# Fisheries Technical Session

## Population Size and Movement Patterns of Shortnose Sturgeon in the Ogeechee River System, Georgia

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Abstract: A 2-part study (multiple mark-recapture and telemetry) was used to estimate the size of the shortnose sturgeon (*Acipenser brevirostrum*) population and their habitat use in the Ogeechee River, Georgia. The mark-recapture study was conducted from July 1993 to December 1994 and used the modified Schnabel model for estimating population size. Sixty-two shortnose sturgeon were marked; 17 were recaptured at least once. Seventy-eight percent of the marked fish were older juveniles and adults [>56.0 cm fork length (FL)]. Estimated population size was 266 (95% CL 236–300) in 1993 and 72 (95% CL 57–91) in 1994. CPUE declined 6-fold from 1993 to 1994. The telemetry study was conducted from June 1994 to June 1995. Radio and ultrasonic transmitters were used to monitor the movements of 20 adults and 1 juvenile shortnose sturgeon. Tagged fish never left the river system and used specific regions of the river during summer, fall/spring, and winter. During the summer, when water temperature was >27.0 C, fish were found frequently aggregated in deep holes (>4.5 m) at tidal freshwater locations [>44.0 river kilometer (rkm)]. During spring and fall, when water temperature was <27.0 C and >16.0 C, respectively, shortnose sturgeon moved into mesohaline areas (26.2–36.6 rkm); during winter when water temperatures dropped below 16.0 C, sturgeon moved farther downriver to polyhaline regions (19.2–30.5 rkm). Shortnose sturgeon were more dispersed and their movement increased when water temperatures were <27.0 C. This behavior altered the catchability of these fish and may have influenced our population estimates.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 52:18–28

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Shortnose sturgeon *Acipenser brevirostrum* is an amphidromous fish found historically in 24 Atlantic coast rivers ranging from the St. John River, New Brunswick (Leim and Day 1959), to the Indian River, Florida (Evermann and Bean 1898). Shortnose sturgeon has declined rangewide and the detrimental effects of fishing, habitat degradation, and pollutants have been blamed for the decline (Natl. Mar. Fish. Serv. 1998). The species' disappearance from commercial fish landings rangewide and the almost absolute lack of information about the species resulted in its being listed as an endangered species in the United States (Miller 1972). Subsequent to its listing, several studies that describe aspects of the biology and ecology of shortnose sturgeon in northeastern U.S. rivers have been published (see Hall et al. 1991). Although many southern rivers have extant populations of shortnose sturgeon, most of these populations have not been studied (Hall et al. 1991).

Historically, shortnose sturgeon inhabited all the major coastal rivers in Georgia (Natl. Mar. Fish. Serv. 1998). However, 1 recent study suggests that they have been extirpated from the Satilla and St. Marys rivers (Rogers and Weber 1995*a*). In the Altamaha and Ogeechee rivers, Georgia, and the Savannah River, which separates Georgia and South Carolina, shortnose sturgeon occupy oligohaline to fresh tidal portions of estuaries year-round (Hall et al. 1991, Flournoy et al. 1992, Smith et al. 1992, and Rogers and Weber 1995*b*). Reduction or absence of summer refuges, bycatch mortalities in the shad (*Alosa* spp.) fishery, and habitat degradation (e.g., eutrophication) may be limiting the abundance of shortnose sturgeon in Georgia (Rogers and Weber 1995*a*, Collins et al. 1996, Boreman 1997); however, basic information on population size, population dynamics, and habitat use needed to assess these threats and better manage this endangered species are scarce or lacking. The specific objectives of this study were to estimate population size and length distribution, and to determine movement patterns of shortnose sturgeon in the Ogeechee River.

Fort Stewart Military Reservation (Department of Defense), Fort Stewart, Georgia, in conjunction with the Nature Conservancy of Georgia provided funding for this study. The Georgia Department of Natural Resources provided equipment and facility support. National Marine Fisheries Service Anadromous Grant Program provided additional financial support. We thank Craig Crumbly, Dominic Guadagnoli, Steve Pete, Ximena Prudencio, Chet Roundtree, Lynn Wilson, and the many volunteers and interns for their work in the field. Our thoughts and conclusions have benefited from discussions with Jim Clugston, Mark Collins, Don Dennerline, Carl Hall, Meg Hoyle, Boyd Kynard, and Mary Moser. The Unit is jointly sponsored by the United States Geological Survey-Biological Resource Division, the Georgia Department of Natural Resources, the University of Georgia, and the Wildlife Management Institute.

