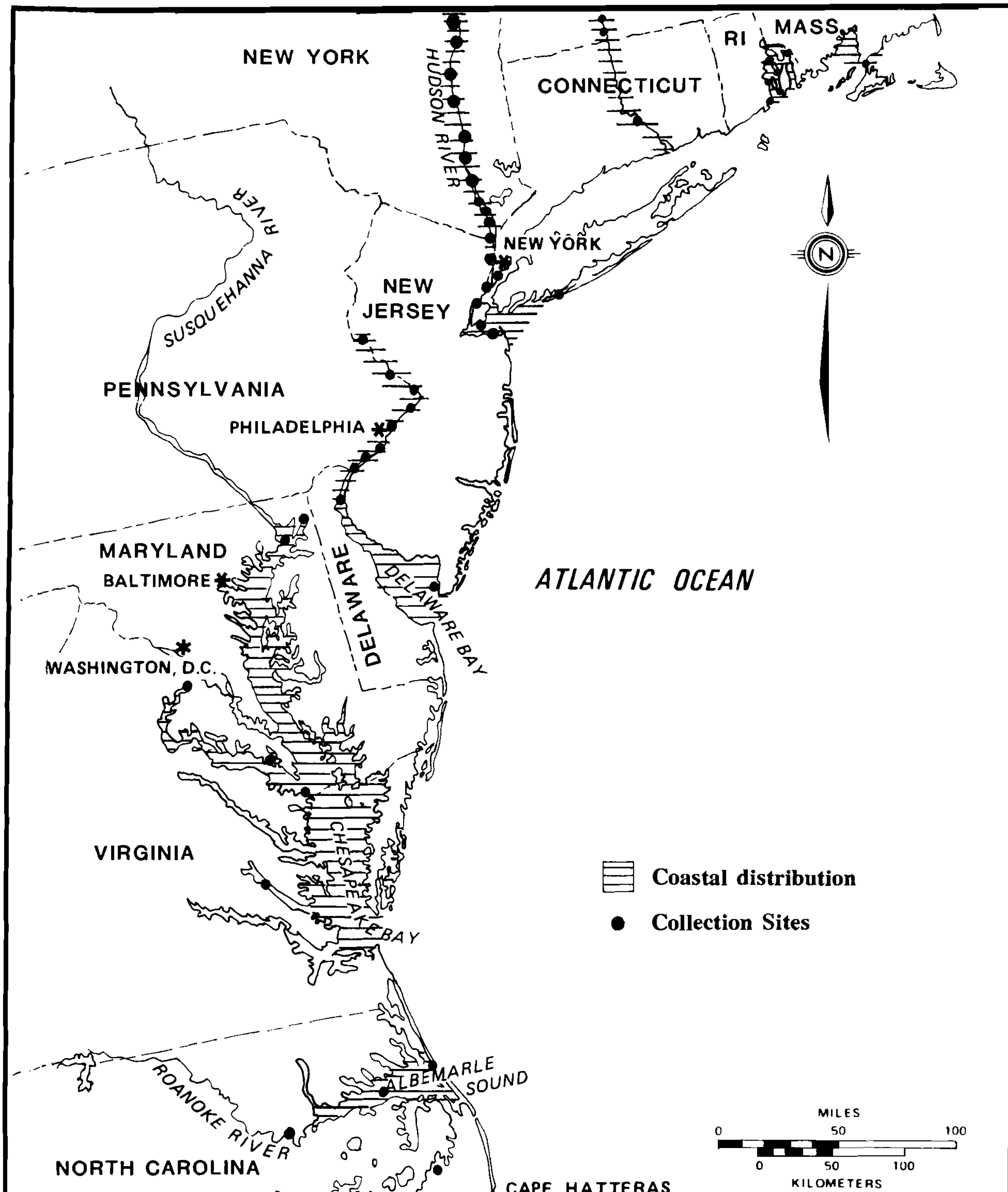

Figure 4. Coastal distribution of shortnose sturgeon in the Mid-Atlantic Bight. No records outside hatched areas have been confirmed (Dadswell et al. 1984). It probably once ranged farther up the Susquehanna and Roanoke Rivers, but upstream movement is now blocked by the presence of dams. Data from Gruchy and Parker (1980b), Dadswell et al. (1984), and C. Smith (1985).

length (TL), less than postorbital distance in fish longer than 95 cm (Figure 5); mouth relatively narrow, the width inside lips less than 3/5 of bony interorbital width; 2-6 bony plates (at least pupil sized) between anal base and lateral row of scutes (Figure 6); total number of gillrakers in outer gill arch averaging 21-22 (range 17-27); pigmentation of lateral scutes same shade as background; intestine lightly pigmented; adult females averaging 245 cm TL and 90-160 kg, depending on condition of fish and presence or absence of eggs; males smaller, averaging 180-210 cm TL and up to 90 kg.

Although various characters have been used to distinguish the two subspecies of Atlantic sturgeon (*A. o. oxyrhynchus* and *A. o. desotoi*), the only character showing a complete and consistent difference at all sizes is the length of the spleen, which makes up 5.7%-6.0% of the fork length (FL) (tip of snout to fork of tail) in the subspecies *oxyrhynchus*, and 12.7%-17.5% in the subspecies *desotoi* (Wooley 1985). Other characters showing average differences between these taxa are lengths of head and pectoral fin (both slightly longer in *desotoi*) and dimensions of the dorsal scutes (slightly higher and more squared in *desotoi*). Although these differences are statistically significant ($P=0.05$), none will permit complete separation of the two subspecies (Wooley 1985).

Shortnose Sturgeon

Snout shorter and blunter (shorter than postorbital distance in individuals of all sizes; Figure 5); mouth wider, the width inside lips more than 3/5 of bony interorbital width; no enlarged bony plates between base of anal fin and lateral row of scutes (Figure 6); total number of gillrakers in outer gill arch averages 25-26 (range 22-29); pigmentation of lateral scutes much paler than background; intestine darkly pigmented; size relatively small, the largest recorded specimen a female, measuring 142 cm TL and weighing 42 kg (Dadswell 1979).

Larvae

Larval specimens of Atlantic and shortnose sturgeons as small as 14.5 cm TL can be separated on the basis of characteristics of the mouth, particularly mouth width (Bath et al. 1981). Ratios of mouth width to head width and mouth width to head length differ consistently between the two species (Figure 7). However, since the mouth width:head length ratio apparently varies inversely with size of the specimen, the mouth width:head width ratio is the more useful discriminating characteristic because it is not related to specimen size. Bath et al. (1981) indicated that larvae of the two species can also be separated on the basis of distance between the oral papillae (greater in shortnose sturgeon), although they presented no substantiating statistical data.

REASON FOR INCLUSION IN SERIES

The Atlantic sturgeon is a high-quality food fish, and its roe is an important source of caviar. It has supported important commercial fisheries in the past, and although these fisheries have nearly been eliminated today, careful management and conservation conceivably could cause them to be revived in some areas. The shortnose sturgeon, because of its smaller size, has historically contributed less total poundage to the overall commercial catch. It is reputed to have once commanded a slightly higher price per pound than the Atlantic sturgeon in some areas (Lesueur 1818), but if so this is no longer true (Ryder 1890). Sturgeons mature slowly, and individuals of both species less than 5 years old use estuaries and large rivers during most of the year. These factors, combined with overfishing, damming of rivers (which prevent the fish from reaching their spawning grounds), and general deterioration of water quality, have resulted in a serious decline of stocks of both species. Consequently, the Atlantic sturgeon is protected over much of its range, and the shortnose sturgeon is classified as a federally endangered species. Sturgeons are also of great scientific interest, inasmuch as they are among the most evolutionarily primitive of all living fishes.

LIFE HISTORY

Numerous studies and summaries have been produced on various aspects of the life history

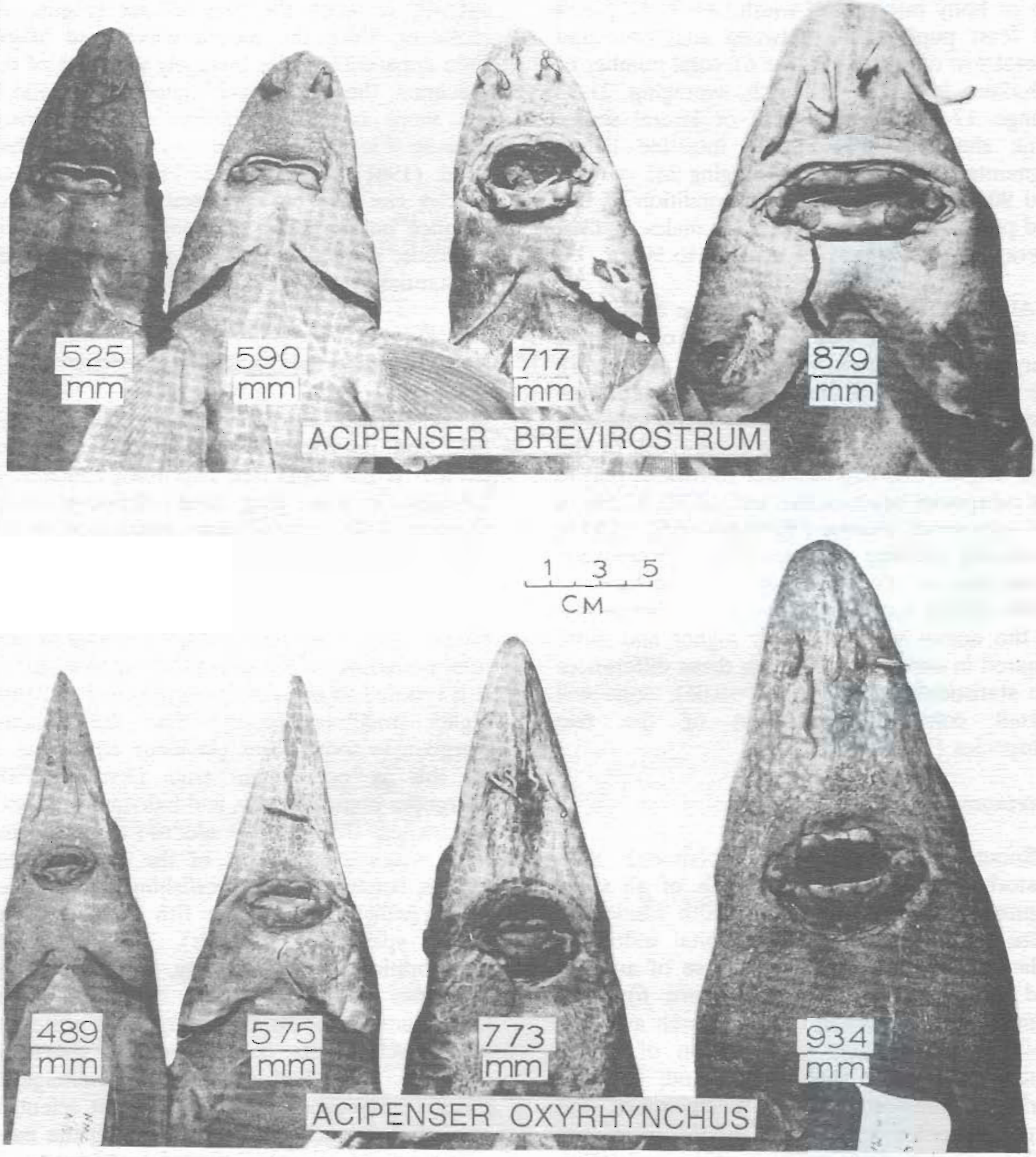

Figure 5. Undersides of heads of shortnose sturgeon (top) and Atlantic sturgeon (bottom), showing differences in snout shape and mouth width at comparable sizes (Gorham and McAllister 1974).

