Age, Growth, and Status of Shortnose Sturgeon in the Lower Ogeechee River, Georgia

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Abstract: Shortnose sturgeon *(Acipenser brevirostrum)* were monitored as part of continuing studies in the Ogeechee and Canoochee rivers adjacent to Fort Stewart, Georgia, during 1999 and 2000. Over 13,000 net-meter h soak time and 1,700 person h of effort were expended; short (27.5-m) experimental gill nets were a satisfactory sampling gear. Retention of externally mounted telemetry tags was poor (mean = 80 d), and spawning habitats were not located. The population, ranging from ages 3 to 14, was estimated at 147 individuals. Growth equation parameters and rates of mortality were similar to those described in other river systems. Recruitment appears to limit the recovery of the population. Modeling suggests this population has been maintained by yearly recruitment of about 30 age-1 fish since 1993. Cultured shortnose sturgeon released into the Savannah River allowed for age validation and contributed substantially to year classes 8, 9, and 11. Compared to other described shortnose sturgeon populations, the Ogeechee River population remains one of the most depressed. Therefore, population trends should be closely monitored, factors limiting recruitment identified, and critical habitats located using improved methods of telemetry.

Key Words: shortnose sturgeon, population status, Ogeechee River

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The endangered shortnose sturgeon *(Acipenser brevirostrum)* was federally listed in 1967 (Miller 1972). Habitat loss, degradation, and mortality were identified as major threats to this species (National Marine Fisheries Service 1998). Shortnose sturgeon are distributed among at least 19 major coastal rivers from New Brunswick, Canada, to Florida (National Marine Fisheries Service 1998), but Kynard (1997) reported viable populations in only five of these river systems. Individual populations tend to reside within their natal river/estuary (Hall et al. 1991, Moser and Ross 1995) and demonstrate differences in biology and movements along a latitudinal gradient (Kynard 1997). Some northern river populations have been monitored extensively, while southerly populations have received much less study (Hall et al. 1991) and generally remain depressed, i.e., with populations of < 1,000 adults (Kynard 1997).

A baseline study of shortnose sturgeon in the Ogeechee River system, Georgia, was conducted from 1993 to 1995 (Rogers and Weber 1994, Weber 1996). The population was characterized as being depressed (*N* ~ 266) and recruitment limited. Spawning and rearing habitats were not located, and additional monitoring was deemed necessary. Thus, the goals of this study were: (1) to characterize parameters such as age, growth, and population size, (2) to evaluate population trends using modeling, and (3) to locate spawning and rearing habitats using telemetry.

Study Area

The Ogeechee River is one of four Georgia river systems with documented shortnose sturgeon populations (National Marine Fisheries Service 1998). This unimpounded, 425-km, black-water river (Fig. 1) begins in the Piedmont and lacks industrialization on much of the drainage (Weber 1996). The Canoochee River flows diagonally through Fort Stewart, a 114,000-ha U.S. Army installation, and drains into the Ogeechee River near river km 55. Twenty-two km of the Ogeechee River form the eastern boundary of the installation, and the system empties into the Atlantic Ocean through Ossabaw Sound.

While the Ogeechee River system appears little impacted by man's activities, two major concerns have arisen. First, aquifer depletion may be changing the suitability of deep holes where shortnose reside during the summer (G. S. Rogers, pers. commun.). Secondly, spawning and recruitment may be affected by degraded water quality (dissolved oxygen, salinity, and contaminants) and by incidental capture from a shad fishery (Rogers and Weber 1994, Smith et al. 1995, Collins et al. 1996).

Methods

Collection

From May through September in 1999 and 2000, shortnose sturgeon were captured in deep pools along the freshwater-saltwater boundary, in a river section approximately 5 km wide, near the Canoochee-Ogeechee confluence. This area has been shown to hold shortnose sturgeon during warm weather periods (Rogers and Weber 1994). Fish were captured using 27.5-m by 2.0-m monofilament experimental gill nets made up of 5 panels consisting of 3.8, 7.6, 12.7, 15.2, and 17.8-cm stretch mesh sections. The nets were anchored to the shore and were set on the bottom perpendicular to the bank. To minimize stress on fish, soak times (time between net set and retrieval) were kept to less than one hour. All captured sturgeon were held in an aerated, wooden holding tank. Soak times were recorded to calculate catch-per-unit-effort (CPUE) and total sampling effort. Water temperature, pH, salinity, and dissolved oxygen were recorded at each netting site.

