Effect of Stocking Density on Production of Advanced Juvenile Hybrid Striped Bass[1]

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Two nursery trials were conducted in 0.1-ha ponds to examine effects of density on production of juvenile reciprocal cross hybrid striped bass (female *Morone chrysops* x male *M. saxatilis*). In 1986, 1.4-g hybrids were stocked at 5,000, 10,000 and 20,000 fish/ha. In 1987, 1.7-g hybrids were stocked at 12,500, 25,000, and 37,500 fish/ha. During the studies, the fish were fed a commercial trout feed (38% protein) several times per day. Aeration and water exchange were provided to maintain satisfactory oxygen levels. After approximately 280 days, fish were harvested. At harvest fish ranged from 165–195 g in mean size, except those stocked at 5,000/ha which were significantly smaller (mean size 116 g). Mean survival was similar in all treatments and ranged from 82%-99% (mean 90.4%). Harvest biomass was related to stocking density with the highest density yielding a significantly greater harvest biomass (5,984 kg/ha). Feed conversion averaged 2.8 in 1987 and were significantly better than those recorded in 1986 (4.0).

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Interest in commercial culture of striped bass (*Morone saxatilis*) and its white bass (*M. chrysops*) hybrids has led to development and testing of a 4-step production model which includes: 1) hatchery phase, for production of larvae; 2) Phase I nursery stage, for rearing newly hatched fry to small fingerling size (1–2 g) over a 30–60 day period; 3) Phase II nursery stage, (6–10 months) for production of large juveniles (150–250 g); and 4) a Phase III growout period, (8–10 months) when market size (0.7–1.5 kg) fish are produced (Smith and Jenkins 1985, Smith et al. 1989). The first 2 steps of the model are well documented and used by state and federal recreational stocking programs for production of striped bass and hybrid striped bass fingerlings (Bonn et al. 1976, Rees and Cook 1983, Parker and Geiger 1984). In recent years, government hatchery programs have also begun to emphasize the third component (Phase II) of the model in order to enhance the survival of hatchery produced striped bass after release. These programs routinely stock Phase II ponds at a density of 62,500 fish/ha and after 5–6 months, the striped bass grow to an average size of 45 g and survival rate averages 50%-60% (Parker and Geiger 1984; Astupenas and Wright, unpub. rep., U.S. Dep. Int., Fish and Wildl. Serv., 1987). Unfortunately, Phase II hybrids are not typically produced in government hatcheries and thus the production data are limited.

Studies in Florida and North Carolina provide some information on the Phase II production characteristics of hybrid striped bass. Reciprocal cross hybrid striped bass (white bass female x striped bass male) fingerlings, stocked at densities of 37,500/ha and 63,750/ha grew to a size of 152–165 g in 6 months in Florida; however, survival averaged 16% (C. Starling, pers. commun., Fla. Game and Freshwater Fish Comm.). In North Carolina, original cross hybrid striped bass stocked at a density of 16,500/ha and reared for 9 months attained a mean size of 170 g and a survival rate of 85% (Kerby et al. 1987). Both of these studies yielded fish that were substantially larger than those routinely produced by government operated striped bass production facilities.

Research in South Carolina is examining the effect of stocking density on growth, survival, feed conversion, and production levels for all phases of hybrid striped bass culture. This manuscript reports the results obtained during 1986–1988 for 2 Phase II production trials involving 6 densities.

Methods

Two (Phase II) nursery trials examining effects of stocking density were conducted in 0.1-ha ponds at South Carolina Wildlife and Marine Resources Department's Waddell Mariculture Center during 1986–1988. Ponds at the facility are lined with 0.8 mm thick, high density black polyethylene and bottoms are covered with 26 cm of sand. Pond depth ranges from 1.8 to 1.2 m (mean depth of 1.5 m). Each pond is supplied with well water (4–6 ppt salinity) and saltwater (25–32 ppt salinity) from the adjacent Colleton River.

Reciprocal cross hybrid striped bass were used in both density trials. During

1986, 1.4-g fingerlings were stocked on 14 May in replicate ponds ($N = 2$) at 3 densities: 5,000, 10,000, and 20,000 fish/ha (Table 1). On 10 June 1987, replicate ponds ($N = 2$) were stocked with 1.7-g fingerlings at densities of 12,500, 25,000, and 37,500 fish/ha (Table 1). Prior to stocking, fish were graded to reduce size variation. In 1986, fish were hand counted into each pond at stocking; however, in 1987, stocked populations were estimated by weight to reduce handling-induced stress.