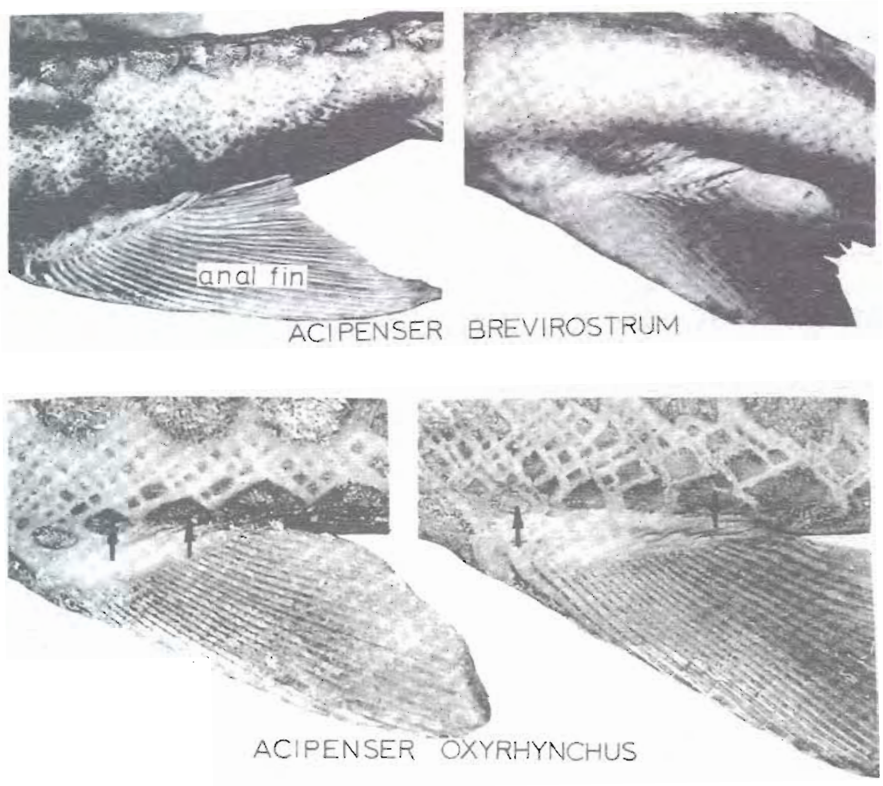

Figure 6. Differences in size and distribution of small bony plates above anal fin in shortnose sturgeon (top) and Atlantic sturgeon (bottom) (Gorham and McAllister 1974).

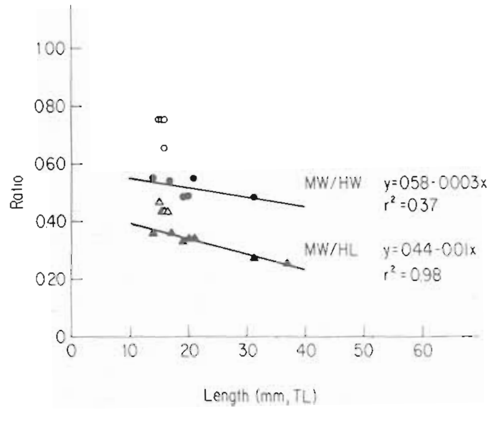

Figure 7. Ratios of mouth width/head width and mouth width/head length correlated with body length for Atlantic sturgeon larvae from Hudson River, New York. Open circles and triangles, shortnose sturgeon; closed circles and triangles, Atlantic sturgeon (Bath et al. 1981).

of the Atlantic sturgeon (Ryder 1890; Borodin 1925; Bigelow and Schroeder 1953; Vladykov and Greeley 1963; Magnin 1963, 1964; Scott and Crossman 1973; Gorham and McAllister 1974; Huff 1975; Murawski and Pacheco 1977; Gilbert 1978; Bath et al. 1981; Smith et al. 1982; van den Avyle 1984; C. Smith 1985; T. Smith 1985; Carr, unpubl.; Hollowell, unpubl.), and several of these also contain information on the shortnose sturgeon, either as a basis for comparison or as separate species accounts. Until the 1970's, few studies existed for the shortnose sturgeon, probably because of its lesser commercial importance. So much attention has recently been accorded this species, however (Dadswell 1976, 1979; Hoff 1979; Taubert 1980a,b; Taubert and Dadswell 1980; Dadswell et al. 1984; Buckley and Kynard 1985), that many of its life-history details are now better known than for the Atlantic

sturgeon. Despite this comparatively large pool of information, certain aspects of these species' life histories remain either poorly known or unknown.

Although basic life-history strategies and habitat preferences of the Atlantic and shortnose sturgeons are similar, they nevertheless differ in a number of important details. Both species are anadromous, spending much of their lives in brackish or salt water and migrating upstream in coastal rivers to spawn. There are differences, however, in migration and spawning times, in temperature and salinity preferences, and in preferred overwintering and spawning sites. Temperature preferences are obviously closely interrelated to times of migration and spawning, and salinity preferences are manifested in the frequency and extent of invasions into the ocean by the two species. The species may also differ in degree of feeding selectivity as adults, but further investigation is required.

Reproduction

The shortnose sturgeon undergoes earlier migration and spawning than the Atlantic sturgeon at comparable latitudes. Temperature is probably the major governing factor, as evidenced by the progressively later spawning season of both species with increasing latitude. Other possible contributing factors are current velocity, occurrence of spring freshets, and substrate character (Dadswell et al. 1984).

Although both species are anadromous, the shortnose sturgeon is more closely restricted to fresh water. One population of shortnose sturgeon was landlocked in Holyoke Pool (an artificial impoundment of the Connecticut River), Massachusetts, after 1848, following construction of the Holyoke Dam (Taubert 1980a). This population remains at least partly landlocked, but since 1955 has been reinforced by fish traversing the dam after a fish ladder was constructed there. A second population, partly landlocked after dam construction, occurs in Lake Marion, South Carolina (Marchette and Smiley, unpubl.). Atlantic sturgeon may have been present in upstream areas after closure of both these dams, but the presence today of only the shortnose sturgeon in these areas provides indirect evidence of its closer affinity to fresh water.

Adult Atlantic sturgeon migrate into fresh water in advance of the spawning season, the males preceding the females by a week or longer (C. Smith 1985). This migration occurs in mid- to late February in southern parts of the range (Suwannee River, Florida; St. Marys River, Georgia; South Carolina) (Huff 1975; Gilbert 1978; Smith et al. 1982; van den Avyle 1984), and in late May to mid-June or even early July in tributaries to the Gulf of Maine and in the St. Lawrence River (Bigelow and Schroeder 1953; Vladykov and Greeley 1963; Scott and Crossman 1973). Smith et al. (1984) indicated that an upriver migration of ripe Atlantic sturgeon in late August and September in South Carolina has also been documented, but further details are lacking. In South Carolina, water temperatures of 7-8 °C were recorded during the time of Atlantic sturgeon migrations in the second and third week of February in 1979, 1980, and 1982 (Smith et al. 1982). C. Smith (1985) reported that mature males begin to move up the Hudson River when water temperatures reach 5.6-6.1 °C, and females appear at the spawning sites when temperatures are about 12.2-12.8 °C. Spawning follows within a few weeks.

Huff (1975) indicated that the Gulf sturgeon spawns from March to early May in the Suwannee River, with peak activity in April. Spawning was observed in downstream areas of the Pee Dee River, South Carolina, during late May and early June (van den Avyle 1984), between 10 and 22 May 1925 in the Delaware River, Pennsylvania (Borodin 1925; Vladykov and Greeley 1963), and from May to early June in New York (C. Smith 1985). It was estimated that a large gravid female caught in the St. Lawrence River on 23 June 1954 would have spawned within a week (Vladykov and Greeley 1963).

Shortnose sturgeon have been observed to migrate upstream during fall in the Hudson, Connecticut, and St. John Rivers; some adults that will spawn during the following spring migrate upstream to deep over-wintering sites

adjacent to the spawning grounds (Dadswell 1979; Dadswell et al. 1984). Despite this, most migratory activities occur during winter and spring. Males usually lead the upstream migration. Some ripening and most non-ripening adults spend much of the winter in deep water in the lower parts of rivers and in estuaries. Dadswell et al. (1984), using a number of information sources, reported spawning of shortnose sturgeon as early as January in South Carolina and Georgia, and as late as mid-May in the St. John River, New Brunswick. Arrival on the spawning grounds occurs at temperatures of 8-9 °C. Dadswell (1976, 1979) indicated that shortnose sturgeon spawn earlier than Atlantic sturgeon in the St. John River, and this observation presumably holds true elsewhere throughout their shared ranges. Partial confirmation appears in reports by Greeley (1935, 1937) of ripe and spawning shortnose sturgeon observed in the Hudson River from February to early April (and which were spent by early May), in conjunction with C. Smith's (1985) report of a late May to July spawning season for Atlantic sturgeon from the same river.

Earlier spawning of the shortnose sturgeon may also result, in part, from the presence of portions of the breeding population overwintering adjacent to the spawning grounds. Shortnose sturgeon in breeding condition were caught between 24 April and 9 May 1977 in the Holyoke Pool of the Connecticut River, Massachusetts, and females were found spawning there between 3 and 9 May (Taubert 1980a). Buckley and Kynard (1985) reported this species spawning in the Connecticut River, below Holyoke Dam, from 30 April to 10 May in 1979-1982.

In the Pee Dee River, South Carolina, spawning sites for the Atlantic sturgeon were characterized by relatively slow current, turbid water, and bottom substrates of sand and silt with abundant organic debris (van den Avyle 1984). These conditions are different from those usually reported for the species. Borodin (1925) found Atlantic sturgeon spawning, in the Delaware River, Pennsylvania, at depths of 11-13 m, over a hard clay bottom at water temperatures of 13.3-17.8 °C. Vladykov and Greeley (1963) reported that *A. o. desotoi* typically spawns in deep water, with strong current, over a hard bottom, or in pools below rapids or waterfalls. In many southern rivers, such conditions occur in and below river bends containing rock outcroppings. Dees (1961) indicated that *A. o. oxyrhynchus* spawns in flowing brackish or fresh water as deep as 3 m over a bottom of small rubble or gravel. C. Smith (1985), however, wrote that spawning "takes place in fresh water, just above the salt front, and the spawning fish may move upstream with the salt front as the season progresses."

Taubert (1980a) found shortnose sturgeon spawning in relatively fast-flowing sections (current velocities 37-125 cm/sec) of the Holyoke Pool, at water temperatures of 10-15 °C, over a mixture of gravel, rubble, and large boulders, with little sand or silt. Buckley and Kynard (1985) found this species spawning in a deep depression of the Connecticut River below Holyoke Dam, and Squiers et al. (1981) reported spawning in a similar area of the Androscoggin River, Maine. Spawning in the Connecticut River occurred when water temperatures rose to 11.5-14.0 °C and water discharge decreased from 679 to 301 m^3/sec. Dadswell et al. (1984), citing data from various sources, indicated that most spawning occurred at temperatures of 9-12 °C. They also reported that northern spawning grounds examined were in regions of fast flow (46-60 cm/sec) with gravel or rubble bottoms, and were generally well upriver from the summer foraging and nursery grounds; in South Carolina, however, spawning areas were reported to be in flooded hardwood swamps along the inland portions of rivers.

The apparent absence of suitable spawning substrate (usually rock, rubble, or hard clay) in the St. Johns River, Florida, suggests that lack of documented spawning of the shortnose and Atlantic sturgeon there more likely reflects the true situation, rather than inability to locate spawning populations. By contrast, the presence of limestone outcrops and deep holes, coupled with the absence of dams, in the geographically adjacent Suwannee River probably is an important contributing factor to the success of the resident Gulf sturgeon population.

Buckley and Kynard (1985) suggested that water velocity and depth may be more critical than type of substrate in determining the specific spawning locations of shortnose sturgeon. They pointed out that eggs released when velocity is too high may not adhere to the substrate, and those released when velocity is too low may clump, resulting in increased mortality from respiratory stress, fungal growth, or possibly increased egg predation. Spawning in water with sufficient velocity is also important to the survival of larvae, since young hatched in areas with insufficient current would not be transported downstream. Buckley and Kynard (1981) described active vertical swimming movement in newly hatched shortnose sturgeon larvae. Presumably, this also is an adaptation for downriver transport.

Observations of shortnose sturgeon in the St. John, Connecticut, and Hudson Rivers indicate that spawning is confined to short (1-2 km) stretches of river (Taubert 1980a; Dadswell et al. 1984). Buckley (1982) found shortnose sturgeon spawning in a longer (6 km) section of the lower Connecticut River, below Holyoke Dam. Bath et al. (1981) indicated that spawning sites for the two species differ in the lower Hudson River, New York: the Atlantic sturgeon spawns in oligohaline sections between river km 64 and 126, and the shortnose sturgeon spawns in more upstream tidal freshwater areas between river km 201.0 and 244.5. These are somewhat longer stretches of river than those described earlier.

Although van den Avyle (1984) stated (in reference to the Atlantic sturgeon) that "spawning has been observed during late May and early June in downstream areas of the Pee Dee River, South Carolina," most of what is known has been inferred from circumstantial evidence (collections of eggs and larvae, physical characteristics of spawning sites, observations based on other sturgeon species, etc.).

Pekovitch (1979) reported a ratio of 2.5 males to 1 female shortnose sturgeon on spawning grounds in the Hudson River in 1979, and Taubert (1980b) found a ratio of 3.5 males to 1 female in the Holyoke Pool spawning grounds over two spawning seasons. Buckley and Kynard (1985) reported similar findings, based on inference from gill-net captures as well as direct observations made on the lake sturgeon, *Acipenser fulvescens*, by Harkness and Dymond (1961) and by Priegel and Wirth (1975). Data appear to be lacking for the Atlantic sturgeon, but it seems likely that similar ratios hold for that species as well.

