Shortnose Sturgeon Stocking Success in the Savannah River

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Abstract: During 1984–1992, adult shortnose sturgeon (*Acipenser brevirostrum*) from the Savannah River were spawned and their offspring reared to various sizes prior to release in this river as part of a stock enhancement program. A total of 79,270 untagged and 18,213 tagged fish were released at various sites from river kilometer (rkm) 54 to 273. Mid and upriver stocking areas appeared to provide higher survival than downriver areas and stocking during November and December appeared more beneficial than during other months. However, regardless of stocking time or site, all stocked juveniles that were captured came from the same downriver nursery area (at the fresh-brackish water interface) used by wild fish. Stocked fish comprised at least 35.4% of juveniles captured and the low total number of juveniles captured suggests that the Savannah River population of shortnose sturgeon may be experiencing poor recruitment. Captures in other rivers indicate that shortnose sturgeon stocked at ≥1 year old exhibit less river fidelity than fish stocked at younger age and thus imprinting may be an issue to consider in future stocking programs. This study indicated that it is possible to enhance the abundance of the endangered shortnose sturgeon, but additional information is needed to conduct an efficient enhancement/restoration program.

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In 1967, the shortnose sturgeon was listed as a federally endangered species (Miller 1972). This species inhabits large coastal rivers from New Brunswick, Canada, to northern Florida (Vladykov and Greeley 1963). Although described as freshwater amphidromous (Kieffer and Kynard 1993), this small [≤1.4 m total length (TL)] sturgeon appears to utilize slightly more saline waters in the southern portion of its range (Collins et al. 1996). The shortnose sturgeon has apparently been extirpated from portions of its historic range (e.g., St. Johns River, Florida), probably due to overfishing and habitat alteration.

Interest in developing methodology for culture and stock enhancement of shortnose sturgeon has resulted in several studies in the Savannah River. Seasonally used habitats and probable spawning locations have been identified (Hall et al. 1991, Collins and Smith 1993), and the magnitude of shortnose sturgeon bycatch in the American shad (*Alosa sapidissima*) fishery has been determined (Collins et al. 1996). The effectiveness of several types of tags and marks have been compared (Smith et al. 1990, Collins et al. 1994), and spawning and culture techniques have been developed (Smith 1990; Smith et al. 1985, 1986, 1995).

In North America, sturgeon stocking programs have had limited success (Harkness and Dymond 1961, Smith 1990). In part, this is due to lack of information on critical stocking parameters (e.g., when, where, how, and at what age/size to stock). In South Carolina, site-specific information on the life history of shortnose sturgeon coupled with availability of cultured animals allowed development of a program to investigate suitable stocking protocols. Results should have application to the sympatric and commercially important Atlantic sturgeon (*A. oxyrinchus*). This species has elicited both historical (Ryder 1890, Dean 1894) and current (Atl. States Mar. Fish. Comm. 1992, 1996) interest in stock restoration.

During 1984–1992, there was a collaborative effort between the South Carolina Wildlife and Marine Resources Department and the U.S. Fish and Wildlife Service (USFWS) to examine the life history, ecology, culture, and potential for stock enhancement of shortnose sturgeon. This manuscript presents results of the stock enhancement research conducted in the Savannah River that was focused on examination of effects of various stocking parameters on capture of stocked shortnose sturgeon. Such information should be extremely useful to fishery managers considering stock restoration programs for shortnose and Atlantic sturgeons, as issues and considerations involved in such programs were identified. However, due to the nature of the project, strict experimental protocols could not be followed.

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Methods

Effects of time of year, age/size of fish, and site of stocking on the capture of stocked fish were examined. In addition, retention of different types of marks were studied. The Savannah River was selected as the test area due to availability of broodstock and ongoing complementary research programs. This river flows along the South Carolina-Georgia border into the Atlantic Ocean at Savannah, Georgia. The study was conducted in the 300 river km between the river mouth and the New Savannah Dam near Augusta, Georgia. This portion of the river is relatively undeveloped except for the heavily industrialized port and harbor area of Savannah.

