Development of Nursery Systems for Shortnose Sturgeon, *Acipenser brevirostrum*[1]

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Abstract: Shortnose sturgeon, *Acipenser brevirostrum*, range from Canada to Florida and are listed as an endangered species in the United States. During 1985, a cooperative state/federal program focused on development of nursery systems for production of stockable size juveniles. Mortality was high (80%) during the first 2–3 months of tank rearing trials in spite of the use of various disease control agents and differing culture techniques. However, once a size of ~180 mm T.L. (30 g) was attained, mortality essentially ceased. Indoor intensive tank systems were more suitable than ponds for producing small juveniles. Growth and survival of advanced juveniles in indoor tanks was similar among initial population densities ranging from 5.4 to 118.4 fish/m^2 tank bottom area. A standing crop of 17.2 kg/m^3 was attained at the highest population density and overall feed conversion for all advanced juveniles was 1.4 using a soft-moist trout ration. Mean size of the 264-day-old fish was 332.8 T.L. 148.2 g. During the course of the study, 918 advanced juveniles were produced and 596 were released as part of a stock rehabilitation effort.

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Shortnose sturgeon are indigeneous to the Atlantic coast of North America and range from Canada to Florida (Scott and Crossman 1973). These relatively small sturgeon (maximum size ~135 cm T.L.; Gorham and McAllister 1974) were formally harvested throughout much of their range. However, exploitation typically occurred in conjunction with the much larger and more abundant Atlantic sturgeon, *A. oxyrhynchus,* and therefore no specific landings data are available for shortnose sturgeon. Today, the shortnose sturgeon is listed as an endangered species in the United States (Miller 1972) and considered rare or endangered in Canada (McAllister 1970).

In 1984, the U.S. Fish and Wildlife Service and the State of South Carolina initiated a cooperative program to develop culture techniques for the production of *A. brevirostrum* for stock enhancement purposes (Smith et al. 1985*a*). The propagation technology is not fully developed, but substantial progress was achieved during recent years. Initial spawning efforts in 1984 and 1985 demonstrated that ripe adults could be induced to spawn using injection of sturgeon or carp pituitaries (Smith et al. 1985*b*). Prior to 1984, only limited success had been achieved in developing nursery systems for shortnose sturgeon (Smith and Dingley 1984, Smith et al. 1985*b*). For example, the longest survival of an artificially produced larvae was 8 weeks and in this case, only 12 larvae were hatched of which 7 died during the first week of culture with only 1 surviving for 8 weeks (Buckley and Kynard 1981). The lack of success was not due to lack of effort. Sturgeon culture in North America was actively pursued to replenish wild stocks beginning around 1875 (Ryder 1890, Cobb 1900, Stone 1900) but success was limited and all efforts were abandoned by 1912 (Leach 1920, Harkness and Dymond 1961).

This paper reports the progress achieved in developing nursery systems for shortnose sturgeon during 1985. In particular, studies examined: 1) early growth and survival of larvae reared in indoor tank systems as well as that of 60-day-old juveniles stocked in an outside earthen pond; 2) the effect of tank stocking density on the production of advanced juveniles.

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Methods

Sturgeon used in the nursery trials were obtained from induced spawnings of wild adults caught incidentally by commercial shad fishermen (Smith et al. 1985*b*). Spawning activities were conducted at the Orangeburg National Fish Hatchery, U.S. Fish and Wildlife Service, and the fry were transferred to the South Carolina Wildlife and Marine Resources Department, Marine Resources Research Institute

(MRRI) in Charleston. The nursery development efforts were divided into 2 phases: Phase I—rearing of fry to a small juvenile size; and, Phase II—a replicated grow-out study examining the effect of population density on growth and survival of advanced juveniles.