## Methods

The Ogeechee River is a black water, nutrient-poor, acid-laden system that rises in the lower Piedmont of Georgia and flows into the Atlantic Ocean through the Ogeechee River-Ossabaw Sound estuary; the river is 425.0 km long and its major tributary, the Canoochee River, is 84.4 km long. The confluence of these 2 rivers is 56 river km (rkm) from the ocean/beach line. Detailed descriptions of this system are given in Weber (1996).

### Fish Sampling

A stratified random design was used to sample shortnose sturgeon for this 2-part study. Every region of the river with a depth >4.5 m was considered a potential sampling site; these sites were identified with a Lowrance X-16 depth finder. Fish for the mark-recapture study were collected during the period June 1993–December 1994, and fish for the telemetry study were collected during the period June 1994–June 1995 between rkm 12.0 and 57.0 in areas that were identified previously.

Shortnose sturgeon were captured with 30- and 100-m long, 1.8-m deep monofilament trammel nets with a 7.6-cm stretched mesh inner panel and 35.6-cm stretched mesh outer panels. Trammel nets were fished almost daily during various tidal stages for about 1 hour. Total fishing effort was 72.3 hours in 1993 and 378.5 hours in 1994. All sturgeon caught were held in an aerated livewell until they were tagged. Each fish received 1 Hallprint t-bar tag in each pectoral fin. Fish >56.0 cm FL also were tagged through the base of the dorsal fin with an Advanced Telemetry Systems (ATS) radio transmitter (21.0 g) and a Sonotronics ultrasonic transmitter (21.0 g). Both transmitters were 18 mm in diameter × 60 mm long and weighed about 21.0 g in air. Set time (hours and minutes), duration (hours and minutes), location (rkm), fish weights (kg), lengths (cm), tag number, notes on acoustical signatures, notes on by-catch, and bathymetric observations were recorded at every location where a fish was recaptured.

### Water Quality

Water quality variables including temperature (C), salinity (ppt), dissolved oxygen (ppm), conductivity (microsiemens), and depth (m) also were recorded for every location where fish were recaptured. The water quality data were analyzed by seasons. These seasons, defined as spring (Mar–May), summer (Jun–Aug), fall (Sep–Nov), and winter (Dec–Feb), were based on seasonal changes in air temperatures. Also, the river was divided into reaches, defined as estuarine (≤22.5 rkm), brackish (22.6–54.7 rkm), and tidal fresh (≥54.8 rkm), were based on major changes in vegetation that corresponded to major changes in salinity.

### Fish Tracking

A total of 368 hours of tracking were expended on the Ogeechee River system. Five more days were tracked in 1995 than in 1994. Tracking of the 21 sturgeon fitted with transmitters was conducted with a scanning programmable radio receiver (ATS R2000) fitted with triangular antenna and an ultrasonic receiver (USR-90) fitted with directional hydrophones. Fish locations for boat-tracked fish were recorded at specific rkm, and latitudes and longitudes were converted to rkm for fish tracked by plane. Tracking began with the first electronically-tagged individual on 30 June 1994 and extended until 26 July 1995. Fish were tracked by boat in the navigable portion of the Canoochee River and in the Ogeechee River from rkm 77.5 through the estuary out to North Ossabaw Sound. The estuary was surveyed daily by boat and the entire river system was checked at least twice weekly by plane. Flights extended on the Ogeechee River arm upstream to the fall line (approximately rkm 400.0) and on the Canoochee River arm upstream to above where the river enters the western property line of Fort Stewart Military Base (Canoochee River rkm 77.5), which is about 133 rkm above the ocean.