Water quality parameters were monitored regularly in all ponds. During summer and fall, surface and bottom dissolved oxygen concentration and temperature were measured daily at sunrise in the deep end, while pH, salinity, and secchi disk visibility were measured twice each week in the afternoon. In winter, frequency of oxygen and temperature monitoring was reduced to 3 days per week, while other parameters were measured weekly. In 1986, due to lack of mechanical aerators, water flow was used to maintain satisfactory oxygen levels. In 1987, both water flow and supplemental mechanical aeration (1 hp paddlewheel) were used intermittently to prevent low oxygen concentrations and pond stratification.

Table 1. Harvest data for hybrid striped bass stocked at different densities in 1986 and 1987. In 1986, fish (mean size 1.4 g) were stocked on 14 May and reared for 293 days. In 1987, fish (mean size 1.7 g) were stocked on 10 June and harvested after 280 days. Standard deviations are shown in parenthesis.

		Harvest data			
Density (*N*/ha)	Replicate No.	Mean weight (g)	Survival (%)	Biomass (kg/ha)	Feed conversion
		1986			
5,000	1	105.8 (71.8)	85.4	452	5.3
	2	126.6 (70.4)	90.8	575	4.8
	Mean	116.2	88.1	514	5.1
10,000	1	186.9 (82.1)	98.7	1,845	2.6
	2	162.2 (76.8)	84.4	1,369	4.0
	Mean	174.6	91.5	1,607	3.3
20,000	1	179.5 (75.3)	80.0	2,870	3.2
	2	150.8 (86.9)	88.4	2,665	3.8
	Mean	165.2	84.2	2,767	3.5
		1987			
12,500	1	205.1 (111.3)	99.1	2,541	2.5
	2	173.3 (107.1)	99.5	2,156	3.0
	Mean	189.2	99.3	2,348	2.7
25,000	1	168.1 (82.5)	89.7	3,770	2.8
	2	176.2 (97.6)	104.6	4,601	2.3
	Mean	172.1	97.0	4,185	2.5
37,500	1	193.8 (97.9)	86.8	6,308	2.9
	2	196.3 (107.7)	76.9	5,661	3.2
	Mean	195.0	82.0	5,984	3.1

Fish were fed sinking trout pellets (38% protein, 8% fat) manufactured by Zeigler Brothers, Inc., Gardners, Pennsylvania. In 1986, feed was broadcast by hand at least 3 times per day. During 1987, 50% of the daily ration was delivered by battery-powered automatic feeders on each pond which dispensed food 3 times between 0700 and 0800 hours and 3 times between 1900 and 2000 hours each day. The remaining 50% of the feed was provided twice each day by hand at approximately 0900 and 1600 hours. After 1 December, use of the automatic feeders was suspended and all feed was provided by hand. During summer and fall, fish were fed daily. When feeding response declined due to low temperatures (December–February), feeding frequency was reduced to 2–3 times per week. When low oxygen concentrations (≤2 mg/liter) were recorded, feed was withheld. During the first month after stocking, fish were fed 100% of the estimated initial biomass per day to provide the fish maximum opportunity to become accustomed to dry feed. As fish grew, percent of biomass fed/day was reduced while feed size and quantity were increased (Table 2).

Growth of fish was monitored at least every 28 days by seine-sampling 2%–3% of fish from each pond. During sampling, fish were anesthetized in a 0.1 g/liter solution of MS-222 and pond water, and individually weighed to the nearest 0.1 g on an electronic balance. Fish were revived before being returned to the pond. After sampling, feeding rates were adjusted based on mean weight and projected biomass (Table 2). Biomass was estimated by assuming that all mortalities occurred during the first 2 months and that overall survival rate was 80%.

Prior to harvest, salinity in the ponds was increased to reduce handling induced stress and risk of bacterial infection. Fish were harvested alive by seining and pond drainage. At harvest, 10% of fish from each pond were individually weighed. These samples were used to determine harvest distribution and mean weight. Since fish were placed in another pond for final growout to market size (Smith et al. 1989), gross weights were not obtained. However, fish from each pond were hand-counted to determine survival rate.

Analysis of variance (ANOVA) was used to determine if there were significant

Table 2. Estimated[a] initial feed rates and feed sizes used during growing season of nursery study. Monthly mean size and temperature are based on 1987 data. Maximum feed is equal to feed provided at highest density treatment.