Phase I—Early Rearing of Fry

Newly-hatched fry (age 7 days, 15.9 mm T.L., 0.018 g) and older (to 48 days old) were stocked in fiberglass culture tanks connected to a recirculated fresh water system at densities ranging from 95 to 926 fish/m^2 tank bottom area. Initially, two types and sizes of tanks were used; 1.8 × 0.5 m deep cylindrical shaped tanks and 5.9 × 1.8 × 0.3 m deep raceways. Water was injected into these tanks at a rate of 20 exchanges/day without causing any rotational water movement. Fish were fed a variety of foods including live *Artemia* nauplii, beef liver, clams, polychaete worms, a flake diet (Zeigler Brothers AP 100), and soft-moist manufactured rations (Bio Products Inc., Biodiet Starter crumble No. 2, 43% crude protein). The dry and soft-moist rations were fed at 5–15 minute intervals using automatic feeders while the natural and live products were provided several times a day to several times a week. Tanks were cleaned daily and salinity, pH, total ammonia, and dissolved oxygen were monitored weekly. Water temperature was recorded daily. During the initial 2 months, sampling of sturgeon was minimal to avoid handling stress which could elevate the already high mortality rates. In addition to the indoor tank culture approach, 3,388 60-day-old (size 46 mm T.L., 0.42 g) sturgeon were also stocked on 20 May 1985 at a density of 3.4 fish/m^2 in a 0.1-ha earthen pond at the Department's Waddell Mariculture Center, Bluffton, South Carolina. Food for these fish consisted of natural pond biota supplemented 1–2 times daily with No. 2 and No. 3 trout crumbles (38% protein). Temperature, salinity, pH, and dissolved oxygen were monitored weekly and water was exchanged as needed. For comparison to the pond trial, 2,570 sturgeon from the same hatch were also stocked in an indoor raceway tank (5.9 × 1.8 × 0.3 m deep) at MRRI at a density of 242 fish/m^2.

Phase II—Intensive Culture of Advanced Juveniles

Small shortnose sturgeon were stocked in indoor tanks to compare the effects of population density on the production of advanced juveniles. Fish were all from the same hatch (21 Mar 1985) and had an average length of 128.6 mm T.L. (range 55–198 mm) and average weight of 8.9 g (range 0.5 to 23.9 g). Five densities were compared in duplicate in 10 indoor 1.8 × 0.6 m deep cylindrical tanks: 5.4, 21.5, 53.8, 86.1, and 118.4 fish/m^2 tank bottom area. Water was recirculated through a common biological filter and culture tank water turnover rate was ~20 times/day. Replacement water exchange rate was minimal at initiation of the study, but by conclusion of the study (day 146), approximately 33% of the system water was being replaced daily.

A soft-moist ration (Bio-Diet Grower pellets, 43% protein) was automatically fed at 1-hour intervals at a rate of ~3% body weight/day. At initiation, a 1.5-mm pellet was used and this size was increased to 3.0 mm by completion of the study.

Tanks were inspected and cleaned daily and salinity, pH, total ammonia, and oxygen were monitored weekly. Water temperature was recorded daily. Fish were sampled at 4-week intervals except initially when the mortality rate was high.

Parametric statistical techniques were used to analyze the data. After testing for homogeneity of variances (Bartlett's Test) an analysis of variance (ANOVA) was conducted on the various data sets. If the ANOVA was significant ($P \leq 0.05$) then a Duncan's Multiple Range Test ($P \leq 0.05$) was used to detect differences. Survival data were transformed by arcsin before analyses were conducted.

Results

Phase I—Early Rearing of Fry

Water temperature, salinity, and total ammonia in the culture tanks appeared satisfactory throughout Phase I (Table 1). However, mortalities continually occurred in spite of treatments with various disease control agents added directly to the water or incorporated in the feed. Live and dead fish were examined by several disease specialists (including B. Rembiesa, Medical University of South Carolina; T. Schwedler, Clemson University; C. Carlson and K. McAllister, U.S. Fish and Wildlife Service) but no consistent diagnosis resulted although infections with *Aeromonas* sp., *Pseudomonas* sp., and *Flexibacter columnaris* were often noted. Occasionally, mortalities would decrease temporarily after a disease treatment but no treatment or procedure (including moving some fish to a flow-through well water source) provided any consistent results. Survival during the first 30 days averaged 50%, and during the next 30-day period survival was 38% (Fig. 1). During this time the sturgeon grew to a mean size of 50.4 mm T.L., 0.53 g. No differences in growth or survival rates were noted among the different tanks but the smaller, cylindrical tanks were much easier to manage.

The 60-day-old sturgeon, stocked in the 0.1-ha earthen pond, were reared for 195 days. The pond was drain-harvested but only 4.1% of the fish stocked were removed. Water temperature, pH, and salinity were slightly higher than that in the

Table 1. Mean water quality data (range) recorded during the shortnose sturgeon nursery studies.