### Data Analysis

Field data were stored electronically with D-Base IV® software and analyzed with SAS® software for microcomputers. Physicochemical and telemetry data were tested for normality with the Shapiro-Wilk test and tested for homogeneity of variances with the *F*-max test (Sokal and Rohlf 1981). Differences in temperature, salinity, and dissolved oxygen levels between the Ogeechee and Canoochee rivers were compared with a *t*-test. The relationship between sturgeon length and total distance traveled was evaluated with regression techniques. Analysis of variance was used to evaluate the following: a) differences in mean mid-depth salinities among reaches of the Ogeechee River, b) seasonal differences in mean mid-depth water temperatures (average mid-depth temperatures during fall and spring were similar; therefore, these data were pooled and reported as a single mean for both seasons), c) water temperature differences at specific sites between the 2 study years, and d) seasonal differences in mean distance traveled by sturgeon. Bonferroni's group comparison tests were used to separate means. All tests were evaluated for significance at $\alpha = 0.05$.

The modified Schnabel method was used to estimate the population size of shortnose sturgeon in the Ogeechee River. This method provides a more accurate estimate of population size than the Peterson Index when the time interval in which the study is to be carried out is large, and the assumptions for the Peterson Index cannot be met (Seber 1973). Approximate confidence intervals were calculated by considering total recaptures (R) as a Poisson variable (Ricker 1987).

## Results

### Population Estimates and Length-Frequency Distribution

Sixty-two shortnose sturgeon were captured, 17 of which were recaptured at least once. Shortnose sturgeon captured in the study ranged from 33.5 to 95.0 cm FL, and 78% of these were ≥56.0 cm FL, the size of older juveniles and adults (Fig. 1). Estimates of shortnose sturgeon population size in the Ogeechee River system were 266 in 1993 and 72 in 1994 (Table 1).

Water quality in the Ogeechee River during the summers of 1993 and 1994 was significantly different between years for some variables and not different for others. Mean mid-depth water temperature in the Ogeechee River was warmer (30.6 C; SD = 1.1) during the summer of 1993 than during the summer of 1994 (27.4 C; SD = 1.3) ($P < 0.05$). Dissolved oxygen, temperature, and salinity values were not significantly different ($P > 0.05$).

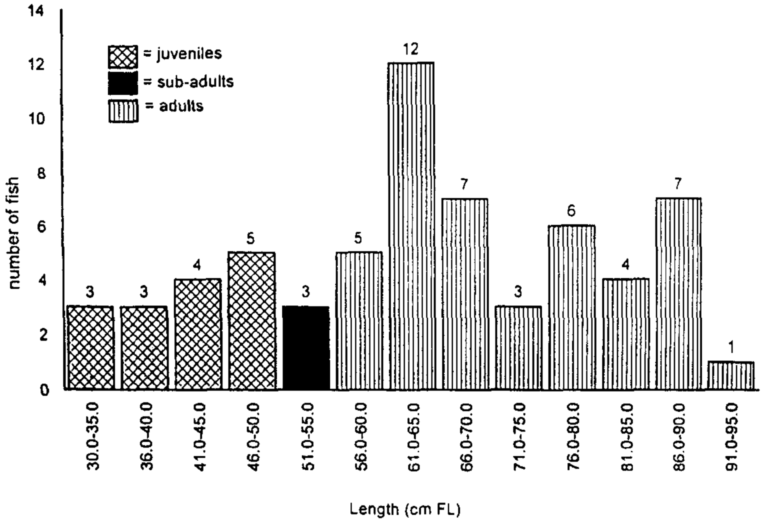


**Figure 1.** Length-frequency distribution of shortnose sturgeon captured in the Ogeechee River, Georgia, 1993–1994.

Mean salinities among the 3 reaches were different from each other ($P < 0.05$), with salinity decreasing with distance upstream. Mean salinity in the tidal fresh portion of the system was 0.0 ppt (SD = 0.9) and ranged from 0.0 to 5.9 ppt, whereas salinity in the brackish portion of the river was 9.0 ppt (SD = 3.5) and ranged from 6.0 to 19.9 ppt. Mean salinity in the estuary was 32.0 ppt (SD = 3.1) and ranged from 20.0 to 35.0 ppt.