Month	Mean water temp. (°C)	Mean wt (g)	Estimated feed rate day (% of biomass)	Maximum feed provided (kg/ha/day)	Trout feed size
Jun	28	1.5	100.0	60	#3, #4
Jul	28	13	14.0	60	#4
Aug	29	39	6.0	72	#4–3/32"
Sep	26	77	5.0	120	3/32"
Oct	20	125	4.0	140	1/8"
Nov	17	166	3.5	174	5/32"

[a]Based on 28-day sample data for size and estimated survival rates.

differences among harvest weight, biomass, survival, feed conversion, or instantaneous growth rate (Ricker 1975) by treatment. Arc sinc transformations were used on all percentage data. Duncan's Multiple Range test was used to identify different means. The computerized statistical analysis system was used for all analyses (SAS 1985). Significance was examined at the 0.05 level.

Results and Discussion

Water Quality

Of the water quality parameters monitored during this study, dissolved oxygen concentration was the most important factor affecting growth and survival of the hybrid bass. Overall average bottom oxygen levels were greater than 5.8 mg/liter for all treatments (Table 3); however, oxygen levels ≤4.5 mg/liter were routinely recorded in the treatments and on one occasion surface and bottom oxygen concentrations of 0.2 mg/liter were recorded. During the current study, no mortalities were observed and the high survival rates (Table 1) suggest that no serious mortalities occurred due to low oxygen levels. Use of mechanical aeration equipment affected oxygen levels. When no equipment was available during June - August, 1986, oxygen levels ≤4.5 mg/liter were recorded an average of 30 days (range 19–38). In contrast, in 1987 when aerators were used, oxygen levels ≤4.5 mg/liter were recorded significantly fewer times (mean = 14 days). Oxygen concentrations below 4.5 mg/liter lead to reduced food consumption and growth among striped bass (Klyashtorin and Yarzhombek 1975). Also, Chittendon (1971) indicated that death of striped bass occurred at oxygen concentrations ranging from 0.5–1.04 mg/liter.

Table 3. Mean water quality data recorded during phase II nursery study. Data reported in 1986 are from May 1986 to February 1987; in 1987 from June 1987 to March 1988.

	1986			1987		
Parameter	5,000/ha	10,000/ha	20,000/ha	12,500/ha	25,000/ha	37,500/ha
Bottom dissolved oxygen mg/liter[a]	7.1	7.0	6.2	7.4	6.7	5.8
Range	1.5–13.6	0.2–11.4	1.0–16.4	1.7–12.6	2.2–12.8	0.2–19.8
Temperature °C[a]	21.5	21.6	21.3	20.4	20.1	20.3
Range	7–32	8–32	8–31	7–32	7–30	7–32
Salinity (ppt)[b]	14.2	13.4	13.8	4.5	4.3	4.7
Range	4–32	4–32	4–31	4–7	3–6	4–7
Secchi (m)	1.4	1.2	1.2	0.6	0.6	0.5
Range	0.8–1.6	0.8–1.5	0.7–1.5	0.3–1.2	0.2–1.1	0.2–1.2
Exchange rate (%/Day)	9.8	12.2	12.2	3.0	4.1	5.9
Aeration days[c]	5	0	1	28	74	156

[a]Measured with a Yellow Springs Instrument oxygen meter and probe, model 57.
[b]Measured with an American Optical refractometer.
[c]One day equals 24 hours of aeration.

High flow rates maintained in 1986 resulted in high secchi disk readings (mean 1.3 m) (Table 3). Consequently, substantial growths of rooted aquatic vegetation occurred in the ponds. Vegetation caused a significant problem during harvesting, particularly in the 5,000/ha density treatment where widgeon grass (*Ruppia maritima*) covered approximately 50% of 1 pond. In 1986, extent of infestation decreased as stocking density increased. In 1987, secchi disk visibility averaged 0.6 m, and there were no aquatic weed problems. This may be due to increased stocking densities which resulted in greater inputs of feed and the use of paddle wheel aerators. In addition, a 50% reduction in water exchange during 1987 (Table 3) also helped maintain phytoplankton blooms which discouraged growth of macrophytes.

In 1986, salinity was increased from 5–30 ppt in late November in anticipation of harvest; however, fish were not harvested until early February 1987. As a result, overall mean salinity was 13.8% ppt in contrast to 4.5 ppt in 1987 (Table 3). Higher salinity in 1986 should not have affected growth as striped bass hybrids grow similarly in salinities ranging from 0–28 ppt (Smith et al. 1986).

Growth and Survival

There were no significant differences in mean fish size at harvest among densities of 10,000 to 37,500/ha (overall mean 179 g) but fish reared at 5,000/ha were significantly smaller at harvest ($\bar{x}$ 116 g). In 1987, overall mean size of fish at harvest was significantly larger than that in 1986 even though stocking densities were greater and stocking date was 1 month later in the growing season (Table 1, Fig. 1). This difference may in part be due to more frequent feedings with the automatic feeders in 1987 and/or the chronically low oxygen concentrations which occurred in 1986. Research on striped bass fry and fingerlings indicates that increased feeding frequency enhances growth and survival rates (Lewis et al. 1981, Fitzmeyer et al. 1986). Additionally, fingerlings of a number of other fish species adapt to commercial diets much better when feeding frequency is increased (Stevenson 1980, Stickney 1986).

