Fingerling Densities Produced by a Spawning Population of Striped Bass in the Santee-Cooper Reservoir, South Carolina

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Abstract: Densities of fingerling striped bass (*Morone saxatilis*) resulting from natural reproduction in the Santee-Cooper Reservoir were estimated. Estimates during July and August of 3 years were 3.9, 4.0, and 7.8 fingerlings per hectare, which are much lower than typical reservoir stocking rates. Estimates were derived using a combination of the Petersen method and relative abundance.

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Shortly after the Santee-Cooper Reservoir was impounded in 1941, it became apparent that striped bass (*Morone saxatilis*) that had been trapped within the system were reproducing (Scruggs 1955, Scruggs and Fuller 1955). This resulted in an expanding landlocked population of striped bass that produced excellent catches in the 1950s and early 1960s (Scruggs 1955). However, since the mid 1960s, the number and average size of catchable sized fish have declined. This decline has been attributed, in part, to fishing pressure which increased from 9.2 man-hours/ha in 1972 (White 1974) to 27.8 in 1982 (Bulak et al. 1983). Perhaps more significant is a decline in reproductive success within the system. A juvenile index, obtained by beach seining in late summer since 1965, has declined from an average of 14 juveniles per seine haul for 1965–1970 to <1 in the years since 1977 (White 1987). To offset lower reproductive success and prevent further declines of adult stocks, stocking with hatchery produced fingerlings was considered as a possible management strategy.

Experience gained during recent years of stocking other southern reservoirs with striped bass juveniles has provided a knowledge of appropriate stocking rates in systems where no reproduction occurs and a standard against which the natural production within the Santee-Cooper system could be compared. The objective of this study was to determine the densities of naturally produced striped bass fingerlings in the Santee-Cooper Reservoir. This information would be used to decide if supplemental stocking of hatchery produced striped bass was warranted and what stocking rates might be appropriate.

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Methods

The Santee-Cooper Reservoir is located in central South Carolina and consists of Lake Marion (39,366 ha) and Lake Moultrie (22,418 ha) connected by a 12-km canal. The system was formed in 1941 for hydrogeneration of electricity and flood control. The primary tributaries, Congaree and Wateree rivers, provide spawning habitat for striped bass (May and Fuller 1965).

The population of young-of-the-year striped bass occurring within the system in late summer of 1980, 1981, and 1982 was estimated using a combination of the Petersen method (Ricker 1958) and relative abundance.

The marked population consisted of hatchery produced fish ranging in total length from 40 to 100 mm. These fish were produced at the Moncks Corner Striped Bass Hatchery and reared at the Dennis Wildlife Research Center in Bonneau, South Carolina. Marking was accomplished by clipping the anal fin at its emergence from the body. Marked fish were prophylactically treated with potassium permanganate, furacin, and salt. These fish were released in upper Lake Marion the day after being marked. In 1980 the release area was zones 6 and 7 (2,683 ha) and in 1981 and 1982 was zone 6 (1,562 ha, Fig. 1). Striped bass juveniles are known to occur in this portion of the lake during late summer.

Handling mortality was estimated for each batch of marked fish by retaining a sample of 100 fish at the time of stocking. These fish were held in a 466-liter trough for 3 days. It was assumed that the same mortality rate was experienced by the sample group and the stocked fish from that batch. The number of marked fish resulting from each stocking was adjusted, using the mortality rate that had been determined for that batch.