Mean temperatures varied among some seasons within each year ($P < 0.05$). During the summer, average mid-depth water temperature was 28.0 C (SD = 0.6), whereas average spring and fall mid-depth water temperature was 22.0 C (SD = 3.3). Average winter temperature was 12.0 C (SD = 2.1). Average mid-depth temperatures during summer and winter 1994 were warmer ($P < 0.05$) than those meas-

**Table 1.** Modified Schnabel population estimates of shortnose sturgeon in the Ogeechee River, Georgia.

| Date | Estimated population | 95% CL |
|---|---|---|
| July 1993 | 361 | 326–400 |
| Aug 1993 | 257 | 227–290 |
| Sep 1993 | 266 | 236–300 |
| Jun 1994 | 36 | 25–50 |
| Jul 1994 | 27 | 18–39 |
| Aug 1994 | 30 | 20–43 |
| Sep 1994 | 33 | 23–46 |
| Oct 1994 | 36 | 25–50 |
| Nov 1994 | 57 | 44–74 |
| Dec 1994 | 72 | 57–91 |

ured during 1995. Average summer mid-depth temperature during 1994 was 27.4 C (SD = 1.3) compared to 25.3 C (SD = 1.2) during 1995. Average winter mid-depth temperature was 15.3 C (SD = 2.4) during 1994 compared to 11.0 C (SD = 1.7) during 1995.

### Habitat Use and Movement Patterns

Lost or faulty transmitters reduced the number of tagged fish at large from 21 to 14. Six of the 21 fish dropped their tags within 4 months of tagging, and another fish had a broken transmitter that had indicated activation of the mortality switch (e.g., beeping rapidly continuously), though movement was detected by the ultrasonic receiver. Five percent of the radio transmitters failed.

Individual sturgeon were relocated 2–80 times and traveled 16.1–300.8 rkm. Mean distance traveled did not differ among length classes ($P > 0.05$). All fish tracked ($N = 9$) during summer (water temperature >27.0 C) were relocated upstream of rkm 40.0 at least once and usually remained motionless in deep holes (>4.5 m). The majority of shortnose sturgeon were captured repeatedly during the summer in 1 deep hole (11.5 m) and remained there until water temperature was <27.0 C. This large hole, located in the center of the channel at rkm 56.8, contained many logs and other large debris on the bottom. All fish ($N = 11$) tracked during spring and fall (water temperature <27.0 C) moved downriver (rkm 24.0–56.2; avg. rkm 36.7) into more saline water. Increased localized movement was detected during this time. When mid-depth water temperatures dropped below 16.0 C (winter, range 9.0–15.2 C), the sturgeon migrated into the polyhaline regions from rkm 19.2 to 30.5 (avg. rkm 23.0).

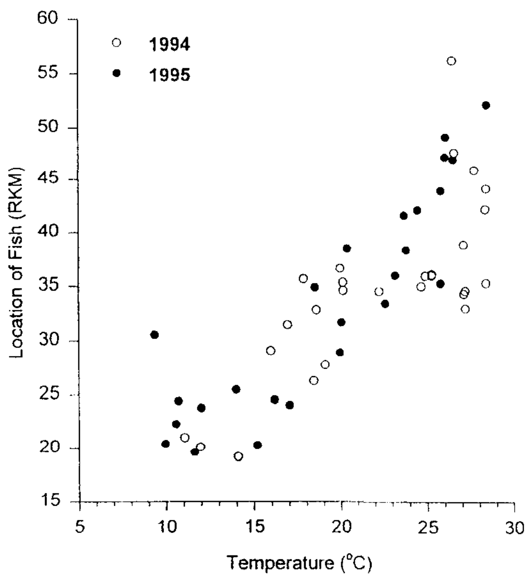


**Figure 2.** Total distance (rkm) traveled by shortnose sturgeon in relation to water temperatures in the Ogeechee River, Georgia.

These fish often swam from bank to bank, making short movements near gradually sloping channel banks or near mid-channel islands with gradually-sloping banks. Most (9) remained in the lower estuary until temperatures rose to about 15.0–16.0 C.