The various species of *Acipenser* appear to have a compressed spawning period for each individual of perhaps no more than 3-5 days (Harkness and Dymond 1961; Khoroshko 1972; Taubert 1980a). Eggs are presumably broadcast into flowing water, becoming widespread after fertilization, with no evidence of parental care (Gilbert 1978; van den Avyle 1984). The eggs are demersal and, after about 20 min, become strongly adhesive, occasionally occurring in stringy clusters of ribbons (Murawski and Pacheco 1977), and becoming attached to rocks, weeds, and other submerged objects (Vladykov and Greeley 1963).

Spent Atlantic sturgeon gradually return to salt water (Vladykov and Greeley 1963). Scott and Crossman (1973) reported downstream migration from September through November in the St. Lawrence River. C. Smith (1985) indicated that females move downstream and out of the Hudson River soon after spawning, but that males remain until cold weather begins in fall. Huff (1975) reported that Gulf sturgeon in Florida migrate downstream from October through December. Recaptures of tagged shortnose sturgeon in the St. John River, New Brunswick, and the Kennebec River, Maine, indicated that spent fish normally move back downstream during May and June (Dadswell 1979); however, non-spawning fish may move even farther upstream and may overwinter there (Dadswell 1979; Buckley 1982). Dadswell et al. (1984), quoting reports by Heidt and Gilbert (1978) and Marchette and Smiley (unpubl.), indicated that spawned shortnose sturgeon in Georgia and South Carolina move back downstream in April and May and spend the rest of the year in the lowermost parts of rivers and in estuaries, or at sea within 5,000 m from shore. No mention was made of overwintering in the upper areas of southern rivers.

Age and size of *Acipenser oxyrhynchus* at maturity vary with gender and locality (Vladykov and Greeley 1963; Huff 1975), with individuals from more southerly areas appearing to mature sooner, on average. Huff (1975) reported female Gulf sturgeon in the Suwannee River, Florida, to be sexually differentiated at 8-12 years of age and males at 7-10 years; the youngest ripe females examined were 12 years of age and the youngest males were 9 years old. Length at time of sexual differentiation was 50 to 70 cm FL. On the basis of these observations, Huff (1975) speculated that spawning may be delayed for 1 or 2 years after maturity is reached, as reported for other sturgeons (Roussow 1957). Smith et al. (1982) and T. Smith (1985) reported that female Atlantic sturgeon in South Carolina first spawn at 7-19 years (average 10.9) and males at 5-13 years (average 8.1). Dovel (1979) reported that females in the Hudson River, New York, mature at 20 to 30 years and males at 11 to 20 years, observations that are essentially in agreement with those of C. Smith (1985), who reported that females from this area first spawned at 18-19 years at a weight of about 33 kg. Scott and Crossman (1973) wrote that female Atlantic sturgeon mature at 27-28 years and males at 22-34 years in the St. Lawrence River, Canada. The smallest ripe male encountered by Vladykov and Greeley (1963) in the St. Lawrence River was 175 cm long and weighed 32 kg. Vladykov and Greeley (1963), presumably summarizing the situation throughout the range of *A. oxyrhynchus*, concluded that females are not mature until they are 10 years old and weigh at least 68 kg.

Age of shortnose sturgeon at first maturation also varies latitudinally. Males may mature in 2-3 years in Georgia, 3-5 years in South Carolina, and 10-11 years in the northernmost parts of the range. Females require longer to mature, ranging from 6 years in the southernmost parts of the range to 13 years in the north. In the St. John River, New Brunswick, the 50% maturation level for the population as a whole averaged 12.4 years for males and 17.2 years for females (Dadswell 1979). First spawning of males did not occur for another 1-2 years in males and up to 5 years in females. Thus, earliest spawning in females is at about 15 years of age in the St. John River, 7-10 years in the Hudson and Delaware Rivers, and 6 years or less in the Altamaha River (Georgia). These data agree with the findings of Taubert (1980a), who reported female shortnose sturgeon, 52-67 cm FL and 1.1-1.9 kg, caught in the Holyoke Pool to be sexually mature and to range in age from 9-14 years. Because no spawning checks were found on any pectoral-ray sections examined, he concluded that these fish, which were 8-12 years old, probably were spawning for the first time. Ripe males caught at the same time and calculated to be 10-20 years old, ranged from 58-79 cm FL, and weighed from 1.5-4.1 kg.

Scott and Crossman (1973) indicated that spawning probably occurs yearly in some female Atlantic sturgeons, and Vladykov and Greeley (1963) suggested that some females of this species spawn only once every 2 or 3 years. In South Carolina, Smith et al. (1982) indicated that, on the average, 5.4 and 3.5 years elapsed between the first and second and second and third spawnings, respectively, in female *A. oxyrhynchus*. In males, these periods were 4.5 and 1.6 years. Taubert (1980a), on the basis of analysis of spawning checks on pectoral fins of 51 shortnose sturgeon (sexes combined) from the Holyoke Pool, found the range in years between first and second spawning to be 4-12 years, at ages of 14-20 years; no fish examined appeared to have spawned more than twice.

Although non-annual spawning in sturgeons appears to be normal, some fish may spawn more frequently than most under favorable environmental conditions. According to Buckley and Kynard (1985), "There is some evidence in fishes that the yearly reproductive rhythms are under control of an endogenous circannual (or longer) mechanism, mediated by environmental conditions that control recrudescence and regression of gonads (de Vlaming 1972; Baggerman 1979). In the context of life history strategy the relationship between endogenous and exogenous factors is further complicated in ... species like sturgeon. In these species, if environmental conditions are not suitable, presumably natural selection would favor reabsorption of gonadal tissue. Two studies have reported gonadal regression in sturgeon

under unfavorable environmental conditions (Kozlovsky 1968; June 1977)."

Early Developmental Stages

Sturgeons lay great numbers of eggs. Female Atlantic sturgeon from the Delaware River (size not indicated) contained from 0.8 to 2.4 million eggs (Ryder 1890), and fish from North Carolina contained from 1.0 to 2.5 million (H. Smith 1907). The ovary of a ripe 2.7 m TL, 160 kg Atlantic sturgeon weighed 41 kg and contained an estimated 3.75 million eggs (Vladykov and Greeley 1963). Smith et al. (1982), estimating the fecundity for 11 female Atlantic sturgeon (48-104 kg total weight) from South Carolina, calculated the linear relation between number of eggs (Y) and body weight (X, in kg) to be: $Y = 233{,}064 + 13{,}307\ X$ ($r = 0.84$). Female shortnose sturgeon produce fewer eggs, presumably as a direct consequence of their much smaller body size. C. Smith (1985) gave a range of 40,000-200,000 eggs for this species, but did not indicate sizes of the fish from which these data were taken. Dadswell et al. (1984) reported a range of 27,000-208,000 eggs for fish from the St. John River, and presented the following relation: $\text{Log } F\ (\text{eggs} \times 10^3) = 3.92 + 1.14 \log W$ (total weight in kg). Heidt and Gilbert (1978) reported the fecundity of Altamaha River shortnose sturgeon to be between 79,000 and 90,000 eggs for fish 75-87 cm in FL, and Marchette and Smiley (unpubl.) found an estimated 30,000 eggs in 58-cm (FL) female from the Pee Dee River. St. John River fish were reported to have a mean of 11,568 eggs/kg body weight (Dadswell 1979), but those in the south had about 14,000-16,000 eggs/kg body weight (Heidt and Gilbert 1978; Marchette and Smiley, unpubl.). Egg size in the South Carolina fish examined was the same as in fish of the northern populations, which may indicate that southern shortnose sturgeon produce more eggs at a given size.

An inverse correlation exists between length of incubation and water temperature. Eggs of the Atlantic sturgeon were reported to hatch in 94 hr at about 20 °C (Dean 1895), in 121-140 hr at about 18 °C (Smith et al. 1980), and in 168 hr at 17.8 °C (Vladykov and Greeley 1963). Eggs of the shortnose sturgeon hatch in 8 days (192 hr) at 17 °C (Dadswell et al. 1984) and 13 days (312 hr) at 10 °C (C. Smith 1985). Jones et al. (1978) provided an illustrated summary of egg development of the Atlantic sturgeon (Figure 8). Jones et al. (1978) and van den Avyle (1984) reported ripe (unfertilized) eggs of the Atlantic sturgeon to be 2.5-2.6 mm in diameter, globular in shape, and of a light to dark brown color; fertilized eggs are up to 2.9 mm in diameter and slate gray or light to dark brown, and become oval as development proceeds. Ripe eggs of the shortnose sturgeon average about 3 mm in diameter (Vladykov and Greeley 1963).

Little information is available for either species on larval life history, and until recently larvae had not been described or illustrated in the literature. Smith et al. (1980, 1981) described hatchery-reared Atlantic sturgeon larvae from South Carolina and reported that under culture conditions, fish grew from 7.8 mm TL at hatching to 177 mm by day 204. They also reported that the darkly-pigmented, newly-hatched young were active swimmers, frequently leaving the bottom and swimming throughout the water column. In 9 to 10 days after hatching, the yolk sac was absorbed and the larvae began to show more strictly benthic behavior. Bath et al. (1981), who described and illustrated larvae of Atlantic sturgeon captured in the lower Hudson River, reported that the yolk sac in Atlantic sturgeon disappears at about 14 mm TL; this is nearly identical to the size (15 mm TL) at which Buckley and Kynard (1981) reported yolk absorption in the shortnose sturgeon. Although specific information is lacking, it may be assumed that once the yolk sac is absorbed, larvae feed on the bottom as do the adults, where they eat minute bottom organisms.

Bath et al. (1981) illustrated and described larval stages on the basis of 26 specimens of Atlantic and shortnose sturgeons, ranging from 8.4 to 31.5 mm TL, collected at various localities in the Hudson River (Figures 9 and 10). Of these, 7 specimens were identified as Atlantic sturgeon, 4 as shortnose sturgeon, 2 could not be determined, and 13 (ranging from

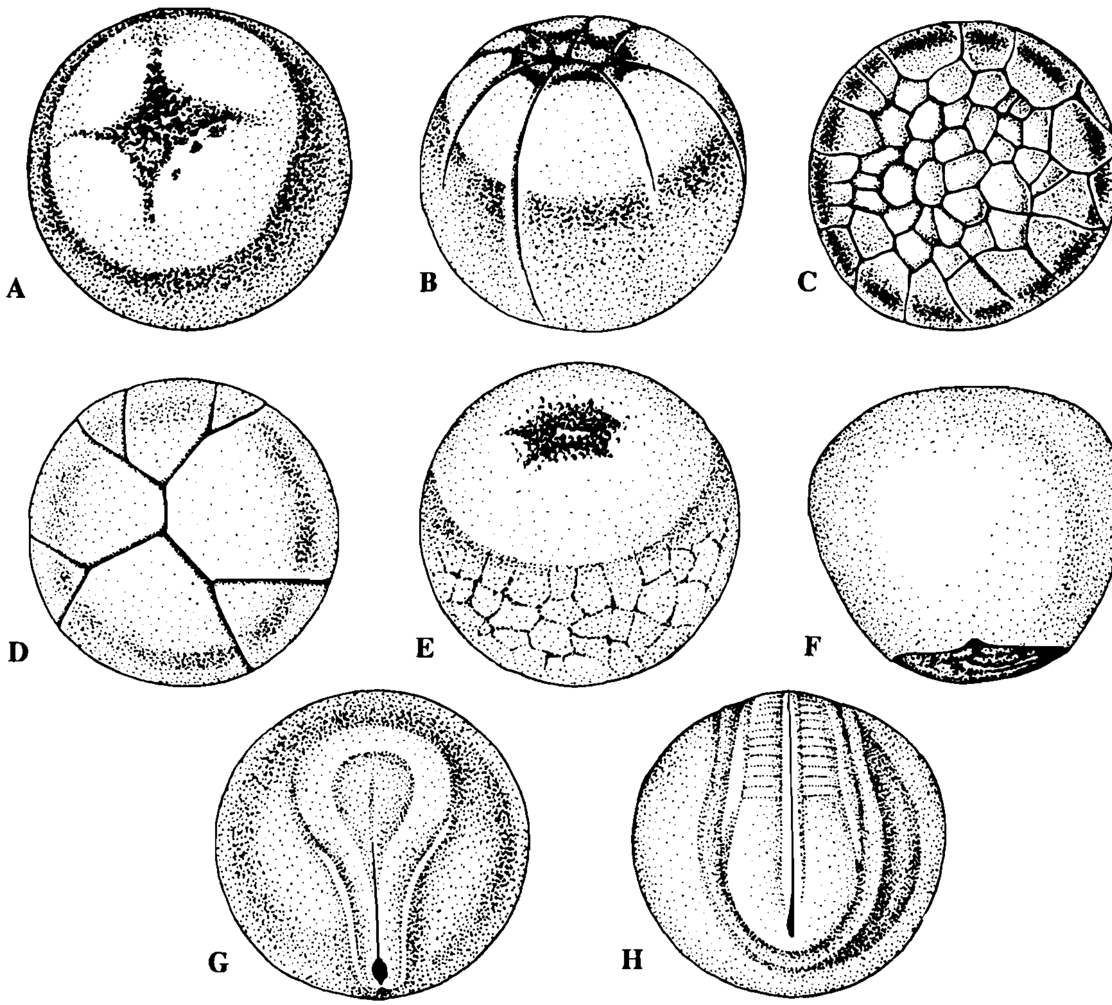

Figure 8. Egg development in Atlantic sturgeon from unfertilized egg to 48 hr stage (Jones et al. 1978).

