STRIPED BASS CULTURE IN CONTINUOUSLY AERATED PONDS

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Abstract: Production of striped bass (*Morone saxatilis*) fingerlings in eight 0.02-ha ponds aerated with continuously operated airlift pumps averaged 181,000 fish/ha. Ponds were initially fertilized with hay at either 560, 1120, or 2240 kg/ha and zooplankton blooms were maintained with hay and meat scrap fertilizers. The average daily application of organic fertilizers ranged from 32 to 82 kg/ha. Five-day-old fry were stocked at the rate of 250,000, 500,000, or 1 million/ha. Fry were supplementally fed a 45% protein diet 3 times per day after they were 22 days old. After 44 days in the pond the average weight and total length of the 49-day-old fingerlings were 0.5 g and 3.0 cm. Return per treatment averaged 116, 29, and 22% for the low, medium, and high stocking densities, respectively, and daily production averaged 2.1, 1.2, and 2.6 kg/ha. The airlift pumps maintained dissolved oxygen above 3 mg/l when organic input averaged 62 kg/ha per day or less. The average number of fingerlings produced per hectare was 2.4 times greater than that commonly achieved in conventional pond culture.

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Striped bass, are currently produced at the rate of 15 million fingerlings per year for stocking in reservoirs and estuaries in the United States (Stevens 1979). conventional pond-culture techniques yield about 75,000 fingerlings/ha but production results are highly variable and may reflect differences in pond management.

Although stocking rates usually range from 125,000 to 500,000 fry/ha, 250,000 fry/ha is considered to be the optimum rate (Bonn et al. 1976). High densities usually result in smaller fish than do low densities when survival percentages are similar. Ponds are typically fertilized with hay, organic meals, animal manure, meat scraps, dried grain, or other organic materials to establish a zooplankton bloom before the fry are stocked. Fertilization rates of 560 to 1120 kg of hay/ha were recommended by Bonn et al (1976), but higher rates might support increased production. Increased organic loadings are accompanied by lower levels of dissolved oxygen (DO) due to the increased biochemical oxygen demand (BOD).

Inasmuch as continuous aeration has proved effective in increasing production of channel catfish (*Ictalurus punctatus*) in earthen ponds (Parker 1979), similar continuous supplemental aeration might maintain sufficient DO in striped bass ponds to allow increased fertilization and stocking rates. The objective of this study was to determine striped bass fingerling production rates in continuously aerated ponds heavily fertilized with hay.

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MATERIALS AND METHODS

Pond Preparation

Nine 0.02-ha ponds, fallowed over-winter, were filled from 28 February - 3 March 1979 and treated with 2.5 mg/l Aquazine ® [1] on 4 March to contorl filamentous algae.

[1]Reference to trade names does not imply Government endorsement of commercial products.

All ponds were drained on 19 March to remove any residual Aquazine® and to reduce numbers of aquatic insects. Ponds were refilled on 23-27 March. Ground coastl Bermuda hay, approximately 12% protein, was applied to all ponds on 6 April. Triplicate ponds were initially treated with 560, 1120, or 2240 kg hay/ha (Table 1). These 3 treatments (identified as low, medium and high) corresponded to fish stocking densities of 250,000, 500,000 and 1 million fry/ha.

TABLE 1. Fertilization and feeding treatments for striped bass fry stocked in 0.02-ha ponds at three densities.

Fry stocked (No./ha)	Pond No.	Initial hay (kg/ha)	Post stocking hay (kg/ha)	Total hay (kg/ha)	Meat scraps post stocking (kg/ha)	Supplemental food (kg/ha)	Total days fed
250,000	4	560	1120	1680	336	134	27
250,000	8	560	560	1120	336	134	28
250,000	9	560	560	1120	336	134	28
500,000	2	1120	1120	2240	336	134	27
500,000	3	1120	1120	2240	336	134	27
500,000	7	1120	1120	2240	336	134	26
1,000,000	5	2240	560	2800	336	134	26
1,000,000	6	2240	1120	3360	336	134	26
1,000,000	10	2240	1120	3360	336	134	28
Total		11760	18750	20160	3024	1206	243
Average		1300	933	2240	336	134	27

Aerated well water (19C) was continuously added to each pond at 2.6 liters/minute. An additional volume of water was added twice daily to keep ponds completely filled without allowing them to overflow. Total water added to each pond was reported as the average liter per minute inflow.

Aeration

Airlift pumps operated continuously in each pond provided aeration and circulation (Fig. 1). One pump was initially installed in each of the ponds but an additiona airlift pump was placed in each of the high density ponds after the fry were stocked. Airlift pumps consisted of a 5-cm diameter pipe with a 1.2-m vertical entrainment and a 3-m horizontal discharge (Fig. 2). Each airlift was supplied with 57 liters of air per minute and moved 114 liters of water per minute at a cost of $0.10 per 0.02-ha pond per day ($5.00/ha/day).