The total distance traveled by shortnose sturgeon in summer and winter differed among years. During the warmer (avg. 27.4 C; SD = 1.3) summer of 1994, the total distance traveled by telemetered fish was 112.7 rkm, and the total distance traveled during the cooler summer (25.3 C; SD = 1.2) of 1995 was 167.6 rkm. Distance traveled by shortnose sturgeon also varied during winter. For example, in 1994 when the average water temperature was 15.3 C (SD = 2.4), the total distance traveled by telemetered fish was 449.2 rkm. By comparison, shortnose sturgeon traveled a total distance of 1,170.9 rkm during 1995 when the average water temperature was 11.0 C (SD = 1.7). More movements by telemetered fish were recorded during the cooler water months than the warmer water months (Fig. 2). During summer, the minimum total movement of all telemetered fish was 336.3 rkm, compared with 1,671.8 rkm during spring/fall, and 1,620.1 rkm during winter.

## Discussion

### Population Estimates and Length-Frequency Distribution

The estimated number of shortnose sturgeon in the Ogeechee River was relatively low in 1993 and even lower in 1994. Variability in catchability may explain the decreasing numbers of individuals from year to year. When the water temperatures exceeded 27.0 C, shortnose sturgeon often were aggregated in deep (>4.5 m) holes in the upstream portions of the river (approximately rkm 57.0). Historically, these holes may have contained cool-water springs that provided sturgeon with conditions that allowed them to better survive warm water conditions.

Similar areas of dense aggregations have been found in the Altamaha River, Georgia, and Cape Fear River, North Carolina (Flournoy et al. 1992, Moser and Ross 1995). When sturgeon were centralized in deeper areas, catch rates were much higher than when temperatures dropped below 27.0 C and the sturgeon were distributed widely throughout the lower river regions, as was seen in 1994. As a result, the 1993 population estimate probably was a more accurate estimate of the number of individuals in the population. The magnitude of the differences in population estimates between the July, August, and September periods of 1993 and 1994 was reflected in the difference in CPUE between the 2 years (1993 approximately 0.6 fish/hour; 1994 approximately 0.1 fish/hour).

Population estimates for 1993 may be low if all the summering sites were not identified and sampled during hot water conditions (i.e., >27.0 C). This scenario is unlikely because of the thoroughness of the river survey. Another possible explanation for the low estimate of the number of shortnose sturgeon may be that a segment of the population remained upriver near spawning sites during the summer months (Rogers and Weber 1995*a*). If all the summering refuges had been identified and sampled in a stratified random fashion, estimates obtained during hot summer conditions (water temperatures >27.0 C) may be more accurate than estimates obtained at times when water temperatures are cooler and the fish are dispersed throughout the river and less likely to be captured. Nonetheless, the 1993 estimate is still relatively low compared to other south Atlantic rivers where shortnose sturgeon occur. Even if these estimates were off by several hundred percent, the population still would be <1,000 individuals.

Recent recaptures of tagged shortnose sturgeon may indicate that these fish are not restricted to a single river and may suggest migration among populations. A shortnose sturgeon that was tagged in the Altamaha River, Georgia, was recaptured in the Edisto River, South Carolina; several shortnose sturgeon that were released in South Carolina rivers were recaptured in Georgia; and several shortnose sturgeon captured and tagged in the Ogeechee River were recaptured in the Altamaha River (Mark Collins, pers. commun.; S. G. Rogers and W. Weber, unpubl. data). These recaptures suggest that shortnose sturgeon migrate between rivers and that genetic mixing of stocks may be occurring to an unknown extent. Accordingly, the apparently low number in the Ogeechee River may not be the same individuals through time, and the functional (i.e., reproductive) population size may be larger than the low point-in-time estimates we obtained.

The size structure of the shortnose sturgeon within the Ogeechee River is skewed towards adults (>58.0 cm FL). Studies conducted in the Altamaha River with the same type of sampling gear and similar sampling regions demonstrated that juveniles and adults occur in the same summer habitat and that both groups are vulnerable to the sampling gear used in this study (Flournoy et al. 1992, Rogers and Weber 1995*a*). The length-frequency distribution of shortnose sturgeon collected during summer conditions in the Altamaha River indicated that all size classes were present and that the population contained more juveniles than adults. Therefore, the absence of juveniles in our samples probably reflected their absence from the river and was not an artifact of our sampling.