Tagging—Mark and Recapture

Each sturgeon was examined for tags. A passive integrated transponder (PIT) tag scanner was used to search for internal tags. Utilization of PIT tags has been found to be an effective means of marking shortnose sturgeon (Smith et al. 1990) and two were injected into the posterior musculature beneath the dorsal fin.

Tagging—Telemetry

Shortnose sturgeon were tagged with external, custom made, 49 MHz radio transmitters or Lotek 76.8 kHz/149.6 MHz combined acoustic/radio transmitter (CART) tags. These tags were anchored in the musculature below the dorsal fin with monel wire or through holes in dorsal scutes with monofilament fishing line. Surgically implanting telemetry tags in high water temperatures (~28 C) was deemed inappropriate (Moser et al. 2000) and was not permitted by our National Marine Fisheries Service permit during summer months. Tracking was conducted using either boats or aircraft.

Age Determination

Age was determined by removing a 1.25-cm section from the right pectoral fin ray, a procedure shown to be nondeleterious (Collins et al. 1996). Pectoral fin rays were prepared, sectioned, and mounted as described by Rien and Beamesderfer (1994). Using this procedure, sections were allowed to air dry in a coin envelope until they could be sectioned. Fin rays were cut into sections, 0.46- to 0.52-mm thick, with a Buehler low-speed saw. Sectioned fin rays were mounted and sealed with nail polish and allowed to dry further before being read for age. All differences in assigned ages of fish were reconciled. Known age fish (i.e., cultured fish tagged with numbered floy tags, released into the Savannah River, and subsequently recaptured in this study), allowed for age validation.

Population Analysis

Population size was estimated using the Schnabel method (Schnabel 1938, Everhart et al. 1975). A weight-length relation was determined after Ricker (1975) using the form: $w = a L^b$ where w is weight (g), L is fork length (mm), and a and b are growth coefficients. Growth (of both sexes) was described by a von Bertalanffy growth equation (Ricker 1975) using mean fork length-at-age and NLIN procedures in SAS (SAS 1988).

Mortality was computed using two methods. The first method used a catch curve (Ricker 1975) with age data pooled for both 1999 and 2000. The second method was that of Beverton and Holt (1956) using length at capture and von Bertalanffy growth equation parameters. The form of this equation follows:

$$Z = K(L_\infty - Lmean)/(Lmean - Lmin)$$

where Z is the instantaneous rate of total mortality, L_∞ is the asymptotic fork length and K is the growth coefficient, Lmean is the mean fork length of captured fish, and Lmin is the fork length of the smallest fish captured.

Population modeling was performed with an age structure model, MOCPOP 2.0 (Beamesderfer 1991), using the estimates of shortnose sturgeon population size, age structure, growth, mortality, weight-length relation, and recruitment. Two simulations were conducted applying varying mortality rates from the previously described methods. The first simulation used 12% annual mortality and the second used 12%