Recapture efforts began about 2 weeks after marked fish were released, allowing these fish time to disperse. The recapture period was 2 July to 13 August 1980, 6 July to 26 August 1981, and 1 July to 31 August 1982. Recapture was accomplished by seining during a 2-hour period around sunrise or sunset along sandy beaches. Seines were 15.2 m long and 1.5 m deep with 6.3 mm mesh. On each morning or afternoon sampling trip, seining was conducted in 1 of 9 zones (Fig. 1). The number of seine hauls per trip varied from 5 to 15, depending on the amount of suitable beach in that zone. Each seine haul consisted of a ¼ circle sweep of the seine; beginning with the pivot end at the water's edge and the seine perpendicular to the shore, the deep end of the seine was pulled to shore. These procedures were used consistently throughout the study so that a seine haul could be treated as a uniform unit of sampling effort. The catch of juveniles per seine haul was deter-

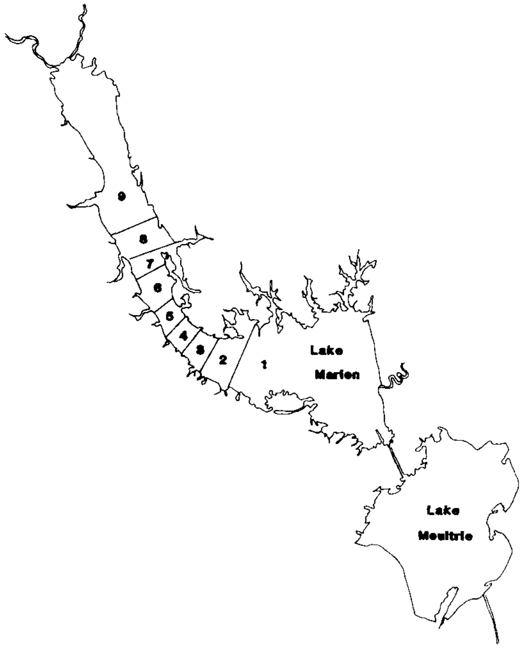

Figure 1. Fingerling striped bass sampling zones within Lake Marion, Santee-Cooper Reservoir.

mined for each zone, and those catch rates were assumed to represent the relative abundance between zones.

Criteria for recognizing marked recaptures were incomplete regeneration or deformity of the anal fin. Mark retention was tested and determined to be adequate for this study. In a randomized, blind test, using fish held in ponds for 2 months, marked fish and unmarked controls were distinguished with 97% accuracy ($N = 100$).

In 1980, all recaptures came from within the portion of Lake Marion where marked fish had been released (zones 6, 7) and it was assumed that no movement out of the release area occurred (Table 1). An estimate of the total population of juveniles, including marked fish, within the release area (N_r) was obtained using $N_r = n_r T_r / m_r$ where:

T_r = number marked fish in population
n_r = number of fish in sample
m_r = number marked fish in sample.

Confidence intervals associated with Petersen estimates were derived as described by Seber (1982). N was then obtained for each of the other zones based on the relative abundance in that zone compared to the release area. The formula used to calculate relative abundance was $N_x = N_r (C_x / C_r)$, where C = catch per seine haul for that zone.

Table 1. Summary of sampling results and population estimates of striped bass fingerlings for the Santee-Cooper Reservoir, 1980.

Zone[a]	Catch Total	Catch Marked	Effort (seine hauls)	CPUE[b]	Population estimate
1	0	0	46	0	0
2	2	0	13	0.1538	9,936
3	5	0	10	0.5000	32,302
4	1	0	18	0.0556	3,592
5	19	0	49	0.3838	25,054
6,7	260	111	122	2.1311	137,683
8	6	0	15	0.4000	25,842
9	2	0	25	0.1333	8,612
Total					243,023

[a]Fish released in zones 6 and 7 (see Fig. 1).
[b]Catch per unit effort (CPUE) is expressed in numbers of fish captured per seine haul.

In 1981 and 1982, movement of marked fish out of the release area (zone 6) occurred evidenced by recaptures from other zones. During those years it was necessary to determine the number of marked fish remaining in the release area before calculating Petersen estimates. In 1981, 16 recaptures came from the release area and a total of 7 from zones 1, 3, and 5 (Table 2). Because of unequal effort between zones, the number of recaptures from zones 1, 3, and 5 were adjusted to obtain recaptures per 84 seine hauls, the amount of effort expended in the release area. The adjusted total number of recaptures from outside the release area was 8.15. The portion of the original marked populations (31,220) which had emigrated from the release areas was calculated as 31,220 x (8.15/24.15). Thus, the number of marked

Table 2. Summary of sampling results and population estimates of striped bass fingerlings for the Santee-Cooper Reservoir, 1981.