Specific daily growth rate (G) during the growing season (June–November) averaged 2.5 and 3.0 during 1986 and 1987, respectively. These growth rates are similar to the specific growth rate of 2.8 recorded in North Carolina (Kerby et al. 1987). Between November and February, fish growth virtually stopped and specific growth rates for this period averaged 0.036. Reduction in striped and hybrid bass growth rates in temperate areas during winter has been noted by other researchers (Williams et al. 1981, Woods et al. 1985, Kerby et al. 1987) and occurs at water temperatures below 16° C. Specific growth rates from stocking-harvest averaged 1.59 in 1986 (1.51–1.64) and 1.67 in 1987 (1.65–1.69). Fish in the lowest density treatment exhibited a significantly lower growth rate than fish in all other densities tested.

There were no significant differences in survival rates during the study. In 1986, mean survival rates were 88.1%, 91.5% and 84.2%, respectively, for 5,000, 10,000 and 20,000/ha stocking densities (Table 1). Mean survival rates in 1987

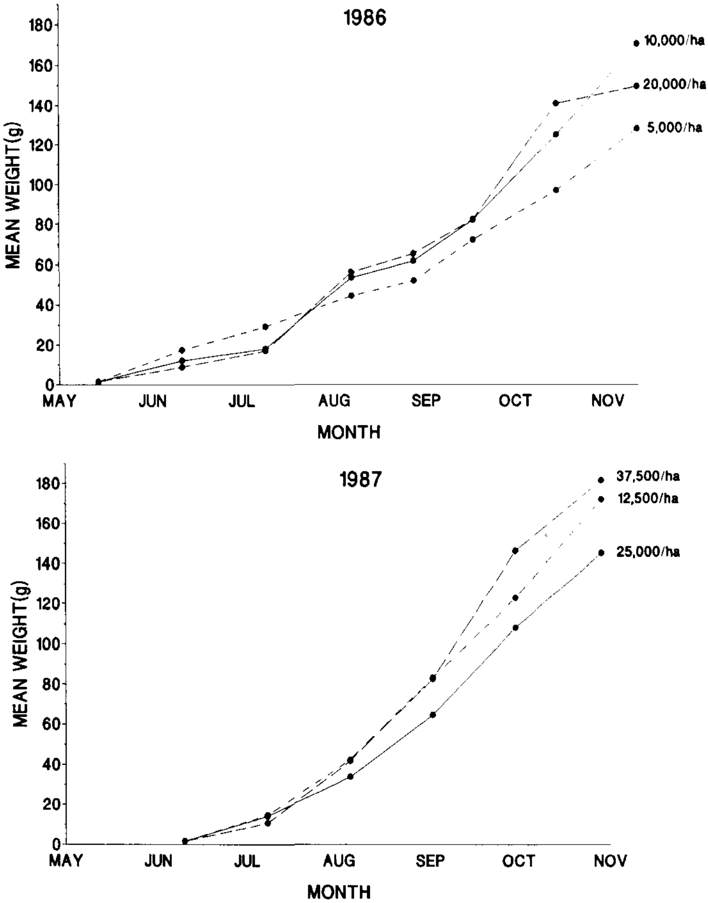

Figure 1. Growth of hybrid striped bass reared at different densities in phase II nursery ponds during 1986 and 1987 growing seasons.

were also high at 99.3%, 97.0%, and 82.0% for 12,500, 25,000, and 37,500/ha stocking density treatments, respectively (Table 1). A survival rate of 104.6% was recorded in 1 replicate in 1987 which illustrates that errors can occur when number of animals are estimated by weight at stocking.

The survival rates achieved during this study are much higher than those achieved in Florida (C. C. Starling, pers. commun., Fla. Game and Freshwater Fish Comm.) at densities of 37,500 and 63,750/ha, (14% and 19% respectively) and are similar to those obtained in North Carolina (84%) at a density of 16,500/ha (Kerby et al. 1987). Predators encountered during the study included alligators (*Alligator mississippiens*) and ospreys (*Pandion haliaetus*), but losses to these predators appeared low.