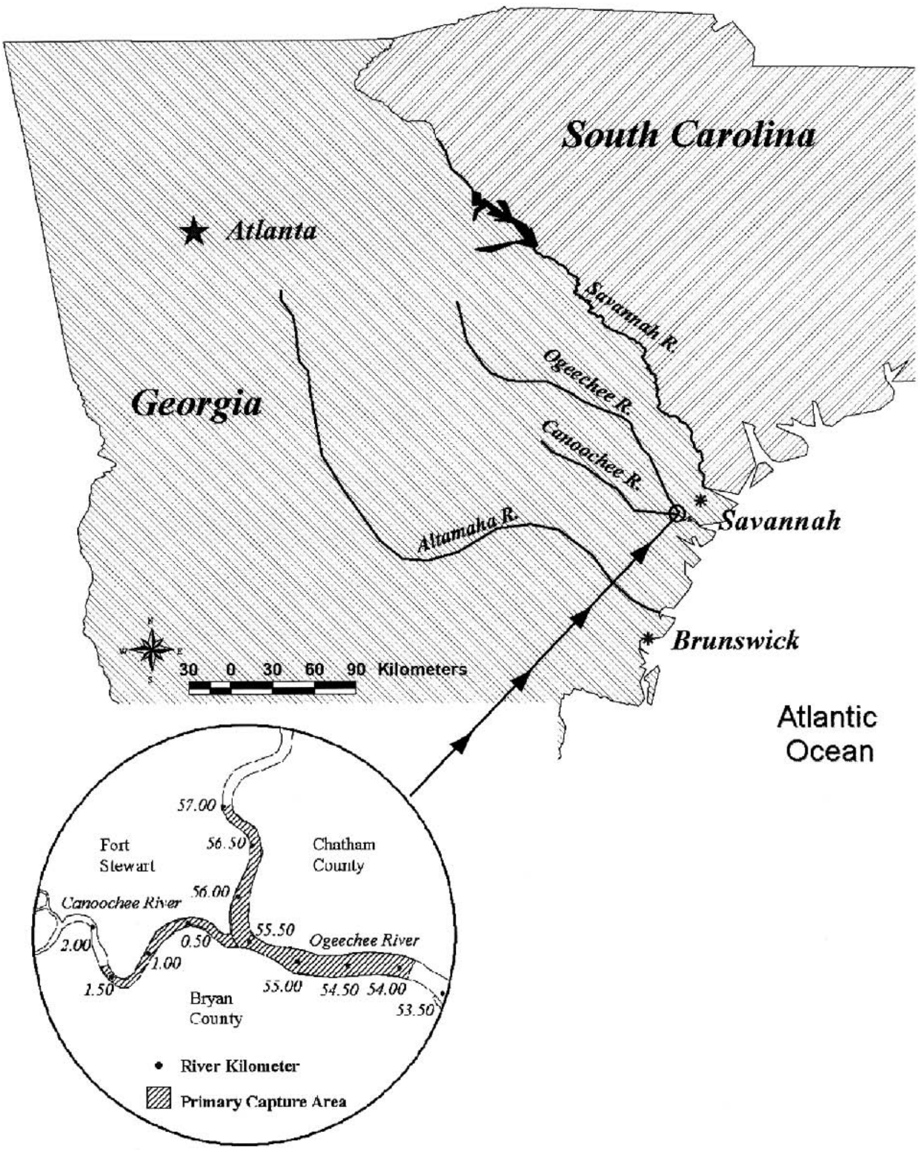

Figure 1. The Ogeechee River system, Georgia.

annual mortality through age 8 and then 51% afterwards. A period of 30 years (one generation) was selected for projecting population trends (National Marine Fisheries Service 1998).

Results

Collection

A total of 6,990 net-meter hours of netting and 1,056 person hours were expended in 1999 and 6,242 net-meter hours and 654 person hours were expended during 2000. During 1999, 21 shortnose sturgeon were captured: CPUE averaged 0.0030 fish per net-meter h, and a peak success of 0.0326 fish per net-meter h was measured during June. A total of 67 shortnose sturgeon were captured during 2000: CPUE was 0.0153 fish per net-meter h, and peak success was 0.0708 fish per net-meter h in late July.

Water quality variables associated with capture were within the range expected during warmer weather: water temperature averaged 27 C (95% CI = 25 to 28 C), dissolved oxygen averaged 5 ppm (95% CI = 4.5 to 5.6 ppm), and pH ranged from 6.47 to 7.19. During 2000, the mean salinity level 0.97 ppt (95% CI = 0.60 to 1.34 ppt) was higher than in 1999 when the mean was 0.27 ppt (95% CI = 0.11 to 0.32 ppt).

Tagging—Mark and Recapture

Cultured shortnose sturgeon (identified by numbered floy tags) contributed to the Ogeechee River population and allowed for age validation. A total of three fish in 1999 and five fish in 2000 were identified as cultured by the South Carolina Department of Natural Resources and released between 1990 through 1992, at age 1, into the Savannah River.

No shortnose sturgeon were recaptured during 1999. A total of 28 shortnose sturgeon were recaptured in 2000 and the population was estimated at 147 fish (95% CI = 104 to 249) that were vulnerable to the gear.