Zone[a]	Catch Total	Catch Marked	Effort (seine hauls)	Adjusted[b] marked	CPUE[c]	Population estimate
1	2	1	62	1.35	0.0323	3,507
2	21	0	58	0	0.3621	39,320
3	14	2	60	2.8	0.2333	25,334
4	4	0	53	0	0.0755	8,198
5	18	4	84	4	0.2143	23,271
6	60	16	84	16	0.7143	77,565
7	33	0	70	0	0.4714	51,189
8	2	0	41	0	0.1707	18,536
9	–	–	0	–		
Total						246,920

[a]Fish released in zone 6 (see Fig. 1).
[b]Adjusted to an equivalent effort of 84 seine hauls.
[c]Catch per unit effort (CPUE) is expressed as number of fish captured per seine haul.

fish remaining in the release area was 20,684. Using this value for T_r, estimates for the release area and whole lake estimates were derived as in 1980. In 1982, the procedures were the same as described for 1981 (Table 3).

During the 3 years of the study the total number of juveniles collected from Lake Moultrie was only 2. As this sample was too small to permit meaningful estimates, the population of Lake Moultrie was assumed to be 0.

Results and Discussion

The total marked population, after subtracting handling mortality, was 58,780 in 1980, 31,220 in 1981, and 41,623 in 1982 (Table 4). Post stocking handling mortality for individual stockings ranged from 1.5% to 22.4%, with a mean of 11.6%. In 1980 the Petersen estimate of the number of fingerlings in the release area was 137,683 (95% C.I. = 137,683 ± 19,064) and the estimate for all zones combined was 243,023. For 1981 the estimate for the release area was 77,565 (95% C.I. = 77,565 ± 29,109) and for all zones was 246,920. In 1982 the estimate for the release area was 256,019 (95% C.I. = 256,019 ± 162,509) and for all zones was 483,951. The validity of a Petersen estimate rests on the following assumptions (Everhart and Youngs 1981):

1. That marked fish, during the period between release and recapture, suffer no different mortality rate nor emigrate further than unmarked fish;
2. that no marks are lost, nor are any recaptured marked fish overlooked;
3. that marked fish are caught at the same rate as unmarked;
4. that marked fish are randomly distributed, or if not, the recaptures are; and
5. that there will have been no additions to the population.

It is possible that the assumption of equal mortality was not satisfied in this study. Estimates of handling related mortality were based on small numbers of fish

Table 3. Summary of sampling results and population estimates of striped bass fingerlings for the Santee-Cooper Reservoir, 1982.

Zone[a]	Catch Total	Catch Marked	Effort (seine hauls)	Adjusted[b] marked	CPUE[c]	Population estimate
1	1	0	50	0	.0200	16,188
2	2	1	48	0.04	.0417	33,753
3	3	0	56	0	.0536	43,385
4	0	0	41	0	0	0
5	3	0	57	0	.0526	42,575
6	31	3	98	3	.3163	256,019
7	7	0	85	0	.0824	66,696
8	1	0	32	0	.0313	25,335
9	0	0	10	0	0	0
Total						483,951

[a]Fish released in zone 6 (see Fig. 1).
[b]Adjusted to an equivalent effort of 98 seine hauls.
[c]Catch per unit effort (CPUE) is expressed as number of fish captured per seine haul.

Table 4. Estimates of the number of striped bass juveniles in the release area and the entire Santee-Cooper Reservoir, 1980–1982. Marked population (*T*), number of fish examined and marked (*n*), number of recaptures (*m*), Petersen estimate of population in the release area (*N*) and 95% confidence interval (CI), population estimate of entire lake (*L*).