Parameter	Phase I		Phase II
	Tanks	Pond	Tanks
Temperature (°C)[a]	23.6 (19.1–27.0)	26.8 (25.0–29.5)	23.6 (20.9–25.6)
Salinity (‰)[b]	0.3 (0.0–3.0)	3.6 (2.0–5.0)	0
pH[c]	7.6 (7.2–8.1)	8.2 (7.6–8.7)	7.3 (7.0–8.0)
Total ammonia (mg/l)[d]	≤1.0 (≤1.0)	—	≤1.0 (≤1.0)
Dissolved oxygen (mg/l)[e]	—	6.5 (2.5–11.0)	7.3 (6.3–8.0)[f]

[a]Measured with a glass mercury thermometer.
[b]Measured with an American Optical Company Refractometer.
[c]Measured with a Lamotte Chemical Company test kit, Model P-5085 Code 2119.
[d]Measured with a Lamotte Chemical Company test kit, Model PAN, Code 21795.
[e]Measured with a Yellow Springs Instrument Company oxygen meter, Model 57.
[f]Data available for days 77 to 133 only.

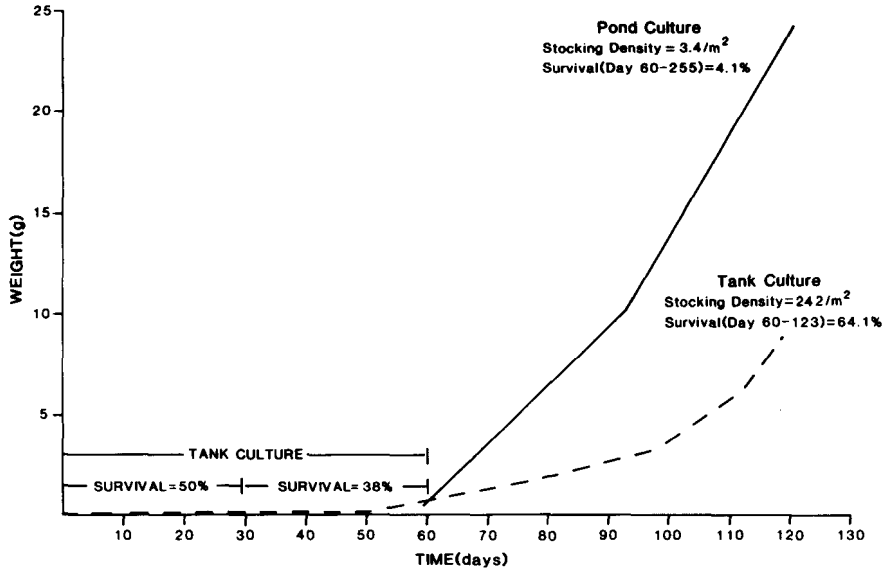

Figure 1. Early growth and survival of shortnose sturgeon reared under indoor tank and outdoor pond conditions.

tanks (Table 1) but diurnal fluctuations in water quality were more rapid in the pond. The 60-day-old fish stocked in the indoor tank for comparative purposes were harvested after 63 days and survival was 64.1%. Growth of the pond-reared sturgeon was more rapid than that recorded for the tank-reared sturgeon. After 60 days, these fish averaged 24 g as compared to 9 g for the tank-reared fish (Fig. 1). Population density, water temperature, and diet considerations probably account for most of the difference in growth rates.

Phase II—Intensive Culture of Advanced Juveniles

No substantial differences in water temperature, salinity, pH, and total ammonia were noted among the 10 culture tanks used during Phase II and in general these data are similar to that recorded during the Phase I study (Table 1). However, as biomass increased there was an inverse relationship between stocking density (i.e. standing crop) and oxygen levels (Table 2). This occurred in spite of the injection of inflow water through perforated PVC pipe to increase the aeration and to cause a rotational spin to the water and a flow rate of 21.8 liters/minute/tank.

Mortality during the first 28 days for all 5 densities averaged 25.0% and ranged from 12.5% to 32.9% but decreased substantially during the remainder of the study (Fig. 2). Final survival averaged 64.6% and ranged from 56.4% at stocking density 86.1/m² to 73.4% at stocking density 53.8/m². Statistical analysis indicated that survival at density 53.8/m² was significantly higher than that at 86.1/m² but all other treatment comparisons were similar (Fig. 2). There was a statistical difference

Table 2. Effect of population density of shortnose sturgeon on dissolved oxygen levels during day 76 to 126 of Phase II nursery study.