During 1984–1992, 107 adult females were captured during the spawning season (January–April; Collins and Smith 1993) of which 38 were successfully spawned using hormone injection (Smith et al. 1985, 1995). Females had a mean TL of 80 cm (range 60–106) and a mean weight of 3.5 kg (range 1.1–10.0). Eggs from each female were fertilized with milt from 1–3 males. Males averaged 72 cm TL (range 53–100) and 2.1 kg (range 0.9–5.4). Small juveniles were produced using established techniques (Smith et al. 1986, 1995). Due to limited nursery facilities, 79,270 untagged small juveniles (age 2–10 weeks, mean 41 mm TL, range 17–70 mm) were stocked at upriver locations (≥rkm 190) during April–May 1984–1990.

A total of 18,213 sturgeon of various sizes were produced and tagged during 1986–1992 (Table 1) at 2 state and 3 federal hatcheries for use in the stocking effort. Culture facilities included concrete raceways and cylindrical fiberglass tanks of various sizes and earthen ponds. Culture water consisted of well water, dechlorinated tap water, and brackish water (mixture of ocean and dechlorinated tap water). Savannah River water was not used to culture juveniles. Stocked fish were marked with a variety of techniques (Table 1) based on limited mark retention data available at time of stocking and cost of tags (Smith et al. 1990). All tags were individually numbered (except binary-coded wire tags) so that specific data on stocked and captured fish could be examined. Barbels were differentially clipped in 1988–1989 to allow identification of groups of fish stocked (Bordner et al. 1990). However, this technique was discontinued when results of a 1990 pond study showed that barbels of 33% of the juvenile shortnose sturgeon would be fully regenerated and the remainder of the fish would have at least 50% regeneration after 734 days. In many cases, fish were marked with more than 1 type of tag before release. Fish were released at different times of the year and at 8 sites encompassing the lower (rkm 54–58), middle (rkm 103–166), and upper (rkm 190–273) river (Table 2). Although efforts were made to stock similar numbers of fish at each site during each stocking event, this was often not possible due to logistical constraints (e.g., number of fish available, boat landing flooding,

Table 1. Descriptive data for cultured shortnose sturgeon tagged and stocked in the Savannah River.

Year	Month	*N* fish	Length (TL mm) Mean	Range	Mean age (months)	Tag type[a]
1986	Jan, Oct	634	240	180–422	10	Carlin
1988	Oct, Nov	2,112	273	178–336	6	PIT, BC
1989	Jan, Oct	6,115	246	231–351	6	PIT, BC, BCW
1990	Apr–Jul, Oct, Dec	8,199	170	76–620	6	PIT, BCW, AA, TB
1991	Jan, Dec, Oct	492	472	284–762	14	PIT, BCW, AA, TB
1992	Apr	661	378	270–550	13	PIT, AA, TB
Total		18,213				

[a]Carlin = modified Carlin tag, attached at base of dorsal fin;

PIT = passive integrated transponder tag, inserted in abdominal cavity or dorsal fin musculature;

BC = barbel removed, at base;

BCW = binary-coded wire tag, inserted in snout;

AA = abdominal anchor tag (orange or yellow polyethylene with T anchor attached to 45-mm long monofilament), inserted in abdominal cavity;

TB = T-bar tag (orange or yellow polyethylene with T anchor attached to 45-mm long monofilament), inserted in dorsal musculature.

Table 2. Capture of stocked juvenile shortnose sturgeon, rkm 32–38, Savannah River, relative to various stocking parameters. Only fish with PIT, abdominal anchor and T-bar tags included.

Variable	*N* stocked	Captured *N*	Captured %
	Time of year		
Jan	425	2	0.5
Apr	1,082	8	0.7
Oct	1,257	5	0.4
Nov	373	7	1.9
Dec	629	7	1.3
	Stocking site[a]		
Upper	1,761	16	0.9
Middle	992	9	0.9
Lower	1,013	4	0.4
	Age at stocking (days)		
0–180	470	7	1.5
181–360	1,698	12	0.7
361–540	933	8	0.9
541–720	524	2	0.4
901–1,080	41	0	0.0
1,081–1,170	100	0	0.0
	Length at stocking (TL cm)[b]		
25.1–35.0	1,242	8	0.6
35.1–45.0	1,087	17	1.6
45.1–55.0	304	4	1.3
≥55.1	220	0	0.0

[a]Upper = rkm 190–273; middle = rkm 103–166; lower = rkm 54–58.
[b]Length distribution based on group means.

vehicle and personnel schedules). Further, marking techniques changed during the program and not every stocking event contained equal representation of all marking techniques.