Year	*T*[a]	*n*	*m*	*N*	CI	*L*
1980	58,780	260	111	137,683	± 19,064	243,023
1981	20,684	60	16	77,565	± 29,109	246,920
1982	24,776	31	3	256,019	± 162,509	483,951

[a]Adjusted for post stocking mortality and movement out of release area.

held in troughs for 3 days after stocking. A more hostile lake environment may have produced greater than predicted mortality among stocked fish or handling mortality may have continued for more than 3 days. Either of these situations would have resulted in a Petersen estimate greater than the actual population. Another possible source of error is related to either addition or subtraction of wild fish to the population or emigration of marked fish at a different rate than estimated. Because calculations of emigration were based on very small numbers of fish, the possibility for substantial error exists. If emigration occurred at a higher rate than estimated, which is especially likely in 1980 when no emigration was assumed, the resulting Petersen estimate would be greater than the population. A final problem is in the method used to estimate fingerling densities in zones other than the release zone, which assumes that the catch rate per seine haul over sand substrates was proportional to the fingerling density throughout the zone. The assumption was not tested; however, based on many years of sampling in this reservoir, it is believed that beach seining results accurately reflect the general distribution of juveniles and that this assumption is reasonable.

The entire lake estimates convert to fingerling densities of 3.9, 4.0, and 7.8 per ha for the 3 years. In 61 other reservoirs where striped bass fisheries have been successfully established, the yearly stocking rates used were 3.2–336 fingerlings per ha, with a mean of 32.6 (AFS Striped Bass Comm., unpubl. 1982 survey). Stocking histories in those 61 reservoirs reveal little about the optimum fingerling density in Santee-Cooper. Vast differences exist between reservoirs and it can reasonably be assumed that a wide range of optimum stocking rates also exists. There was no evidence that the stocking rates used in the 61 reservoirs were ideal, only that they produced the desired results, based on the goals of the respective agencies. Furthermore, the relative value of wild versus hatchery striped bass, in terms of their likelihood to recruit, is not known. However, several factors indicate that stocking is an appropriate management strategy in Santee-Cooper. Fingerling densities estimated during this study were approximately equal to the lowest stocking rates ever used where a reservoir striped bass fishery was established in the United States (AFS Striped Bass Comm., unpubl. 1982 survey). In Santee-Cooper, concurrent declines in reproductive success and fishable stocks suggested that reproduction may have become limiting. Based on this information, stocking of hatchery produced fingerlings was begun in 1984 at a rate of 13 per ha.

Literature Cited

Bulak, J. S., J. S. Crane, and D. W. Gates. 1983. Creel survey —Congaree and Wateree Rivers and Lakes Marion and Moultrie. S.C. Wildl. and Mar. Resour. Dep., Compl. Rep. WC-2, Columbia. 63pp.

Everhart, W. H. and W. D. Youngs. 1981. Principles of fishery science. Cornell Univ. Press, London. 349pp.

May, O. D., Jr. and J. C. Fuller, Jr. 1965. A study on striped bass egg production in Congaree and Wateree Rivers. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 16:285–301.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Board Can. Bul. 119. 300pp.

Scruggs, G. D., Jr. 1955. Reproduction of resident striped bass in Santee-Cooper Reservoir, South Carolina. Trans. Am. Fish. Soc. 85:144–159.

———and J.C. Fuller, Jr. 1955. Indications of a fresh-water population of striped bass *Roccus saxatilis* (Walbaum) in Santee-Cooper Reservoir. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 9:64–69.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Macmillan Publ. Co., Inc., New York. 506pp.

White, M. G. 1974. Fisheries studies in district five. S.C. Wildlf. and Mar. Resour. Dep., Prog. Rep., Fed Aid. Proj. F-16–4, Columbia. 19pp.

———. 1987. Fisheries studies in district five. S.C. Wildl. and Marine Resour. Dep., Prog. Rep., Fed. Aid Proj. F-16–17, Columbia. 52pp.