Stocking density (N/m^2)	Estimated standing[a] crop (kg/m^3)	Dissolved oxygen level (mg/l)	
		Mean	Range
5.4	0.6	7.4	7.0–7.7
21.5	3.2	7.0	6.8–7.2
53.8	7.2	6.7	6.1–7.1
86.1	10.9	6.1	5.5–6.8
118.4	14.4	5.4	4.9–6.2

[a]Estimated standing crop on day 126.

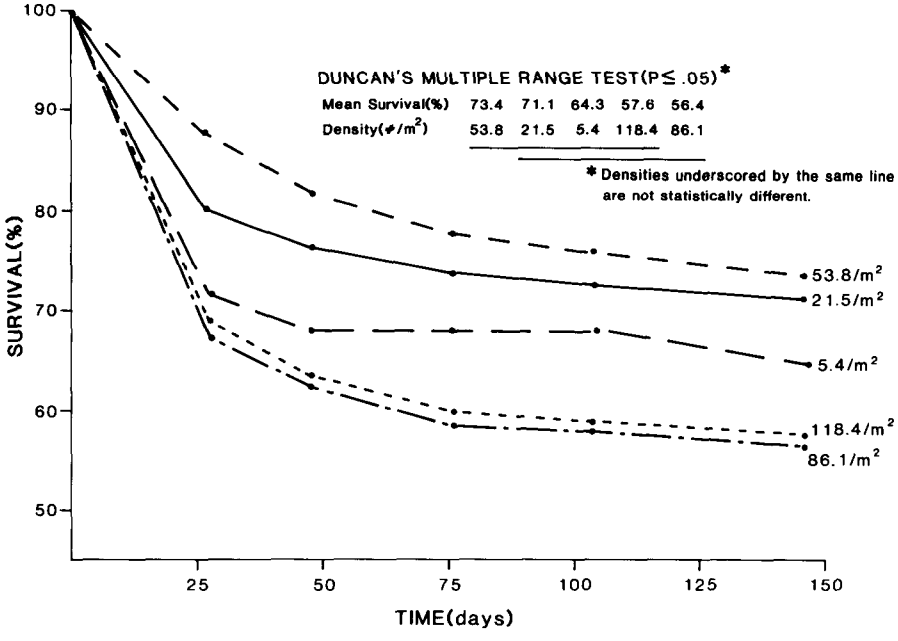

Figure 2. Survival of shortnose sturgeon reared in indoor tanks at different densities.

in growth of sturgeon between density 86.1/m² and density 5.4/m² (Fig. 3). Harvest size at completion of the study averaged 148.2 g and ranged from 131.8 to 170.3 g among the various density treatments (Table 3). The range in fish sizes within a treatment was substantial. For example, at stocking density 86.1/m², individual fish size ranged from 7.1 g to 324.9 g at harvest.

At the conclusion of the study, standing crop and feed conversion data were obtained (Table 3). Standing crops ranged from 0.8 kg/m³ at the lowest stocking density (5.4/m²) to 17.2 kg/m³ at the highest stocking density (118.4/m²). Feed conversions were similar among the four highest stocking densities and ranged from 1.2 to 1.5 (mean 1.3). Poorest feed conversion (1.9) occurred at the lowest stocking