Tagging—Telemetry

Twenty-six shortnose sturgeon were tracked with either radio or sonic/radio equipment during the study. Retention of external tags was poor. Eight tags were known failures and of those whose retention could be measured, the mean retention time was 80 days (range 22 to 199 days). While some data were collected on local movements, no fish were tracked while making seasonal migrations or a spawning run.

Age Determination

The presence of known age fish aided in aging and readers were able to come to agreement on all spines examined for age. Ages for shortnose sturgeon ranged from 3 through 14 (Table 1).

Table 1. Size (mm), number of individuals *(N),* and age structure of all aged shortnose sturgeon in the lower Ogeechee River system from 1993 through 2000.

	1999 Shortnose Sturgeon			2000 Shortnose Sturgeon		
Age	*N*	Mean (mm)	Range	*N*	Mean (mm)	Range
1						
2						
3	1	545	—			
4	2	622	605–638	2	523	505–540
5				5	570	486–660
6	2	689	633–744	7	623	572–719
7	5	696	664–690	5	734	640–810
8	6	715	642–828	7	760	656–855
9	5	766	613–910	19	781	655–910
10				14	835	766–905
11				5	825	772–866
12				1	840	—
13				1	1040	—
14				1	985	—

Mean fork length (mm) of shortnose sturgeon captured from 1993 through 2000

Year	Mean (mm)	*N*
1993	670	37
1994	600	19
1995	608	7
1997	808[a]	4
1998	762	5
1999	697	19
2000	758	67

a. Significantly different.

Population Analysis

A von Bertalanffy growth equation was developed for shortnose sturgeon. The growth equation parameters were: L_∞ = 1,222 mm fork length, se = 402 mm; t_0 = –4.27, se = 2.82; and K = 0.075, se = 0.058 (Fig. 2). The weight to length relation was weight (g) = 0.000000754 fork length$^{3.38}$, r^2 = 0.81.

Shortnose sturgeon total annual mortality was estimated at 51% based upon a catch curve. Shortnose sturgeon were not fully recruited to the sampling gear until age 9 (Table 1). Therefore, the mortality estimate is for fish between ages of approximately 9 through 14. The mortality estimate that relied upon size and von Bertalanffy growth equation parameters (Beverton and Holt 1956) was approximately 12%. Mean fork length, estimated during this study was 741mm, and with the exception of 1997, was not statistically different from mean fork lengths measured during a previous study beginning in 1993 (Table 1).

An age structure model was used to simulate population trends (Beamesderfer

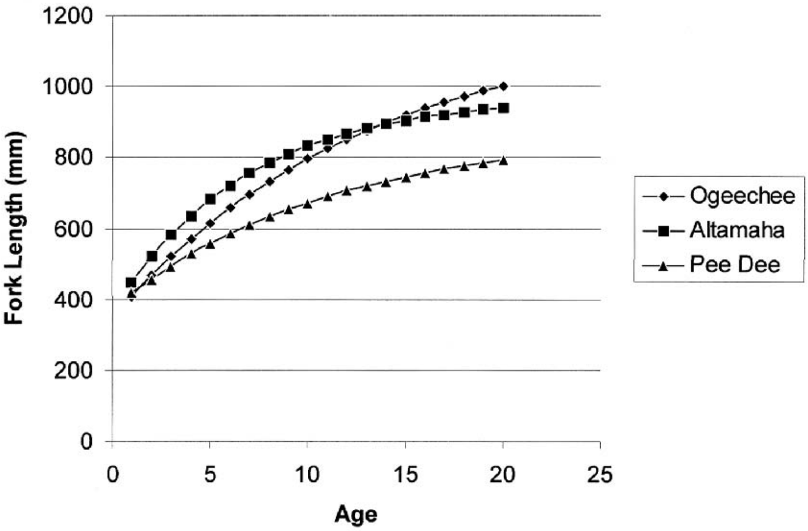

Figure 2. Growth in fork length of shortnose sturgeon (both sexes included) in the Ogeechee River (Georgia), Altamaha River (Georgia), and Pee Dee–Winyah River system (South Carolina). Growth is computed from growth equation parameters and projected over a 20-year period.