8.4-14.3 mm) were too small for positive identification, but were considered to be Atlantic sturgeon on the basis of location and time of capture. All were collected at depths of 9.1-19.8 m, at water temperatures of 15.0-24.5 °C, and at salinities of 0-22 ppt. Yolk-sac larvae were robust, opaque, and dull brown, with scattered melanophores that increased in number as the yolk was absorbed and size increased. A continuous fin fold extended from behind the head dorsally around the notochord and ventrally to the posterior end of the yolk sac. The mouth was visible in the 8.4-mm specimen, and gill clefts and rudimentary gills were visible in specimens as short as 9.5 mm. Barbels first appeared as buds in a 9.7 mm

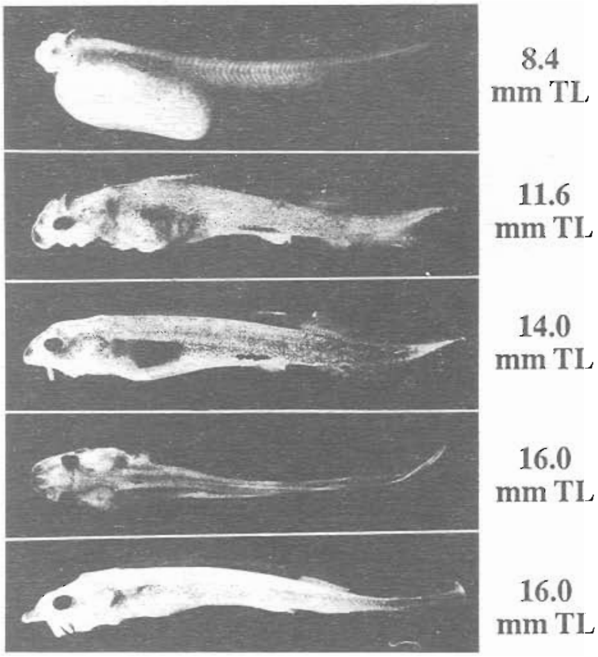

Figure 9. ***Acipenser*** **larvae from 8.4 mm TL (yolk-sac larvae) to 16.0 mm TL. (Top three figures,** ***A. oxyrhynchus*****; bottom two figures,** ***A. brevirostrum*** **(Bath et al. 1981).**

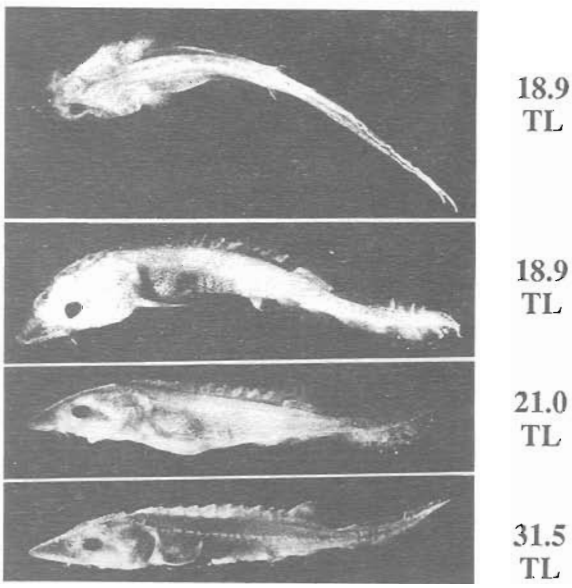

Figure 10. ***Acipenser oxyrhynchus*** **larvae from 18.9 mm TL to 31.5 mm TL (Bath et al. 1981).**

specimen. The eye was fully formed by about 11.0 mm. Pectoral-fin buds were apparent at 8.4 mm, and the fins were well developed in specimens >14 mm. Pelvic-fin buds and basal supports for the dorsal fin were not apparent until about 11.6 mm. The yolk sac was nearly absorbed in specimens of about 14 mm, and differentiation of the median fins was well established. At this size, the presence of barbels, morphology of the mouth, and head shape made the larvae easily identifiable as sturgeons. Teeth were visible in most specimens >14.2 mm. Dermal ossification began to appear at about 19.0 mm, and incipient dorsal scutes were observed in the fin-fold area. Incipient lateral scutes were apparent on larvae >29 mm. Metamorphosis was virtually complete by about 31.5 mm, at which point specimens were considered to have passed from the larval to the prejuvenile stage. At this size, the snout was more elongate; dorsal, ventral, and lateral scutes were countable; and the skull was hard and opaque, with a pair of longitudinal ridges between the eyes.

Information on small juveniles of both species is surprisingly scant. In part, this may be related to difficulties in sampling the habitat in which they occur, as discussed by Huff (1975) in relation to his work on Gulf sturgeon in the Suwannee River. Consequently, most information on juveniles is based on collections of rather large specimens taken by gill netting, trawling, or incidentally in commercial gear. This situation may have been further complicated by past confusion of Atlantic and shortnose sturgeons at small sizes, although this confusion no longer persists (Bath et al. 1981). Recently, however, the shortnose sturgeon has spawned and the young have been raised in captivity (Buckley and Kynard 1981), and small juveniles have been available for study. Dadswell et al. (1984) indicated that juvenile shortnose sturgeon begin to resemble adults by the time they are 20-30 mm long and remain in the juvenile stage until they are 45-55 cm FL, or 3-10 years of age, depending on latitude. Dadswell et al. (1984) also illustrated a young-of-the-year specimen, 50 mm TL (taken from the stomach of a yellow perch, *Perca flavescens*), which appeared to be a miniature version of the adult (Figure 11).

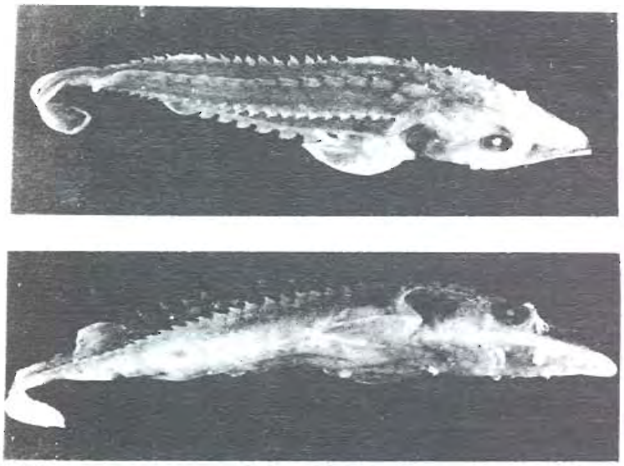

Figure 11. Dorsal and ventral views of 5 cm TL young-of-year shortnose sturgeon taken from the stomach of a yellow perch (Dadswell et al. 1984).

Non-Spawning Movements

In the Hudson River, larval and juvenile Atlantic sturgeon remain upstream from May to July, but move downstream to congregate in deep water (7 m or deeper) when the water temperature drops below 20 °C (C. Smith 1985). They stay there until temperatures begin to rise in spring and then begin to move upstream. As the water continues to warm, the fish again move downstream to seek temperatures of 24.2-24.7 °C and salinities of 4.2-4.3 ppt. Smith et al. (1982) captured young-of-the-year Atlantic sturgeon in lower sections of the Edisto and Waccamaw Rivers, South Carolina, where these rivers broaden and are under tidal influence. The rivers here are characterized by hard sand or shale substrates; salinities range from 1 to 5 ppt in the Edisto and 0 to 3 ppt in the Waccamaw. Juveniles in both the Hudson River and in the South Carolina rivers remain in upstream freshwater areas during the warmer months, and in brackish areas during the colder months, for a period of from two to six years before they migrate out to sea.

Magnin and Beaulieu (1963) stated that juvenile Atlantic sturgeon may make oceanic excursions as long as 1,450 km. Tagged juveniles from the Hudson River have been recaptured from Nantucket, Massachusetts, and as far south as North Carolina (C. Smith 1985). Holland and Yelverton (1973), reporting on recaptures of juvenile Atlantic sturgeon along the North Carolina coast, noted that several individuals were caught in sounds and inlets other than those in which they were tagged. Recaptured fish tended to move southward along the coast from November through January and northward during late winter and early spring. One 9.5-kg fish moved 645 km northward to Long Island in 65 days. Smith et al. (1982), who tagged 35 juvenile Atlantic sturgeon (38-78 cm FL) in South Carolina, reported six recaptures: one fish tagged in the Edisto River moved about 600 km northward to Pamlico Sound, North Carolina, in 326 days; another tagged in Winyah Bay, South Carolina, reached Chesapeake Bay, 550 km away, in 80 days; and 4 had moved only 60 km. Migrating Atlantic sturgeon apparently stay relatively close to shore, inasmuch as the greatest confirmed depth at which an individual has been captured is only 46 m (Bigelow and Schroeder 1953). Despite their extensive oceanic migrations, Atlantic sturgeon are believed to be highly site specific and apparently return to the same river and even the same general hatching area to spawn (Hollowell, unpubl.).

Shortnose sturgeon also move considerable distances, but (in contrast to the Atlantic sturgeon) such movements are apparently confined to estuarine and riverine environments. In the St. John Estuary, the mean minimum distance traveled by fish that moved more than 1 km between recaptures was about 22.9 km (Dadswell et al. 1984). The maximum river distance traveled between tagging and recapture was 160 km (Dadswell 1979), and the mean minimum distance traveled by 11 fish was 4.0 km/day. In the Altamaha River, an individual moved downstream 193 km in 11 days (Heidt and Gilbert 1978), and in the Connecticut River one moved 60 km in 2 days. McCleave et al. (1977) documented a mean daily rate of movement of 29 km in Montsweag Bay, Maine. On the other hand, Taubert (1980b) found that landlocked sturgeon in Holyoke Pool had small home ranges, except during those times of the year when they migrated upstream to spawn.

Buckley (1982) found that shortnose sturgeon in the lower Connecticut River also tended to stay in localized areas during summer, but migrations in spring and fall were similar to those in other rivers. Shortnose sturgeon have not been found to move into the sea away from the influence of the home river (Dadswell et al. 1984).

Longevity and Mortality

Longevity may vary with latitude, although no estimates of average life expectancy have been made. There is evidence of greater longevity in northern populations of the shortnose sturgeon, as evidenced by the following maximum reported ages from various river drainages (from Dadswell et al. 1984): St. John River (New Brunswick), 67 years (female); Kennebec River (Maine), 40 years; Hudson River, 37 years; Connecticut River, 34 years; Pee Dee River (South Carolina), 20 years; Altamaha River (Georgia), 10 years. Although a similar relation might also be expected for the Atlantic sturgeon, clear evidence of similarity is lacking and even conflicting, since the maximum ages reported to date are for specimens from near the peripheries of the species' geographic range. The oldest reported age for *A. oxyrhynchus* is 60 years, based on an individual from the St. Lawrence River (Magnin 1964; Murawski and Pacheco 1977; van den Avyle 1984), whereas the next oldest reported age (42 years) is based on a specimen of the Gulf sturgeon from the Suwannee River, Florida (Huff 1975; van den Avyle 1984). Elsewhere, maximum reported ages are about 30 years for the Pee Dee, St. John, and Hudson Rivers (Magnin 1964; Dovel 1979; van den Avyle 1984; T. Smith 1985). These seeming inconsistencies likely result partly, if not entirely, from inherent difficulties in aging sturgeons. Further discussion of this problem appears in a later section.

There is some indication, for the shortnose sturgeon at least, that females live longer than males. The oldest male examined by Dadswell (1979) was from the St. John River and was only 32 years old; this implies that the older ages presented earlier for shortnose sturgeon from the various drainages were all based on females, although sex was usually not specifically indicated.

Although mortality estimates have been published for the Gulf and shortnose sturgeons, they differ greatly with regard to types of results reported. Huff (1975) found the average annual survivorship of Gulf sturgeon of ages VIII through XII to be 54%. Mortality rates for the shortnose sturgeon were computed on the basis of instantaneous mortality of individuals in gill-net samples and were based on work done in the St. John River (Dadswell 1979), Holyoke Pool (Taubert 1980b), and the Pee Dee River (Marchette and Smiley, unpubl.). In the St. John River, total instantaneous mortality for ages 14 through 55 was 0.12 for 1974 and 0.15 for 1975. The overall figure was 0.14 for Holyoke Pool, and between 0.08 and 0.12 for the Pee Dee River. As might be anticipated, mortality was relatively high among young fish and declined with increasing age.