Sampling was conducted for stocked fish with gill and trammel nets (total 129 net sets) from February 1990 through January 1993 from rkm 300 (New Savannah Dam) to the mouth of the river. Nets varied depending on specific location (e.g., bottom topography, river width). Gill nets were 33–99 m long and 1–4 m deep with 1.2- to 14.0-cm stretch mesh. Trammel nets were 33 m long and 3 m deep with a 9-cm stretch mesh inner wall and 30.4-cm stretch mesh outer walls. Sampling efforts were focused in the vicinity of the fresh-brackish water interface as this area had previously been identified as a nursery area in the Savannah River (Hall et al. 1991). Additional fishing effort was provided by 2 American shad fishermen fishing at rkm 42–75 and rkm 160–299 during January–April. All sturgeon captured were measured, and untagged fish were tagged prior to release at the capture site. Data for 2 fish captured within 20 days after release were not included in the results as it was felt that these fish had not had sufficient time to acclimate to river conditions. Recapture data from outside the sampling area, reported to the authors by others from 1994 through 1996, are included in results.

Unfortunately, a number of problems precluded statistical analyses of the data. First, no permanent mark had been identified and shedding rates for the various tags was based on short term studies (about 2–12 months). Longer term studies showed higher tag loss. Also, 10,367 fish were tagged only with binary-coded wire tags and none were later detected with field equipment. This suggests retention and or equipment problems. Second, numbers, age/size of fish, and time and site of stocking were often controlled by culture success and individual hatchery management rather than by experimental design. Third, the number of positively identified recaptured stocked fish was low, thereby precluding rigorous analyses. Fish marked with Carlin and binary-coded wire tags or by barbel clipping were excluded from the results unless specifically noted as there was no recovery of fish containing these marks.

Results

Juvenile shortnose sturgeon (both stocked and wild) were all taken from the vicinity of the fresh-brackish water interface at rkm 32-38. Thus, juveniles stocked at different sizes, at different sites, and at different times of year moved downriver and occurred together in the previously identified nursery area (Hall et al. 1991). Within this area, the most productive capture site was the King's Island Turning Basin at rkm 32, which yielded 69% of all juveniles caught. This part of the Port of Savannah has heavy ship traffic, is dredged relatively often, and the south bank is industrialized. Mean time at large for the captured juveniles was 452 ± 61.4 (SE) days (range 61-1,412 days). While in the river, most fish grew in length (Fig. 1). However, there was considerable variation in individual growth (Fig. 2).

Although capture data could not be statistically analyzed, the results are informative. Stockings during November (1.9% captured) and December (1.1%) yielded

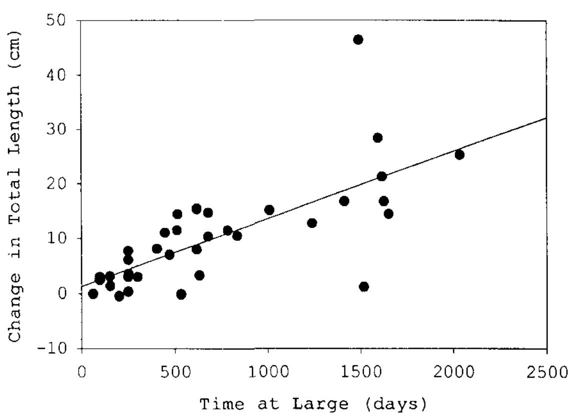

Figure 1. Change in total length of shortnose sturgeon stocked in the Savannah River and subsequently captured.