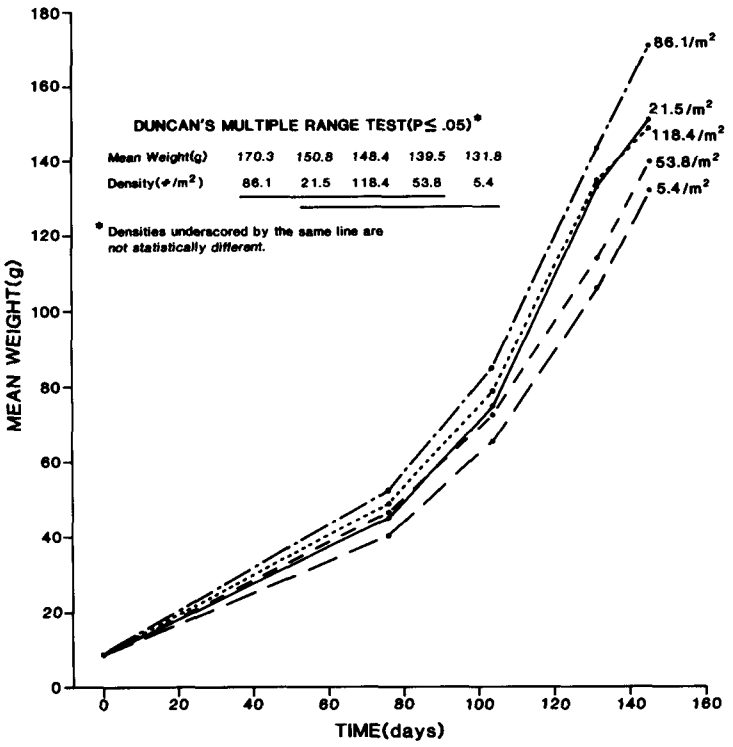

Figure 3. Growth of shortnose sturgeon reared in indoor tanks at different densities.

Table 3. Stocking and harvest data for Phase II study comparing effects of population density on production of shortnose sturgeon.

Stocking				Harvest				
Density	Fish size		Duration	Survival	Fish size		Standing	Feed
(N/m^2)	Wt. (g)	T.L. (mm)	(days)	(%)	Wt. (g)	T.L. (mm)	crop (kg/m^3)	conversion
5.4	8.9	128.6	146	64.2	131.7	318.8	0.8	1.85
21.5	8.9	128.6	146	71.1	150.8	336.7	4.0	1.30
53.8	8.9	128.6	146	73.4	139.4	331.2	9.4	1.20
86.1	8.9	128.6	146	56.4	170.3	344.4	14.2	1.25
118.4	8.9	128.6	146	57.5	148.4	332.7	17.2	1.45

density (Table 3). Fish reared at the lowest density were often unaware that feed was in the tank and this factor probably accounts for the slower growth and poorer feed utilization recorded at this density. In contrast, at the higher stocking densities some fish would always be near the food when it reached the tank bottom and would display a feeding response which was observed by the other fish. In this manner, most food was consumed at the higher densities and little food was broken down and wasted and/or washed out through the drain.

Discussion

Substantial progress was achieved in identifying suitable nursery conditions for culturing shortnose sturgeon. Indoor intensive tank systems were more suitable for producing small juveniles than was a 0.1-ha pond. A similar conclusion was reported previously for shortnose sturgeon (Smith et al. 1985*b*) and for young Atlantic sturgeon (Smith et al. 1981). Apparently, sturgeon are sensitive to widely fluctuating conditions typical of ponds in the southeastern United States during summer. In particular, dissolved oxygen, pH, carbon dioxide, and water temperature can change drastically over a short period depending on natural ambient conditions and phytoplankton densities. As reported by other investigators (Buckley and Kynard 1981. Anon. 1981. Smith et al. 1985*b*) mortalities of fry and small juveniles are substantial. Such losses are probably related to handling stress, disease and nutritional problems including the inability of some fish to accept natural and formulated rations. Nevertheless, more Phase I fish were produced during these culture trials than previously.

Our studies showed that shortnose sturgeon can be reared to advanced juvenile size at relatively high populations densities. Growth and survival rates were generally similar in spite of the almost 22-fold difference in stocking densities. Most mortality occurred during the first several weeks after stocking and once the fish attained a size of about ~180 mm T.L., (30 g) mortality was rarely observed. At this size, the sturgeon were more tolerant of handling and culture stress and little affected by diseases.

Final standing crops and feed conversions were attractive from a culture standpoint. Standing crops of 14.2, and 17.2 kg/m^3 were recorded at the 2 highest stocking densities, 86.1, 118.4/m^2, respectively, at conclusion of the study. These levels are quite high especially for "wild fish" being reared in small culture tanks. Feed utilization was also high and overall feed conversion for all densities averaged 1.4 (range 1.2–1.9) using a pelleted trout ration.

In summary, our research demonstrated functional culture techniques for producing a large number of advanced juvenile shortnose sturgeon. However, additional work is needed to further refine the nursery parameters and to identify and alleviate the cause(s) of mortality which occur during the early life stages. As a result of this research, a total of 918 advanced juveniles were produced of which 596 were stocked into native waters for stock restoration and enhancement purposes.

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