GROWTH CHARACTERISTICS

Early growth (in terms of increase in body length) of larval and juvenile sturgeon is rapid, particularly during the first 3 years of life (Figures 12 and 13) (Dadswell 1979). Growth rates of both Atlantic and shortnose sturgeon are fastest in the south (Dadswell et al. 1984; T. Smith 1985), but individuals there are shorter lived and do not reach as large a maximum body size (Figure 12). Differential growth of Atlantic and shortnose sturgeons begins at an early age, and the studies by Dadswell et al. (1984) in the St. John River indicated that by the fifth year the Atlantic sturgeon attains a length about double that of the shortnose sturgeon (Figure 13).

Scott and Crossman (1973) considered Atlantic sturgeon specimens collected in the St. Lawrence River in August, 6.5-11 cm long and weighing 0.7-4.2 g, to be less than 1 year old. Fish collected in October of the same year were 13 to 20 cm long and weighed 7 to 48 g. Dadswell et al. (1984) indicated the shortnose sturgeon attains a length of 14 to 30 cm (depending on latitude) by the end of the first growing season. In the St. John River, juvenile shortnose sturgeon ranged from 15 to 19 cm during their second growing season, but in the Hudson River they may reach 25 cm by the end of their first growing season, an average 0.3 mm increase per day (Pekovitch 1979).

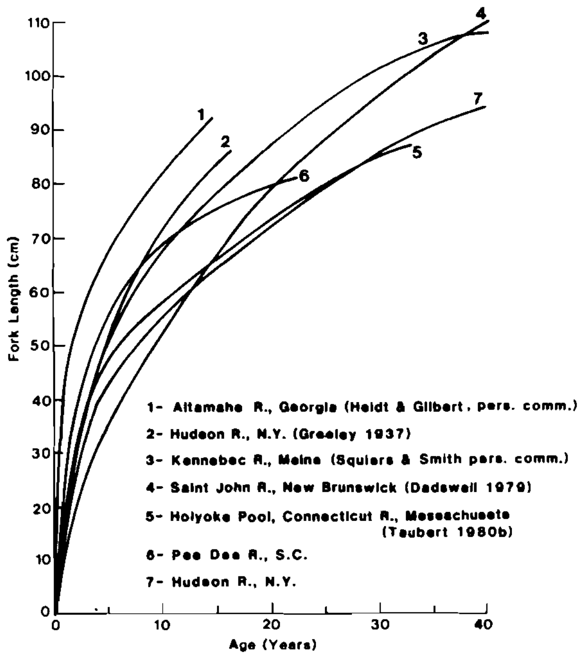

Figure 12. Growth of shortnose sturgeon (sexes combined) from various rivers (Dadswell et al. 1984).

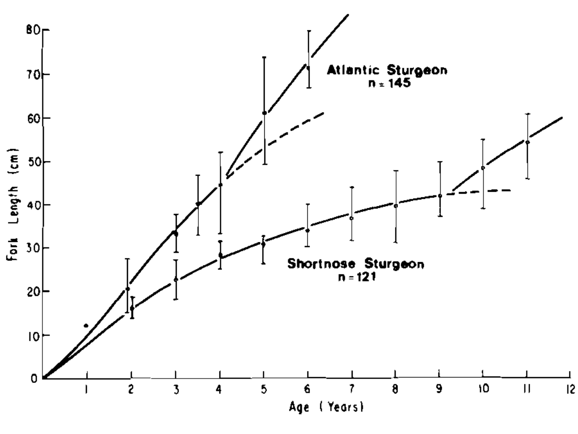

Figure 13. Comparative juvenile growth of shortnose sturgeon from ages 1 to 11 and of Atlantic sturgeon from ages 1 to 6 in St. John River, Canada. Bars represent range of length at age and dots are mean size (Dadswell et al. 1984).

In the shortnose sturgeon, early rapid growth during the first 3 years was followed by an even, but slightly less rapid, growth rate until age 8-10 (or until the onset of sexual maturity); males grew slightly faster than females. Growth then decelerated, and in males thereafter continued at a slow but steady pace throughout life. In contrast, growth of females was extremely inconsistent, with "check periods" of little or no growth lasting 3-5 years, followed by spurts of rapid growth. Dadswell (1979) indicated that the check periods were related to gonad development and maturation (discussed by Roussow in 1957), whereas spurts of rapid growth resulted from heavy feeding after spawning, when normal body condition is regained. Most female shortnose sturgeon have a consistent period of growth reduction, probably corresponding to their first spawning period, at or near age 15.

In terms of real (i.e., non-percentage) increase in weight of shortnose sturgeon throughout life, the growth pattern expressed above is essentially reversed. Weight gain for the first 10 years of life is slow (100 g/yr), but increases between 10 and 40 years of life to about 0.3 kg/yr. Weight gain subsequently tapers off (Dadswell 1979).

Growth information of comparable detail appears to be lacking for the Atlantic sturgeon, although it may be assumed that growth patterns in the two species are probably similar.

As indicated earlier, aging of sturgeons (particularly females) is difficult, due largely to the unusual life-history pattern of these fish. During the several years required for the development of eggs, feeding is curtailed and growth is limited. Annuli on various body hard parts (e.g., pectoral-fin rays, operculi, vertebrae) are compressed and are difficult to read and interpret (Figure 14). Under these circumstances, what appears to be a single annulus may actually represent several years of reduced growth (Roussow 1957). Huff (1975), in his review of aging techniques in sturgeons, also concluded that annual marks are more likely to become obscured with age on the operculi than on the fin rays.

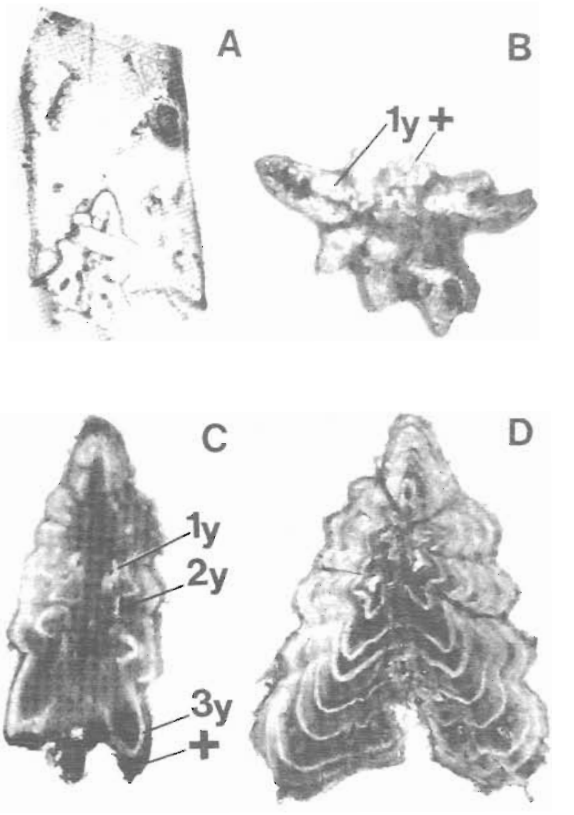

Figure 14. Transverse sections of marginal ray of pectoral fin of shortnose sturgeon, showing annuli. Dark zones are summer-formed dense bone; translucent zones, winter period. (A) Juvenile: 45 cm, 0.8 kg; 9 yr (x 18). (B) Male: 97 cm, 9.4 kg; 27 yr (x 8) (annuli 17 and 19 each have a false annulus associated; yr 1 is almost obscured, arrow). (C) Female: 112 cm, 12.5 kg; 40 yr (x 5). Matured age 11, spawned at 21, 26, 32, 37 yr. (D) Female: 86 cm, 6.1 kg; 23 yr (x 5). Matured at 10, spawned at 16, but no later spawning checks discernible (Dadswell et al. 1984).

ECOLOGICAL ROLE

Food and Feeding

The relative kinds and percentages of food eaten by shortnose sturgeon change between the juvenile and adults stages (Dadswell et al. 1984). Juveniles feed mostly on benthic crustaceans and insect larvae (Townes 1937; Curran and Ries 1937; Dadswell 1979), and shortnose sturgeon of 20-30 cm FL often feed extensively on cladocerans (Dadswell et al. 1984). Adults feed largely on molluscs, which are sometimes supplemented by polychaetes and small benthic fish in estuarine areas (Dadswell et al. 1984). Taubert (1980a) found benthic crustaceans and insects to be relatively more important in the diet of adult shortnose sturgeon from the upper Connecticut River, but this may reflect differences in food availability rather than a change in preference. Although a similar dietary shift may hold true for Atlantic sturgeon, specific data are lacking.

Sturgeons usually feed by rooting along the bottom with their snouts, using their barbels as organs of touch, and "vacuuming" the bottom with their protrusible mouths. Such feeding behavior is indiscriminate, since large quantities of mud and debris are also consumed. Juvenile shortnose sturgeon clearly feed in this way. Curran and Ries (1937) and Dadswell (1979) reported stomachs of juvenile individuals from the Hudson and St. John Rivers, respectively, to contain 85%-95% non-food matter (mostly mud) mixed with plant and animal material. Marchette and Smiley (unpubl.) reported similar stomach contents in juvenile shortnose sturgeon collected in winter in South Carolina. Adults also usually feed indiscriminately, especially in estuarine areas where the molluscs upon which they feed are buried in the mud. In some cases, however, the feeding of adult shortnose sturgeon appears to be more selective. Fish foraging in muddy backwater areas containing abundant aquatic vegetation have been observed feeding on small gastropods living on the undersides of lilly pads and on the stems and leaves of submerged macrophytes (Dadswell et al. 1984; Marchette and Smiley, unpubl.). Stomach contents of adults from both the St. John River, New Brunswick, and Winyah Bay, South Carolina, have been found to be comprised exclusively of small gastropods, with no sign of non-food debris.

All reports published so far suggest that the Atlantic sturgeon feeds indiscriminately throughout life (Bigelow and Schroeder 1953; Vladykov and Greeley 1963; Murawski and Pacheco 1977; van den Avyle 1984). Bigelow

and Schroeder (1953) reported that the fish "ate molluscs, polychaete worms, gastropods, shrimps, isopods, amphipods, and small bottom-dwelling fishes such as sand lances (*Ammodytes* spp.)." Vladykov and Greeley (1963) reported that "half-grown" individuals taken in salt water ate polychaete worms, gastropods, shrimps, amphipods, and isopods, and that those from freshwater areas of the St. Lawrence River ate aquatic insects, amphipods, oligochaete worms, and larvae of the burrowing mayfly (*Hexagenia*). C. Smith (1985) wrote that in fresh waters this species' diet is dominated by insects, amphipods, and oligochaetes. T. Smith (1985) indicated that post-spawning adults, which remain in fresh water, feed mostly on gastropods and other benthic organisms. The selectivity of shortnose sturgeon for molluscs living on freshwater macrophytes has not been reported for the Atlantic sturgeon.

Food eaten by larval sturgeon in natural settings has not yet been documented. Smith et al. (1980) reported on the successful rearing of Atlantic sturgeon from sac fry to the juvenile stage. Sac fry were fed a variety of foods, including live brine shrimp (*Artemia*) nauplii, beef liver puree mixed with salmon mash, freeze-dried *Daphnia*, squid pellets, and assorted tropical fish flakes. After yolk sacs were absorbed, food was restricted to beef liver, salmon mash mixture and live *Artemia*, and after 54 days only salmon mash and liver were fed. Buckley and Kynard (1981) reported that shortnose sturgeon spawned and reared in captivity were fed zooplankton, insect larvae, and worms, all of which were collected in the field. This feeding was begun after absorption of the yolk sac, which occurred when the larvae were about 15 mm long.

Shortnose sturgeon apparently feed mostly at night or on windy days when turbidity is high (Dadswell et al. 1984). Adult shortnose sturgeon move into shallow water at these times, where they forage in weedy backwaters and along river banks in water 1-5 m deep (Dovel 1978; Dadswell et al. 1984; Marchette and Smiley, unpubl.). During late summer, feeding tends to occur in deeper water (5-10 m), perhaps in response to higher water temperatures in the shallows. The relatively little feeding in winter takes place in deeper water (15-25 m). The regular spatial dispersion of foraging shortnose sturgeon captured in gill nets suggests that they do not feed in groups (Dadswell et al. 1984).

Feeding of shortnose sturgeon in freshwater portions of the St. John River, Canada, and Winyah Bay, South Carolina, was confined largely to periods when water temperatures exceed 10 °C (Dadswell 1979; Dadswell et al. 1984). During winter, when water temperatures are lower, little feeding activity takes place in fresh water, and feeding decreases in salt water to about half the summer level (Dadswell 1979; Dadswell et al. 1984). Dadswell (1979) found that female shortnose sturgeon ceased feeding about 8 months before spawning, but that developing males continued to feed. Both sexes feed heavily after spawning.