1991). Two rates of mortality, derived during this study, were used; in both cases, the population was sensitive to small changes in recruitment of age-1 fish. A minimum recruitment of approximately 30 age-1 shortnose sturgeon was the point where the population would remain stable. Annual recruitment of 40 age-1 fish would cause a slight increase in the population size, and recruitment of 60 age-1 fish per year would cause the population to approximately double over a 30-year period.

Discussion

Collection

Characterizing a depressed shortnose sturgeon population in a 425-km river was difficult, especially using 27.5-m gill nets. However, losing a 100-m trammel net in fast tidal currents and potentially killing sturgeon was a greater concern. Short gill nets were as effective (Table 1) as trammel nets used in an earlier study (Weber 1996). Thus, while labor intensive, the practice of using short nets and short soak times (less than an hour) should be continued in future studies.

Capture results for 1999 and 2000 differed greatly. Weather, water flow regimes, and other environmental factors were shown by Weber (1996) to influence sampling success. Peak CPUE, as well as the absolute number of shortnose sturgeon captured, varied between years. Drought conditions during 2000 caused an upstream movement of the freshwater/saltwater interface. Such conditions may have narrowed suitable habitat for shortnose sturgeon to a smaller section of river allowing a greater catch rate during the second year of the study.

Tagging—Mark and Recapture

The shortnose sturgeon population in the unimpounded and apparently pristine Ogeechee River remains one of the most depressed populations in the United States (National Marine Fisheries Service 1998). Because of variability, our population estimate (approximately 147 individuals) was not significantly different from that of approximately 266 individuals measured by Weber (1996). Several points are in order. First, in both studies, high variability insured that only large differences in population size could be detected. Hence, trends could not be detected. Therefore, sensitivity analysis should be utilized to determine appropriate levels of sampling (Morrow et al. 1999) to detect population trends. Also, the entire shortnose sturgeon population may not have been effectively sampled in this or previous studies. Shortnose sturgeon were not fully recruited to trammel nor experimental gill nets until about age 9 as the mean fork length, with the exception of 1997, has remained unchanged (Table 1). It is, therefore, likely that both gears produced comparable results. We speculate that some juvenile and younger adult fish may have avoided capture due to habitat differences between the juvenile and the adult segments of the population. These habitat differences are not apparent in most summering populations (Kynard 1997). Therefore, additional effort should be made to locate and sample the younger component of the population.

Tagging—Telemetry

Telemetry was unsuccessful due to poor retention of external tags. Spawning and other habitats remain unidentified. For recovery of the Ogeechee River population, it is critical that such habitats be located (B. Kynard, pers. commun.). With an average retention time of 80 days, external tagging is an unsatisfactory telemetry method. In the future, shortnose sturgeon could be netted during winter months, when internal tags may be used. However, only one ripe female has been tagged during the efforts of this and a previous study (Weber 1996) and this individual was almost immediately netted by a commercial fisherman. Capturing and tagging spawning adults (in a population of approximately 147 system-wide) will require luck and an intensive effort.

Age Determination

Despite validation of aging structures, determining the age of several individuals was difficult, and the readers frequently disagreed on the initial reading. Collins et al. (1996) demonstrated that removing sections of shortnose sturgeon pectoral fins was nondeleterious; however, minor risks could be associated with this procedure during certain conditions. Despite concerns and difficulties, aging studies are worth continuing and provide information that is essential for describing the population's growth, recruitment, and mortality. These parameters are critical to monitoring and restoration efforts (Collins et al. 1996).

Population Analysis

Fish (>97,000 shortnose sturgeon at age 6 to14 months) cultured and released by the South Carolina Department of Natural Resources from 1984 through 1992 (Smith et al. 1995, Smith and Collins 1996) may have contributed substantially to the Ogeechee River population. Of the six age-8 fish captured in 1999, three (50%) were cultured fish. In 2000, at least four of the 20 age-9 fish were cultured (20%) while one of the 5 age-11 fish was cultured (20%). The contribution to the total population could have been much higher as only about 19,000 of the cultured fish were tagged at the time of release. Smith and Collins (1996) noted that cultured shortnose sturgeon may migrate to other nearby rivers, and the dispersal of the cultured fish from the Savannah River could have significant implications on other systems. The addition of these fish could enhance depressed populations in nearby systems but may adversely affect genetic viability (Kynard 1997). The addition of these migratory fish may also be masking a decline in the Ogeechee population and influencing mortality estimates.