Stress-related mortality of juvenile fish because of poorly-understood interactions with physicochemical conditions and pollutants may limit survival and recruitment. For example, Jenkins et al. (1993) found that juveniles are less tolerant than adults of high salinities (>15.0 ppt) and low dissolved oxygen levels (≤2.5 mg/liter). Whether the absence of juveniles in our samples is related to such stress is unknown. However, water quality in the Ogeechee River has been decreasing (Smith and Alexander 1983, Ga. Dep. Nat. Resour. 1993). Further, U.S. Geological Survey (1990) test wells in the vicinity of summer refuge areas of the Ogeechee River and similar areas of the Savannah River show that the Floridian aquifer has been depleted to a degree that artesian seepage, even to the deepest holes in the rivers, is no longer possible. The contrast between the size and structure of the shortnose sturgeon populations in the Ogeechee and that of the Savannah and Altamaha rivers is striking (Flournoy et al. 1992, Smith et al. 1992, Rogers and Weber 1995*b*, and Weber 1996), and may support the altered-water quality hypothesis for explaining the levels of juveniles in the Ogeechee River.

### Habitat Use and Movement Patterns

Habitat use and movement patterns of shortnose sturgeon in the Ogeechee River seem to be related to water quality, primarily temperature and salinity. Fish in this study moved more frequently and for longer distances during cool water conditions than during warm water (>27.0 C) conditions. Further, in this and other studies (McCleave et al. 1977, Buckley and Kynard 1985, Hastings et al. 1987, Hall et al. 1991, Collins and Smith 1993, Kieffer and Kynard 1993, Moser and Ross 1995), adult shortnose sturgeon seemed to use saline estuarine waters when water temperatures were low. The timing of such movements varies between northern and southern rivers, but occurs at similar water temperatures. Our results show that the timing of movement of shortnose sturgeon in the Ogeechee River to more saline waters is similar to that reported in the Cape Fear River, North Carolina (Moser and Ross 1995), and inferred for the Savannah (Hall et al. 1991, and Collins and Smith 1993) and Altamaha rivers (Rogers and Weber 1995*a*). Whether these movements were in response to a physiological need for more saline water or were in response to the abundant food supply in the estuary is unclear. What is clear is that water quality affected habitat use by shortnose sturgeon in the Ogeechee River.

## Summary

Average summer catch rates of shortnose sturgeon in the Ogeechee River during 1993, when average water temperature was 30.6 C (SD = 1.1), was 2–20 times higher than the summer catch rates aggregated over a 5-year period at comparable sites in the nearby Altamaha River, Georgia (Flournoy et al. 1992). Estimates of shortnose sturgeon population size in the Altamaha River (Shortnose Sturgeon Recovery Plan) are 200:1, 300% higher than in the Ogeechee River. Although the Ogeechee River is a smaller system, with much smaller summer refuges where shortnose sturgeon can concentrate, the fish were aggregated at least as densely as in the Altamaha River. Similar seasonal catch rates were found in the Delaware River, New Jersey, where sturgeon catches were lower during the cool-water period (winter and spring) than during the warm-water period in the summer (Hastings et al. 1987). The duration of water temperatures >27.0 C perhaps is an important factor in determining the presence of sturgeon and amount of time they are confined to cool-water refuges. Surveys in the Canoochee River did not identify extensive deep holes, which may explain why shortnose sturgeon were not captured there during the summer. We assert that surveying the low salinity and fresh tidal portions of southern rivers while water temperatures are >27.0 C, concentrating particularly on deep holes in the river, constitutes a viable technique for determining presence or absence of shortnose sturgeon and is useful for estimating population size.

Specific habitats (e.g., summer refuges) may be critical to the survival of shortnose sturgeon in the Ogeechee River, and determining whether shortnose sturgeon are resident at certain locations during various times of the year can help plan for potentially threatening activities. For example, bridge construction and channelization could be scheduled for times when sturgeon are known to be absent from an area.

Therefore, identifying critical habitats specifically and seasonal habitat use in general are vital to the management of this endangered species.

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