Although there is considerable information in the literature on food and feeding habits of Atlantic sturgeon (Ryder 1890; Vladykov and Greeley 1963; Scott and Crossman 1973; Huff 1975; van den Avyle 1984), this is generally much less specific than for shortnose sturgeon. In contrast to the situation for shortnose sturgeon, nothing has been reported for the Atlantic sturgeon regarding time (day or night) or specific physical conditions (water temperature, water depth, etc.) in which most feeding occurs.

Competition and Other Ecological Interactions

Sturgeons probably have few ecological competitors. Shortnose sturgeon spawn earlier than Atlantic sturgeon, and thus spawning competition is reduced or avoided in areas where the two species occur together. Other species that might also spawn over sturgeon spawning grounds include walleye (*Stizostedion vitreum vitreum*) and rainbow trout (*Salmo gairdneri*), both of which have been introduced into the range of these two sturgeons.

Sturgeons may compete for food with certain other benthic feeders, particularly those that exploit molluscs. At the extreme peripheries of its range, the Atlantic sturgeon may compete for this resource with two species of the sucker

genus *Moxostoma*. Dadswell et al. (1984) reported that shortnose sturgeon may compete for gastropods with lake whitefish (*Coregonus clupeaformis*) in upper parts of the St. John Estuary, although this competition is lessened by temporal segregation (sturgeons feed primarily in summer and whitefish in late fall and winter) and by different sizes of the molluscs consumed. In the lower St. John Estuary, sturgeons may compete for food with the winter flounder (*Pseudopleuronectes americanus*). Dadswell (1979) found that juvenile shortnose sturgeon in the St. John River occupied the deep freshwater channels and thereby avoided competition with juvenile Atlantic sturgeon, which lived in the deeper, more saline parts of the estuary. Although competition for food elsewhere has not been studied, possible competitors with one or both sturgeon species include the tautog (*Tautoga onitis*) and cunner (*Tautogolabrus adspersus*) on the upper Atlantic coast, and certain species of porgies (Sparidae), croakers (Sciaenidae), and stingrays (genus *Dasyatis*). Van den Avyle (1984) suggested that non-selective feeding of juvenile and adult sturgeons may reduce the potential for competition with other fish species. In addition, several species of ducks and invertebrates (e.g., certain crabs and predatory molluscs) feed on molluscs.

Although adult shortnose sturgeon may compete for space with similar-sized juvenile Atlantic sturgeon, the two species rarely occupy the same habitat in the St. John Estuary. This segregation is apparently based on salinity preference, the large juvenile Atlantic sturgeons predominating in water of >3 ppt salinity and adult shortnose sturgeons in water of <3 ppt (Appy and Dadswell 1978; Dadswell 1979).

Juvenile and adult shortnose sturgeon have few predators, particularly in freshwater habitats. There is one confirmed case of predation on a small juvenile shortnose sturgeon by yellow perch (Dadswell et al. 1984). Scott and Crossman (1973) stated that Atlantic sturgeon are attacked and sometimes killed by sea lampreys (*Petromyzon marinus*), and Dadswell et al. (1984) included sea lampreys in their list of parasites of shortnose sturgeon. In southern fresh waters, alligators (*Alligator mississippiensis*) and large gars (*Atractosteus spatula* and several species of *Lepisosteus*) may be responsible for mortality. In marine waters, sturgeons are occasionally preyed upon by certain birds, seals, sharks, and perhaps other fishes, as evidenced by healed wounds or missing fins (Dadswell et al. 1984).

Dadswell et al. (1984) provided a checklist and associated information (parasite locations, capture localities, and reference sources) on parasites of the shortnose sturgeon. A total of 13 taxa were listed, including four coelenterates, two nematodes, three hirundinids (leeches), one arthropod, and the sea lamprey. Of these, the coelenterates, nematodes, and acanthocephalans are internal and the rest external. Intensity of infestations was reported to be low, and none appeared to be harmful. No diseases have been reported for either shortnose or Atlantic sturgeons. In the St. John River, Appy and Dadswell (1978) found five helminth and one arthropod parasite species in juvenile and adult Atlantic sturgeon, but only one helminth and one arthropod among the five species of shortnose sturgeon parasites. These differences probably reflect both species specificity (parasite species are frequently specific to one host species) and different distributions of the hosts in the area studied.

Natural abnormalities and healed injuries appear to be common in sturgeon. Dadswell et al. (1984) summarized examples reported in the shortnose sturgeon, which included forked or missing barbels, missing tails, no nasal septum, missing snout tip, and unilaterally or bilaterally blind specimens in which the eyes were completely overgrown by flesh or seem never to have been present. Although comparable examples undoubtedly occur in Atlantic sturgeon, they have not been documented in the literature.

ENVIRONMENTAL REQUIREMENTS

Atlantic and shortnose sturgeons are anadromous species that spend much of their lives in salt water or brackish water and migrate into fresh water to spawn. Both require large rivers unobstructed by dams or in which the dams are situated above their preferred

spawning areas. This is particularly important for the Atlantic sturgeon, for which there is no evidence of permanent freshwater (i.e., landlocked) populations, and the construction of dams on rivers such as the Apalachicola (Florida) has had profound effects on the sturgeon populations there (Huff 1975; van den Avyle 1984; Hollowell, unpubl.). The shortnose sturgeon, by contrast, has been able to maintain more or less permanent freshwater populations in at least two places (Connecticut River, Massachusetts; Santee River, South Carolina).

The following subsections are, in part, abbreviated summaries of earlier discussions.

Temperature

The preferred temperature ranges and upper and lower lethal temperatures for shortnose and Atlantic sturgeons are not known. It was previously noted that, in rivers inhabited by both species, migration and spawning occur earlier in the shortnose than in the Atlantic sturgeon, indicating possible preference and tolerance for lower average temperatures by the former species. This suggestion seems to be contradicted, however, by the more northern range limit of the Atlantic sturgeon.

Dovel (1979) and Dadswell et al. (1984) reported that the shortnose sturgeon, in northern parts of its range, is seldom found in shallow water where water temperatures exceed 22 °C, and in the St. John River, surface temperatures above 21 °C appear to stimulate movement to deeper water. In the Connecticut River, however, this species was frequently captured in water less than 1 m deep at temperatures of 27-30 °C (Dadswell et al. 1984), and in the lower Altamaha River shortnose sturgeon were found at water temperatures as high as 34 °C (Heidt and Gilbert 1978). Dadswell (1979) and Marchette and Smiley (unpubl.) reported that a 2-3 °C decline in temperature during fall stimulated downstream movement of this species. Temperatures at shortnose sturgeon overwintering sites ranged from 0-13 °C in the St. John River, and from 5-10 °C in Winyah Bay, South Carolina (Dadswell et al. 1984; Marchette and Smiley, unpubl.). Fewer details of temperature preferences and tolerances are available for non-spawning Atlantic sturgeon. C. Smith (1985) reported that juveniles of this species in the Hudson River move downstream to congregate in deeper water when water temperatures drop below 20 °C, and remain there until spring, when they again move upstream. As the river warms further, the fish again move downstream to seek temperatures of 24.2-24.7 °C.

Salinity

The shortnose sturgeon generally prefers water of lower salinity than that preferred by the Atlantic sturgeon, which regularly occurs in the ocean. The maximum salinity in which the shortnose sturgeon has been found is 30-31 ppt (Holland and Yelverton 1973; Dadswell et al. 1984; Marchette and Smiley, unpubl.), or slightly less than full-strength sea water. In areas of co-occurrence, similar-sized individuals of the two species (large juvenile Atlantic sturgeon and adult shortnose sturgeon) seem to be segregated by differences in salinity preferences; large Atlantic sturgeon juveniles predominate in water >3 ppt and shortnose sturgeon adults predominate in water <3 ppt (Appy and Dadswell 1978; Dadswell 1979). Although the shortnose sturgeon is no doubt capable of entering the open ocean (salinity ca. 35 ppt), its reluctance to do so is probably the single most important factor in limiting extensive latitudinal coastal migrations in this species.

Current Velocity

Adult sturgeon are generally found in areas of little or no current throughout much of their lives, specifically during times when they are living in the lower parts of rivers, in estuaries, or in the ocean. This is particularly true for Atlantic sturgeon, which tend to occupy more saline environments than those inhabited by the shortnose sturgeon. Currents of varying strengths are encountered by adults of both species during upstream spawning migrations, and spawning usually occurs where the flow of water is fairly strong.

Substrate

Substrate preference varies according to life stage and proximity to spawning season.

Although preferred substrates are probably similar for both shortnose and Atlantic sturgeons, particularly during spawning, preference of the Atlantic sturgeon for more saline (often completely oceanic) waters during much of its life may also mean that, on average, it lives over a cleaner, less muddy bottom.

Vegetation

Adult shortnose sturgeon have been observed feeding in heavily vegetated, muddy backwater areas (Dadswell et al. 1984). In general, however, vegetation does not appear to be an important factor in the life histories of these fishes.

Light

Light appears to be important in the biology of the shortnose sturgeon, although the degree of importance is still largely unassessed. Feeding apparently occurs mostly at night or on windy days when turbidity is high and visibility consequently is low (Dadswell et al. 1984). Gilbert and Heidt (1979) found that all shortnose sturgeon caught in gill nets in the Altamaha River, Georgia, were taken at night. They also found, during radio-tracking studies, that tagged fish remained relatively stationary in deep water during the day, but at night moved into shallow water or moved substantial distances upstream or downstream.

Depth

As indicated earlier, the greatest depth at which an Atlantic sturgeon has been recorded is 46 m, based on a specimen taken in the ocean (Bigelow and Schroeder 1953). All oceanic records of shortnose sturgeon are from lesser depths, which is in large degree a reflection of that species' overall preference for waters of lower salinity. Both species probably occur in the deepest parts of rivers or estuaries where suitable oxygen and salinity levels are present. Dadswell (1979) and Dovel (1979) reported adult shortnose sturgeon in shallow water (2-10 m) in summer and in deeper water (10-30 m) in winter. Dadswell et al. (1984) found juveniles of this species at depths greater than 9 m in river channels.

FISHERY

Historical Aspects

Aboriginal Americans used sturgeons for food (Ritchie 1969). Van den Avyle (1984) reported that sturgeons were exploited commercially in the 17th century to support an export industry to Europe. Sturgeon were not eaten by European immigrants until near the middle of the 19th century, and, in fact, were considered a nuisance in some places. In the Delaware River, where sturgeon populations were exceptionally high, large numbers entered the river during spring migration, where they inadvertently destroyed nets set for other fishes. Beginning about 1853, sturgeon roe was processed into caviar in this country, but demand remained small until 1870, after which the industry expanded rapidly (Cobb 1900). The smoking of sturgeon flesh was begun on a small scale in New York City about 1857. Beginning in the early 1870's, the taste of sturgeon flesh became more greatly appreciated, which resulted in greatly increased commercial exploitation. Large catches were recorded during most of the rest of the century, particularly in the Delaware Bay area. A decline in size of sturgeon populations, first noted during the early 1890's, resulted in protective laws being passed by the State of New Jersey in 1891 and a few years later by the State of Delaware (Cobb 1900). Despite this legislation, commercial landings of sturgeon in the Delaware Bay area during the next 10 years declined precipitously, dropping more than 95% between 1891 and 1901. Commercial sturgeon fishing has since continued on a steady but considerably reduced scale. Beginning in the mid-1920's, the industry shifted southward, to become centered in the area from southern Virginia to South Carolina.

Quality and Value of Commercial Fishery

All sturgeon along the Atlantic coast have been called "common sturgeon" in commercial catch statistics, and these records included both Atlantic and shortnose sturgeon until 1973 (Murawski and Pacheco 1977). Consequently the relative importance of the two species cannot be accurately ascertained. Because of the considerably greater maximum size obtained

by the Atlantic sturgeon, this species undoubtedly comprised by far the greatest percentage of the total weight of the overall catch. Occasionally, however, the shortnose sturgeon may have assumed greater importance, as indicated by Curran and Ries (1937), who reported that in the Hudson River the shortnose sturgeon was considered more important than the Atlantic sturgeon in a declining commercial fishery.

Statistical information on quantities of sturgeon harvested commercially first appeared in 1880 (Table 1). Although the industry was well established by that time, commercial harvests increased greatly during the next few years, so that by 1887 more than 6 million lb were harvested in the Delaware Bay area alone (Murawski and Pacheco 1977). This was the center of the sturgeon industry on the Atlantic coast (Cobb 1900), and between 1887 and 1892 the annual commercial catches of sturgeon in New Jersey and Delaware ranged from 4.9 to 6.5 million lb (Murawski and Pacheco 1977). The catch had dropped to 2.4 million lb by 1897 and to less than 0.24 million lb by 1901. Yearly catches in the Delaware Bay area have rarely exceeded 20,000 lb after 1925. Peak recorded catches for other states over the same period ranged from 349,000 lb (Florida - 1902) to 818,000 lb (Virginia - 1890). Only five times since 1902 has the commercial catch for a particular state during any one year equaled or exceeded 100,000 lb: in 1908 (Georgia), 1918 (South Carolina), and 1969-70 and 1972 (North Carolina).