Production and Feed Utilization

The average percent increase in biomass during the study was 10,011% (7,567–11,972) and no differences were detected by treatment. However, the highest density treatment (37,500/ha), produced a significantly higher total biomass (5,984 kg/ha) than any other density, followed in descending order by the 25,000, 20,000, 12,500, and 10,000/ha densities (Table 1). The total biomass reported for the 5,000/ha density was significantly lower than the other treatments.

Harvest distributions of individual weights for all treatments were broad with animals ranging from 21–538 g at harvest. In the 5,000/ha density treatment 60% of the animals were < 100 g (Fig. 2) while only 28% of the animals in other densities were contained in this size class. In 1986, at treatments of 10,000/ha and 20,000/ha, approximately 17% of harvested fish were larger than 250 g, while in 1987, approximately 29% of the animals were larger than 250 g (Fig. 2).

The feed conversions in 1987 were significantly lower (mean 2.8) than those recorded in 1986 (4.0). Fish reared at the 5,000/ha density treatment had a significantly poorer feed conversion (5.1) when compared to the other densities (Table 1). The improvement in feed conversion during 1987 may be due to better feed management during this year. The feed conversion rates obtained during the study, while higher than those routinely reported for catfish (*Ictalurus punctatus*) (Foltz 1982, Robinson and Wilson 1985) and rainbow trout (*Salmo gairdneri*) (Stevenson 1980),

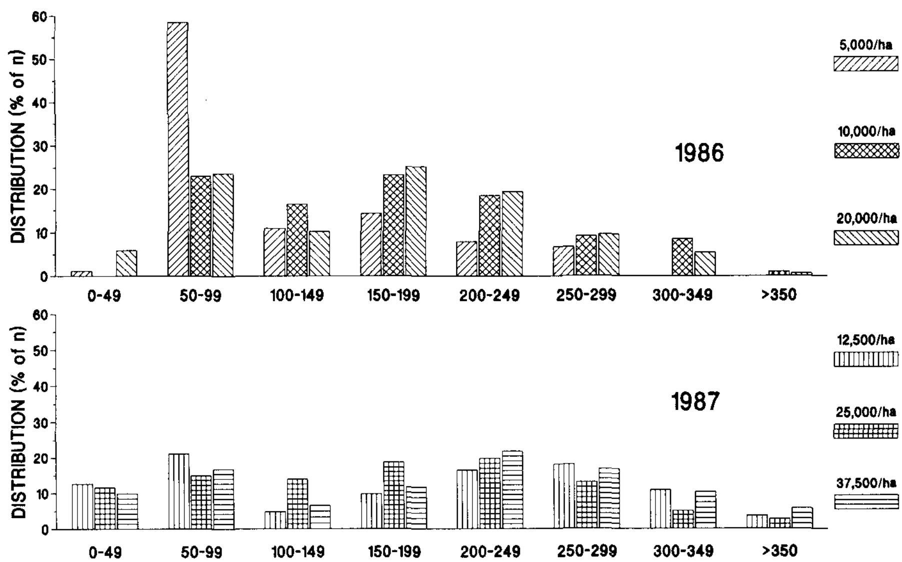

Figure 2. Frequency distribution at harvest for hybrid striped bass reared at different densities in nursery ponds.

are similar to those recorded in tank and pond grow-out experiments with hybrid striped bass (Woods et al. 1985, Kerby et al. 1987).

Conclusions

Results of these experiments indicate that hybrid striped bass can be grown at relatively high densities in Phase II nursery systems. At densities tested, there was no reduction in growth or survival rate with increased density. In fact, fish stocked at higher densities grew faster and utilized feed better than those stocked at the lowest density.

Feed conversions improved during the second year of the study, probably as a result of using the automatic feeders which increased feeding frequency from 3 per day in 1986 to 8 per day in 1987. Continued emphasis on improving feed utilization should further improve conversion rates in future nursery trials.

The ability of hybrid striped bass to survive short-term, low dissolved oxygen concentrations and extensive handling which occurred during sampling and at harvest was demonstrated. Also, the fish's ability to withstand water temperatures of 7° C indicates this hybrid can over-winter in many areas of the United States.

Water use and aeration were excessive in the study but the primary focus was to maximize production of Phase II juveniles rather than minimize use of water and electricity. However, it is apparent that aeration and or water exchange will be necessary to produce and maintain a biomass of 5,984 kg/ha, which was achieved at 37,500/ha treatment. Future research will examine ways to reduce these inputs. Larger size hybrid striped bass have been produced at biomasses of 8,000 kg/ha in 0.5 ha ponds with much lower inputs of aeration (2 hp/ha) than those used in these experiments (10 hp/ha), so reductions in equipment and electrical usage are likely (Smith et al. 1989).

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