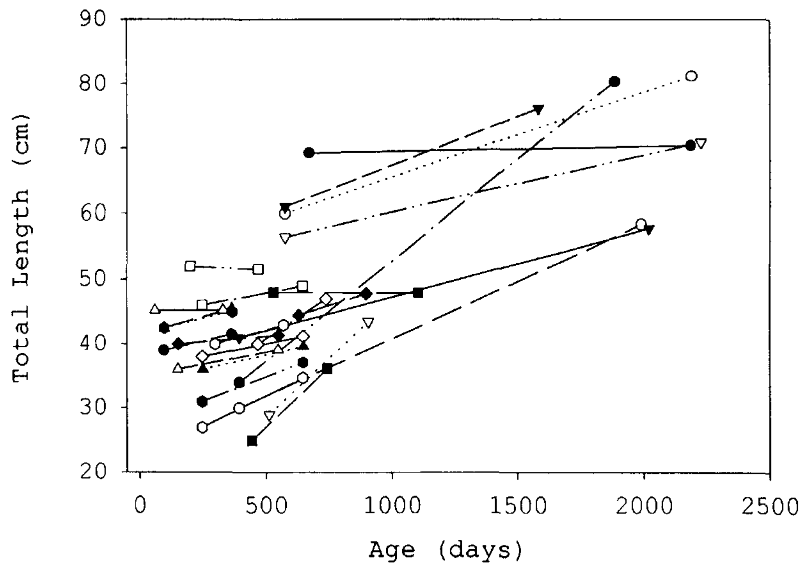

Figure 2. Growth of individual stocked shortnose sturgeon at large for ≥9 months, Savannah River.

higher returns than those during January (0.5%), April (0.7%), and October (0.4%). Also, there appeared to be some advantage to stocking in the middle and upper portions of the river rather than closer to the nursery area (Table 2). Of particular interest were 2 pairs of fish, each released at different upriver sites (rkm 227 and 273). The pairs of fish were later captured, still together, after 614 and 657 days.

Captured fish contained PIT, T-Bar, and abdominal anchor tags, but not Carlin or binary-coded wire tags (Table 3). Of the fish tagged with T-Bar tags, 1.2% were captured and these had been at large for a mean of 245 ± 52.4 days. The PIT tagged

Table 3. Effectiveness of 6 marking methods for juvenile shortnose sturgeon stocked at various locations in the Savannah River. Some fish had more than 1 mark. AA = abdominal anchor, BCW = binary-coded wire, CB = clipped barbel, PIT = passive integrated transponder, TB = T-Bar.

Mark	*N* stocked	Captured		Time at large (days)	
		N	%	Mean	Range
AA	1,698	8	0.5	506	153–1,412
BCW	10,367	0	0.0		
Carlin	634	0	0.0		
CB	2,381	0	0.0		
PIT	2,424	20	0.8	523	151–1,412
TB	952	11	1.2	245	61–629

fish were captured at a level of 0.8%, but mean time at large was double (523 ± 78.7 days) that of those with the T-Bar tags. Mean time at large for fish captured with abdominal anchor tags (0.5% return level) was 506 ± 147.7 days (Table 3).

There appeared to be a trend of decreasing returns with age at stocking, with the highest capture level occurring among fish stocked at 0–180 days of age (Table 2). However, returns did not apparently decrease with length at stocking, probably because size was not strictly related to age (Fig. 2).

During 1990–1993, of the juvenile shortnose sturgeon captured in the nursery area, 30.0, 46.2, 33.3, and 100.0%, respectively, were identified as stocked fish (Table 4). Lengths of the captured stocked and wild fish were similar.

A total of 9 shortnose sturgeon, identifiable as fish stocked in the Savannah River, were reported captured from rivers other than the Savannah (Table 5). One of these fish, captured in Winyah Bay, South Carolina, traveled at least 175 km along the coast. Eight of the fish were >1 year old when released, and the ninth was 210 days old. At capture, the fish were 4.5–7.0 years old, the age at which most fish become sexually mature. While at large, these fish all increased in length; however, the largest fish (69.3 cm TL at stocking) showed only a slight increase after approximately 4 years (Table 5). None of the approximately 700 wild adult shortnose sturgeon captured, tagged, and released in the Savannah River and none of the young fish stocked have been reported captured in other rivers.

Discussion

Results clearly indicate that stocked shortnose sturgeon can substantially increase the number of juveniles in a river system. In fact, during 1990–1993, 35.4% of

Table 4. Descriptive data for captured juvenile (≤56 cm TL) shortnose sturgeon, rkm 32–38, Savannah River, February 1990–January 1993.