Elsewhere in the North Atlantic region, sturgeon have been taken in small but steady numbers in the lower Hudson River of New York, where catches usually exceeded 10,000 lb per year from 1942 to 1970. Farther north, in the New England States, sturgeon have been harvested annually, but catches have consistently remained under 5,000 lb per year.

Modest numbers of "common sturgeon" were still being harvested until the late 1970's, particularly in North and South Carolina (Bureau of Commercial Fisheries 1939-1968; National Marine Fisheries Service 1969-1977), and a small commercial fishery for Gulf sturgeon existed until recently in the Suwannee River, Florida (Huff 1975). The shortnose sturgeon was declared a federally endangered species in 1967 and is now protected throughout its range. The Atlantic sturgeon also receives some degree of local protection in many parts of its range, and this protection, coupled with occasional difficulties in distinguishing adult shortnose sturgeon from juvenile Atlantic sturgeon (and a consequent violation of the law), may have contributed to a further decline in the directed commercial harvesting of sturgeon along the Atlantic and Gulf coasts.

Sport Fishery

Sturgeons support no significant sport fishery, but some fish are taken incidentally with other species. Occasional localized fisheries, in which techniques such as snagging are used, have developed in some areas (e.g., below dams) where sturgeons are concentrated (Burgess 1963; Huff 1975).

Table 1. Catch of sturgeon (both species, but principally Atlantic sturgeon), Atlantic and gulf coasts in thousands of pounds. (From statistics published by U.S. Fish Commission, U.S. Fish and Wildlife Service, and National Marine Fisheries Service in Murawski and Pacheco 1977.)

Year	ME	NH	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC	SC	GA	FL	AL	MI	LA
1880	-	-	10	-	-	144	300	150	570	144	412	437	261	354	3	(1)	-	-
1887	-	-	6	-	-	10	3295	61	2825	8	-	238	182	192	(1)	-	-	-
1888	-	-	5	-	-	10	3682	63	2800	7	-	270	251	174	(1)	-	-	-
1889	-	-	-	-	-	40	3592	64	1327	-	-	228	285°	212°	43	-	-	-
1890	-	-	-	-	-	40	4559	59	1302	100	818	175	216°	84°	30	-	-	-
1891	-	-	-	-	-	30	4526	53	1305	72	724	-	-	-	-	-	-	-
1892	-	-	-	-	-	-	4489	60	1052	-	-	-	-	-	-	-	-	-
1897	-	-	-	-	-	-	1951	10	467	141	585	404°	481°	157	9	-	-	-
1898	12	-	9	-	(1)	428	1298	10	280	146	632	-	-	-	-	-	-	-
1901	-	-	-	-	-	113	169	(1)	76	108	183	-	-	-	-	-	-	-
1902	-	-	-	-	-	-	-	-	-	-	-	145	94	-	349	-	-	-
1904	-	-	-	-	-	10	228	11	84	164	181	-	-	-	-	-	-	-
1905	6	-	12	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
1908	-	-	-	-	-	-	-	-	-	-	-	62	-	100	62	-	-	-
1918	-	-	-	-	-	-	-	-	-	-	-	8	118	39	5	-	-	-
1920	-	-	-	-	-	-	-	-	-	(1)	22	-	-	-	-	-	-	-
1921	-	-	-	-	-	34	46	-	12	-	-	-	-	-	-	-	-	-
1923	-	-	-	-	-	-	-	-	-	-	-	19	50	32	7	-	-	-
1924	4	-	6	2	(1)	-	-	-	-	-	-	-	-	-	-	-	-	-
1925	-	-	-	-	-	-	-	-	-	19	66	-	-	-	-	-	-	-
1926	-	-	-	-	-	9	7	-	6	-	-	-	-	-	-	-	-	-
1927	-	-	-	-	-	-	-	-	-	-	-	27	13	3	8	15	-	-
1928	(1)	-	3	(1)	(1)	-	-	-	-	-	-	8	23	2	16	10	-	-
1929	(1)	-	6	(1)	-	3	9	-	11	(1)	9	2	18	5	13	3	-	-
1930	(1)	-	8	1	-	2	4	(1)	15	-	5	3	15	5	8	2	(1)	-
1931	1	-	5	(1)	(1)	2	10	-	5	(1)	6	1	27	2	15	15	-	-
1932	2	-	6	(1)	-	3	7	-	2	(1)	5	2	23	5	4	11	-	-
1933	2	-	5	(1)	(1)	2	27	-	1	(1)	8	-	-	-	-	-	-	-
1934	-	-	-	-	-	-	-	-	-	(1)	8	2	50	12	1	8	-	-
1935	(1)	-	3	1	-	8	12	-	(1)	(1)	6	-	-	-	-	-	-	-
1936	-	-	-	-	-	-	-	-	-	(1)	27	5	59	10	30	2	-	-
1937	(1)	-	7	(1)	(1)	1	6	-	(1)	-	13	(1)	25	8	34	3	-	-
1938	(1)	-	9	2	(1)	5	5	-	-	(1)	16	(1)	26	8	36	2	-	-
1939	-	-	5	(1)	(1)	4	7	-	-	(1)	8	1	-	6	17	5	-	-
1940	(1)	-	7	(1)	-	5	11	-	-	1	12	(1)	3	5	3	(1)	-	-
1941	-	-	-	-	-	-	-	-	-	(1)	13	-	-	-	-	-	-	-
1942	-	-	2	(1)	-	18	15	-	-	4	8	-	-	-	-	-	-	-
1943	(1)	-	3	-	2	13	7	-	-	-	-	-	-	-	-	-	-	-
1944	-	-	7	2	(1)	9	2	-	-	2	5	-	-	-	-	-	-	-
1945	(1)	-	12	(1)	(1)	10	5	-	(1)	6	11	(1)	36	5	7	(1)	-	-
1946	(1)	-	6	1	2	22	5	-	(1)	3	23	-	-	-	-	-	-	-
1947	(1)	-	5	(1)	3	14	5	-	1	4	18	-	-	-	-	-	-	-
1948	(1)	-	9	2	10	19	6	-	1	4	38	-	-	-	-	-	-	-
1949	(1)	-	7	3	(1)	11	4	-	10	5	12	-	-	-	-	-	-	-
1950	(1)	-	7	3	(1)	13	3	-	(1)	3	16	11	17	15	3	-	-	-
1951	(1)	-	7	2	(1)	7	5	-	-	4	13	4	16	5	3	4	-	(1)
1952	(1)	-	4	4	2	.11	11	-	1	7	14	15	24	7	12	(1)	-	-
1953	1	-	5	3	2	9	6	-	4	6	12	15	22	25	19	1	-	-
1954	2	-	6	3	2	13	12	-	2	19	18	10	9	21	3	3	-	-
1955	1	-	4	4	2	12	7	-	2	7	12	2	67	8	12	1	-	-
1956	(1)	-	4	2	2	5	7	-	3	10	13	12	80	37	14	1	-	-
1957	(1)	-	4	4	3	12	7	-	11	7	5	16	45	12	25	1	-	-
1958	(1)	-	4	3	1	30	8	-	3	6	7	22	35	4	15	(1)	-	-
1959	1	-	9	2	2	14	9	-	1	3	12	19	33	4	7	(1)	-	-
1960	(1)	-	8	3	6	15	7	-	-	11	18	23	42	7	1	-	-	-
1961	(1)	-	5	1	9	9	16	-	-	13	12	40	51	4	14	4	-	-
1962	(1)	-	5	2	11	10	19	-	2	8	5	49	40	2	13	4	-	-
1963	1	-	6	3	8	5	13	-	2	7	4	43	53	3	30	1	-	-
1964	(1)	-	4	4	11	12	13	-	3	16	11	34	64	2	9	1	-	-
1965	(1)	-	4	2	4	6	15	-	(1)	35	22	77	50	3	7	-	-	-
1966	(1)	-	2	5	3	16	14	-	2	14	26	59	43	(1)	8	-	-	-
1967	2	-	3	3	2	12	9	-	-	7	12	38	33	1	6	-	-	-
1968	(1)	(1)	3	(1)	2	12	8	-	(1)	5	13	47	44	(1)	58	-	-	-
1969	3	(1)	2	3	(1)	13	7	-	-	6	19	132	40	1	12	-	-	-
1970	6	(1)	2	4	(1)	14	13	-	-	4	22	120	6	4	18	-	-	-
1971	(1)	(1)	2	5	(1)	8	12	-	-	3	17	78	77	4	25	-	-	-
1972	(1)	(1)	3	2	(1)	4	11	-	-	4	11	154	68	8	4	-	-	-
1973	(1)	(1)	2	(1)	-	4	18	-	-	8	18	56	45	3	9	-	-	-
1974	(1)	-	3	3	-	7	10	-	-	5	9	93	47	2	4	-	-	-
1975	1	-	2	1	-	4	14	-	-	5	7	44	68	2	2	-	-	-

* May include A. oxyrhynchus and A. brevirostrus until 1973.
** From statistics published by U. S. Fish Commission, U. S. Fish and Wildlife Service and National Marine Fisheries Service.
° Includes caviar.
\- Indicates no data found.
() Indicates under 1,000 lbs.

LITERATURE CITED

Appy, R.G., and M.J. Dadswell. 1978. Parasites of *Acipenser brevirostrum* Lesueur and *Acipenser oxyrhynchus* Mitchill (Osteichthyes: Acipenseridae) in the Saint John River estuary, N.B., with a description of *Caballeronema pseudoargumentosus* sp. n. (Nematoda: Spirurida). Can. J. Zool. 56:1382-1391.

Baggerman, B. 1979. Photoperiodic and endogenous control of the annual reproductive cycle in teleost fishes. Pages 533-567 *in* M.A. Ali, ed. Environmental physiology of fishes. Plenum Press, New York.

Bath, D.W., J.M. O'Connor, J.B. Alber, and L.G. Arvidson. 1981. Development and identification of larval Atlantic sturgeon (*Acipenser oxyrhynchus*) and shortnose sturgeon (*A. brevirostrum*) from the Hudson River estuary. Copeia 1981(3):711-717.

Beebe, W., and J. Tee-Van. 1933. Field book of the shore fishes of Bermuda. G.P. Putnam's Sons, New York. xiv + 337 pp.

Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv. Fish. Bull. 74. 577 pp.

Borodin, N. 1925. Biological observations on the Atlantic sturgeon (*Acipenser sturio*). Trans. Am. Fish. Soc. 55:184-190.

Buckley, J.L. 1982. Seasonal movement, reproduction, and artificial spawning of shortnose sturgeon (*Acipenser brevirostrum*) from the Connecticut River. M.S. Thesis. University of Massachusetts, Amherst. 64 pp.

Buckley, J., and B. Kynard. 1981. Spawning and rearing of shortnose sturgeon from the Connecticut River. Prog. Fish Cult. 43:74-76.

Buckley, J., and B. Kynard. 1985. Habitat use and behavior of prespawning and spawning shortnose sturgeon, *Acipenser brevirostrum*, in the Connecticut River. Pages 111-117 *in* F.P. Binkowski and S.I. Doroshov, eds. North American sturgeons: biology and aquaculture potential. Developments in Environmental Biology of Fishes 6. Dr. W. Junk bv Publishers, Dordrecht, Netherlands. 163 pp.

Bureau of Commercial Fisheries (BCF). 1939-1968. Fishery Statistics of the United States 1/62. U.S. Department of the Interior.

Burgess, R.F. 1963. Florida sturgeon spree. Outdoor Life. March:44.

Carr, A. [1976]. Sturgeon project. Interim Report to Phipps Florida Foundation. 8 pp. + unnum. figs. Unpubl. MS.

Cobb, J.N. 1900. The sturgeon fishery of Delaware River and Bay. Rep. U.S. Comm. Fish Fish. (1899) 25:369-380.

Curran, H.W., and D.T. Ries. 1937. Fisheries investigations in the lower Hudson River. Pages 124-145 *in* A biological survey of the lower Hudson watershed. Rep. New York State Conserv. Dep., Suppl. 26. 373 pp.

Dadswell, M.J. 1976. Biology of the shortnose sturgeon (*Acipenser brevirostrum*) in the Saint John River estuary, New Brunswick, Canada. Trans. Atl. Chap. Can. Soc. Environ. Biol. Annu. Meet. 1975:20-72.

Dadswell, M.J. 1979. Biology and population characteristics of the shortnose sturgeon, *Acipenser brevirostrum* Lesueur 1818 (Osteichthyes: Acipenseridae), in the Saint John River Estuary, New Brunswick, Canada. Can. J. Zool. 57:2186-2210.