Mean length at age was used to compute a von Bertalanffy growth equation for shortnose sturgeon. The equation reflected high standard errors for the estimated parameters. Poor fit likely resulted from sexual dimorphism (Dadswell 1979) and from the few older fish used in calculations. The ability to determine sex using tissue, blood, or minimally invasive procedures should be a research priority, and when feasible, growth equations should be developed for each sex. Despite the limitations, growth equation parameters appear to be well within reported ranges (Dadswell et al. 1984, National Marine Fisheries Service 1998). In Fig. 2, growth is plotted for shortnose sturgeon (both sexes) in the Ogeechee and nearby Altamaha and Pee Dee-Winyah rivers based upon published growth equation parameters (Dadswell et al. 1984). While statistical comparisons cannot be made, a visual inspection of growth curves suggests comparable growth among these river systems. We thus conclude that growth is, within the size range captured, satisfactory in the Ogeechee River.

Depending upon the method, total annual mortality was estimated at 12% or 51%. The estimate of 51% annual mortality, derived from a catch curve, was based upon shortnose sturgeon from 9 through 14. This rate of mortality appears excessive for a protected population. Similarly, simulations did not support a constant rate of 51% total annual mortality. Total annual mortality of 51% may represent a senescing population, the addition of cultured fish causing annual mortality to be over estimated, or bycatch from a shad-netting fishery. Some loss to bycatch is possible as described by Weber (1996) when a tagged female was captured in a shad net. For that reason, this mortality rate was used in simulating population trends but only for fish age 9 or older. An estimate of 12% annual mortality developed from growth equation parameters and length at capture data seems much more reasonable for a federally protected population and agrees well with the estimates of natural mortality (about 8% to 15% annually) reported by Dadswell et al. (1984) and the National Marine Fisheries Service (1988).

Simulations and historical data strongly imply that recruitment is limited and insufficient. Simulations, using an age structure model and two rates of mortality, showed that this shortnose sturgeon population is sensitive to changes in recruitment and that the population could remain depressed due to insufficient recruitment. Recruitment would essentially need to double for the population to markedly increase over the next 30 years; and even then, the population would still be less than 1000 adults. Historical data also suggest insufficient recruitment because population size, despite protection, has remained relatively unchanged since 1993, mean length at capture has remained constant (Table 1), and the number of age 7- to 10-year-old fish infers steady but unsatisfactory recruitment.

Summary and Recommendations

This, and a previous study (Weber 1996) describe one of the most imperiled shortnose sturgeon populations that has been evaluated (Kynard 1997). This population, estimated at 147 to 266, has remained essentially unchanged since 1993. Because the population is so depressed, characterization of population dynamics and limiting factors will remain difficult. Growth and mortality were apparently satisfactory based upon values reported by Dadswell et al. (1984). Recruitment appears to be limiting and the population, even if not fully characterized, remains depressed below a critical level (<1000) deemed adequate to assure long-term survival (Thompson 1991).

The Ogeechee River population could rapidly become extinct if mortality increases or recruitment decreases. Therefore, population trends should be carefully monitored in the future. Any potential source of mortality, such as that from shad netting, should be evaluated by resource agencies. Telemetry should be much expanded to locate spawning habitats. However, improved methods of external attachment need to be developed or shortnose sturgeon should be internally tagged during winter months.

Factors limiting recruitment are worthy of separate studies. The authors have reservations about development activities in surrounding communities that would potentially degrade summering habitat by adversely affecting aquifers.

Cultured shortnose sturgeon entering the Ogeechee River raise interesting possibilities. These fish may have made a substantial contribution to the current population and may have influenced the genetics of the Ogeechee River population. Our modeling suggests a relatively small number of cultured fish could sustain the population at its current level. Should use of cultured fish for restoration become a viable recovery option, the protocols outlined in the Shortnose Sturgeon Recovery Plan (National Marine Fisheries Service 1998) should be followed.

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