Origin	*N* fish	%	TL (cm) ± SE
		1990	
Stocked	6	30.0	46.4 ± 1.71
Wild	14	70.0	41.6 ± 2.45
		1991	
Stocked	6	46.2	43.2 ± 2.89
Wild	7	53.8	46.8 ± 2.14
		1992	
Stocked	16	33.3	42.5 ± 1.34
Wild	32	66.7	43.5 ± 0.90
		1993	
Stocked	1	100.0	30.4
Wild	0	0.0	

Table 5. Movement and growth of cultured shortnose sturgeon stocked into the Savannah River and captured elsewhere, 1994–1996.

Length at stocking (cm TL)	Age at stocking (days)	Stocking site (rkm)	Time at large (days)	Capture location	Length at capture (cm TL)
56.5	575	54	1,651	Edisto River, S.C.	71.0
61.0	575	190	1,007	Charleston Harbor, S.C.	76.2
69.3	670	54	1,516	Winyah Bay, S.C.	70.5
60.0	575	190	1,615	S. Edisto River, S.C.	81.3
34.0	395	190	1,489	S. Edisto River, S.C.	80.4
31.5	210	190	2,034	S. Edisto River, S.C.	56.9
29.0	395	190	512	Ogeechee River, Ga.	43.5
30.0	395	190	1,594	S. Edisto River, S.C.	58.4
41.0	395	190	1,625	S. Edisto River, S.C.	57.8

the captured juveniles could be identified as stocked fish. Further, this study probably underestimated the contribution of stocked fish, as many were stocked untagged and others undoubtedly lost tags. The behavior and habitat utilization of stocked juveniles were indistinguishable from those of wild fish. Although substantial additional work is needed in this area, our results suggest stocking at mid and upriver locations during November–December provides the highest level of returns. Age at stocking appears to have considerable importance, as it affects stocking success and degree of straying. Size, if directly related to age, would probably have a similar impact on performance.

Use of lower river habitat by juveniles in this study is similar to that observed in the Altamaha River in Georgia (S.G. Rogers, Ga. Dep. Nat. Resour., pers. commun.). In the extreme southern portion of their range, juvenile shortnose sturgeon appear to be restricted, perhaps physiologically, to the vicinity of the fresh-brackish water interface. In addition, adult shortnose sturgeon use the same area during summer months (Collins and Smith 1993). Anthropogenic modifications to this habitat, such as dredging or diminished water quality, might easily result in serious negative impacts on an entire population. One hypothesis is that many southern populations of sturgeons are declining, or have been extirpated, due to low dissolved oxygen levels (compared to historic levels) during summer in the fresh-brackish water interface area (S.G. Rogers, pers. commun.). This appears to be the case in the Savannah River, as low oxygen levels have been noted in the lower river and our sampling over several years yielded only 82 juveniles. The primary nursery area, King's Island Turning Basin, is regularly dredged to accommodate shipping interests, and this may also impact the shortnose sturgeon population in the river.

Studies conducted in northern latitudes indicate that adult shortnose sturgeon exhibit high river fidelity (Dadswell et al., 1984). Similarly, over 700 adult wild shortnose sturgeon have been captured, tagged, and released in the Savannah River and none have yet been reported from other river systems. In contrast, returns of stocked older fish (>1 year old) were lower than those of smaller fish during the study period. However, during 1994–1996, a number of these older fish were captured in other river systems. Although these data are limited, they suggest that at some unknown age, shortnose sturgeon imprint on their natal river, and that at least some cultured fish did not imprint to the river after stocking. Future stock enhancement studies should examine this issue. Perhaps straying could be reduced by hatching and rearing fish for stocking purposes in water from the target river system or by stocking at younger ages.

Results of this study indicate high potential for restoration of this endangered species through stock enhancement. However, we have several recommendations for future efforts based on considerations which arose during this pilot stock enhancement study. Tags should identify individuals and have long-term retention, and retention rate and tagging mortality values should be determined before stocking, if possible. Stocking should be over several years, and a minimum number of broodstock/year should be determined to provide adequate genetic diversity (Atl. States Mar. Fish. Comm. 1996). Finally, it should be noted that one common definition of stock enhancement, and the one we believe applies in this case, requires that stocked fish reach adulthood and enter the spawning population. Our study was terminated prior to the time at which identifiable stocked fish could be expected to mature (age 5–7 years; Smith et al. 1995). Evaluating the success of a shortnose sturgeon stock enhancement effort will require long-term commitment.

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