Dadswell, M.J., B.D. Taubert, T.S. Squiers, D. Marchette, and J. Buckley. 1984. Synopsis of biological data on shortnose sturgeon, *Acipenser brevirostrum* Lesueur 1818. NOAA Tech. Rep. NMFS 14 (FAO Fish. Synopsis 140). U.S. Dep. Commerce. iv + 45 pp.

Dean, B. 1895. The early development of garpike and sturgeon. J. Morphol. 11:1-62.

Dees, L.T. 1961. Sturgeons. U.S. Fish Wildl. Serv. Fish Leafl. 526. 8 pp.

de Vlaming, V.L. 1972. Environmental control of teleost reproductive cycles: a brief review. J. Fish. Biol. 4:131-140.

Dovel, W.L. 1978. Biology and management of shortnose and Atlantic sturgeon of the Hudson River. New York State Dep. Environ. Cons., Performance Rep. Proj. AFS-9-R. 181 pp.

Dovel, W.L. 1979. The biology and management of shortnose and Atlantic sturgeon of the Hudson River. New York State Dep. Environ. Cons., Final Rep. Proj. AFS-9-R. 54 pp.

Duméril, A. 1867. Prodrome d'une monographie des esturgeons et description des especes de l'Amerique du Nord que appartiennent au sous-genre *Antaceus*. Nouv. Arch. Mus. Hist. Nat., Paris 3:131-188, 6 pls.

Evermann, B.W., and B. Bean. 1898. Indian River and its fishes. Rep. U.S. Comm. Fish Fish. (1896) 22:227-262.

Gilbert, C.R., editor. 1978. Fishes. *In* Rare and endangered biota of Florida. Pt. 4. University Presses of Florida, Gainesville. 58 pp.

Gilbert, R.J., and A.R. Heidt. 1979. Movements of the shortnose sturgeon, *Acipenser brevirostrum*, in the Altamaha River. Assoc. Southeastern Biol. Bull. 26:35.

Gorham, S.W., and D.E. McAllister. 1974. The shortnose sturgeon, *Acipenser brevirostrum*, in the St. John River, New Brunswick, Canada, a rare and possibly endangered species. Syllogeus 5:1-8.

Greeley, J.R. 1935. Fishes of the watershed with annotated list. Pages 63-101 *in* A biological survey of the lower Mohawk-Hudson watershed. Suppl. 24th Ann. Rep. New York State Conser. Dep. (1934). 300 pp.

Greeley, J.R. 1937. Fishes of the area with annotated list. Pages 45-103 *in* A biological survey of the lower Hudson watershed. Suppl. 26th Ann. Rep. New York State Conser. Dep. (1936). 373 pp.

Gruchy, C.G., and B. Parker. 1980a. *Acipenser brevirostrum* Lesueur, shortnose sturgeon. Page 38 *in* D.S. Lee, et al. Atlas of North American freshwater fishes. North Carolina State Mus. Nat. Hist., Raleigh.

Gruchy, C.G., and B. Parker. 1980b. *Acipenser oxyrhynchus* Mitchill, Atlantic sturgeon. Page 41 *in* D.S. Lee, et al. Atlas of North American freshwater fishes. North Carolina State Mus. Nat. Hist., Raleigh.

Harkness, W.J.K., and J.K. Dymond. 1961. The lake sturgeon: the history of its fishery and problems of conservation. Ontario Department of Lands and Forests, Fish and Wildlife Branch. 121 pp.

Heidt, A.R., and R.J. Gilbert. 1978. The shortnose sturgeon in the Altamaha River drainage, Georgia. Pages 54-60 *in* Proceedings of the rare and endangered wildlife symposium. Georgia Department of Natural Resources.

Hoff, J.G. 1979. Annotated bibliography and subject index on the shortnose sturgeon, *Acipenser brevirostrum*. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-731. 16 pp.

Holland, B.F., Jr., and G.F. Yelverton. 1973. Distribution and biological studies of anadromous fishes from offshore North Carolina. North Carolina Dep. Nat. Econ. Res. Spec. Sci. Rep. 24. 132 pp.

Hollowell, J.L. [1980.] Information report: Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi* (Vladykov). U.S. Fish

and Wildlife Service, Jacksonville. 15 pp. Unpubl. MS.

Huff, J.A. 1975. Life history of Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*, in Suwannee River, Florida. Fla. Mar. Res. Publ. 16:1-32.

Jones, P.W., F.D. Martin, and J.D. Hardy, Jr. 1978. Development of fishes of the Middle Atlantic Bight. Vol. 1, Acipenseridae through Ictaluridae. U.S. Fish Wildl. Serv. Biol. Serv. Program FWS/OBS-78/12. 366 pp.

June, F.C. 1977. Reproductive patterns in seventeen species of warmwater fishes in a Mississippi reservoir. Environ. Biol. Fishes 2:285-296.

Khoroshko, P.N. 1972. The amount of water in the Volga basin and its effect on the reproduction of sturgeons (Acipenseridae) under conditions of normal and regulated discharge. J. Ichthyol. 12:608-616.

Kozlovsky, D.A. 1968. Resorption of sexual products in fishes as a stimulus to biological modification. Prob. Ichthyol. 8:803-807.

Lesueur, C.A. 1818. Description of several species of Chondropterigious fishes, of North America, with their varieties. Trans. Amer. Philos. Soc. 1:383-394.

Magnin, E. 1963. Notes sur la répartition, la biologie et particulièrment la croissance de l'*Acipenser brevirostris* Lesueur 1817. Nat. Can. 90:87-96.

Magnin, E. 1964. Crossance en longueur de trois esturgeons d'Amerique du Nord: *Acipenser oxyrhynchus* Mitchill, *Acipenser fulvescens* Rafinesque, et *Acipenser brevirostris* Lesueur. Verh. Int. Ver. Limnol. 15:968-974.

Magnin, E., and G. Beaulieu. 1963. Etude morphométrique comparée de l'*Acipenser oxyrhynchus* Mitchill du Saint-Laurent et de l'*Acipenser sturio* Linné de la Gironde. Nat. Can. 90:5-38.

Marchette, D.E., and R. Smiley. [1982.] Biology and life history of incidentally captured shortnose sturgeon, *Acipenser brevirostrum* in South Carolina. South Carolina Wildl. Mar. Res. Unpubl. MS.

McCleave, J.D., S.M. Fried, and A.K. Towt. 1977. Daily movements of shortnose sturgeon, *Acipenser brevirostrum*, in a Maine estuary. Copeia 1977(1):149-157.

Murawski, S.A., and A.L. Pacheco. 1977. Biological and fisheries data on Atlantic sturgeon, *Acipenser oxyrhynchus* (Mitchill). U.S. Dep. Commer. Natl. Mar. Fish. Serv. Northeast Fish. Cent. Tech. Ser. Rep. 10. 69 pp.

National Marine Fisheries Service. 1969-1977. Fishery statistics of the United States 63-71. U.S. Dep. Commer.

Pekovitch, A.W. 1979. Distribution and some life history aspects of the shortnose sturgeon (*Acipenser brevirostrum*) in the upper Hudson River estuary. Hazleton Environmental Science Corporation, Illinois. 23 pp.

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

Priegel, G.R., and T.L. Wirth. 1975. The lake sturgeon: its life history, ecology, and management. Wis. Dep. Nat. Resour. Publ. No. 240-70. 19 pp.

Ritchie, W.A. 1969. The archaeology of Martha's Vineyard. The Natural History Press, Garden City, New York. 253 pp.

Roussow, G. 1957. Some considerations concerning sturgeon spawning periodicity. J. Fish. Res. Board Can. 14:553-572.

Ryder, J.A. 1890. The sturgeon and sturgeon industries of the eastern coast of the United States, with an account of experiments bearing upon sturgeon culture. Bull. U.S. Fish Comm. 8:231-238.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184:1-966.

Smith, C.L. 1985. The inland fishes of New York State. The New York State Dep. of Environmental Conservation, Albany. xi + 522 pp.

Smith, H.M. 1907. The fishes of North Carolina. North Carolina Geol. Econ. Surv., vol. 2. 453 pp.

Smith, T.I.J. 1985. The fishery, biology, and management of Atlantic sturgeon, *Acipenser oxyrhynchus*, in North America. Pages 61-72 *in* F.P. Binkowski and S.I. Doroshov, eds. North American sturgeons: biology and aquaculture potential. Developments in Environmental Biology of Fishes 6. Dr W. Junk bv Publishers, Dordrecht, Netherlands. 163 pp.

Smith, T.I.J., E.K. Dingley, and D.E. Marchette. 1980. Induced spawning culture of the Atlantic sturgeon, *Acipenser oxyrhynchus* (Mitchill). Prog. Fish Cult. 42:147-151.

Smith, T.I.J., E.K. Dingley, and D.E. Marchette. 1981. Culture trials with Atlantic sturgeon, *Acipenser oxyrhynchus* in the U.S.A. J. World Maricult. Soc. 12:78-87.

Smith, T.I.J., D.E. Marchette, and R.A. Smiley. 1982. Life history, ecology, culture and management of the Atlantic sturgeon, *Acipenser oxyrhynchus oxyrhynchus* Mitchill, in South Carolina. South Carolina Wildl. Mar. Resour. Comm. Tech. Rep. AFS-9. 75 pp.

Smith, T.I.J., D.E. Marchette, and G.F. Ulrich. 1984. The Atlantic sturgeon fishery in South Carolina. N. Am. J. Fish. Management 4:164-176.

Squiers, T.S., M. Smith, and L. Flagg. 1981. American shad enhancement and status of sturgeon stocks in selected Maine waters. Rep. Dep. Mar. Resour. Maine, Proj. AFC-20, pp. 20-64.

Taubert, B.D. 1980a. Reproduction of the shortnose sturgeon (*Acipenser brevirostrum*) in Holyoke Pool, Connecticut River, Massachusetts. Copeia 1980(1):114-117.

Taubert, B.D. 1980b. Biology of the shortnose sturgeon (*Acipenser brevirostrum*) in the Holyoke Pool, Connecticut River, Massachusetts. Ph.D. Dissertation, University of Massachusetts, Amherst. 136 pp.

Taubert, B.D., and M.J. Dadswell. 1980. Description of some larval shortnose sturgeon (*Acipenser brevirostrum*) from the Holyoke Pool, Connecticut River, Massachusetts, USA, and the Saint John River, New Brunswick, Canada. Can. J. Zool. 58:1125-1128.

Townes, H.K., Jr. 1937. Studies on the food organisms of fish. Pages 217-230 *in* A biological survey of the lower Hudson watershed. Rep. New York State Conser. Dep. Suppl. 26. 373 pp.

van den Avyle, M.J. 1984. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (south Atlantic)--Atlantic sturgeon. U.S. Fish Wildl. Serv. Biol. Rep. 81(11.25). U.S. Army Corps of Engineers, TR EL-82-4. 17 pp.

Vladykov, V.M., and J.R. Greeley. 1963. Order Acipenseroidei. Pages 24-60 *in* Fishes of the Western North Atlantic. Mem. Sears Found. Mar. Res. 1(3). xxi + 630 pp.

Wooley, C.M. 1985. Evaluation of morphometric characters used in taxonomic separation of Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*. Pages 97-103 *in* F.P. Binkowski and S.I. Doroshov, eds. North American sturgeons: biology and aquaculture potential. Developments in environmental biology of fishes 6. Dr W. Junk bv Publishers, Dordrecht, the Netherlands. 163 pp.

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16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, range, life history, and environmental requirements of coastal species. The Atlantic and shortnose sturgeons (especially the former) were commercially important fishes between 1880 and 1900, but stocks have since decreased markedly and the shortnose sturgeon is now classified as federally endangered. Although the two species are anadromous, the shortnose sturgeon tends to spawn farther upstream, and spawning in both species usually occurs over a clean, hard substrate washed by a moderate to strong current. The shortnose sturgeon usually spawns earlier at the same latitude, with spawning of this species in the St. John River, New Brunswick, being completed by mid-May, as opposed to late June or even July for the Atlantic sturgeon. During non-spawning periods, the shortnose is largely confined to estuaries and apparently does not undergo the extensive coastal migrations that are characteristic of the Atlantic sturgeon. Atlantic sturgeon mature more slowly than shortnose sturgeon at comparable latitudes, with male and female Atlantic sturgeon from the Hudson River, New York, requiring at least 11 and 18 years, respectively, to reach maturity, compared with less than half that time for the shortnose sturgeon. Spawning in both sexes may occur thereafter only once every several years. Both species are usually indiscriminate feeders and feed by sucking materials off the bottom with their protrusible mouths. Feeding apparently occurs mostly at night in the shortnose sturgeon.

17. Document Analysis a. Descriptors

Anadromous fishes
Estuaries
Growth
Feeding habits
Temperature
Life cycles
Fisheries

b. Identifiers/Open-Ended Terms

Atlantic sturgeon
Acipenser oxyrhynchus
Temperature requirements
Life history
Shortnose sturgeon
Acipenser brevirostrum
Spawning
Habitat requirements
Commercial importance

c. COSATI Field/Group

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