Stocking

Four boxes of striped bass fry hatched on 11 April 1979 were flown by charter plane from Moncks Corner, SC to Marion, AL on 16 April. The 5-day old fry, received at 1700 h, were thermally acclimated to pond water temperature over a 2-h period. Fry were dispersed in the shipping boxes and were counted in 20 volumetric samples taken from each box with a 1.25-cm diameter glass tube. The number of fry stocked in each pond was estimated based on the average fry density per volume of water in the shipping box. They were stocked directly into prepared ponds between 1900 and 2200 h. Larval fish were not exposed to sunlight, nor to intense artificial illumination. Ponds identified by 1 of 3

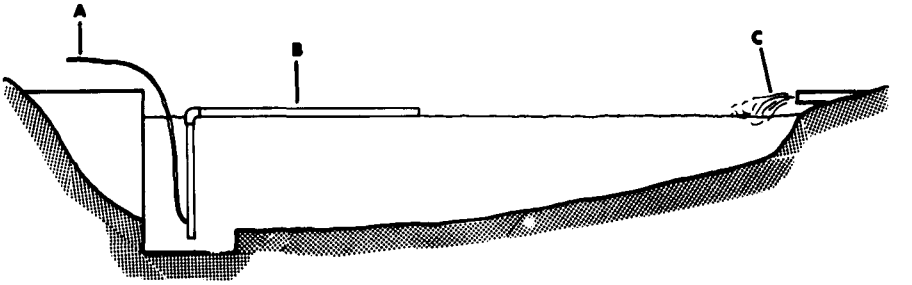

Fig. 1. Schematic representation of an airlift pump installed in a 0.02-ha pond to circulate water from the deep end to the shallow end. (A) airline; (B) airlift pump; (C) well water inflow.

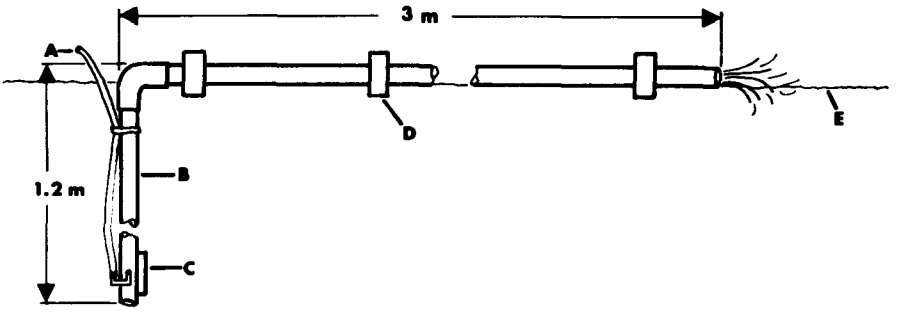

Fig. 2. Component parts of the airlift pump installed in 0.02-ha ponds. (A) airline; (B) 5-cm diameter PVC pipe; (C) ballast; (D) float; (E) pond water level.

density treatments, low, medium, or high, were stocked with 5,000, 10,000 and 20,000 fry per 0.02-ha pond, respectively. Treatments were triplicated and each pond was stocked at the rate of 446 fry per kilogram of hay fertilizer applied pre-stocking.

Post-stocking Fertilization

Ponds were fertilized with dried 50%-protein meat scraps from 27 April through 9 May. Daily application rates varied, depending on DO and planktonic bloom, but all ponds received a total of 136 kg of dried meat during this 13-day period. Ground coastal Bermuda hay (12% protein) was applied to the ponds from 10 May through 17 May. Net algae (*Hydrodictyon*) was controlled with Aquazine treatments of 1.6 mg/l as needed.

Supplemental Feeding

Supplemental feeding 3 times per day at a rate of 2.8 kg/ha per day with number 0 particle size 45%-protein chow began when the fry were 22 days old. After 4 days the feeding rate was increased to 5.6 kg/ha per day. When fry were 37 days old, number 1 size food particles were fed. The feeding rate remained 5.6 kg/ha per day and feeding frequency at 3 times per day until ponds were drained.

Water Quality

Temperature and DO were recorded for all ponds at 0700, 1100 and 1530 h, 5 days per week, and 0700 on weekends. Secchi disc readings were made 5 days per week at 1100. Weekly water samples were analyzed for NH_3, NO_2, NO_3, pH, total alkalinity, total iron, calcium hardness, and total hardness.

Harvesting

Fingerlings were removed from the ponds on 29-31 May; ponds were drained 3 at a time for the 3 consecutive days. Glass V-traps (Anderson 1974) were placed in the kettles of each pond to trap fry as the ponds were drained through double screens.

Fish were separated from tadpoles and trash after being placed in tanks with flow-through aerated well water. Numbers of fish in 3 weighed samples were counted to estimate total number harvested based on total weight harvested. Additionally, 20 fish from each pond were individually weighed and measured to ascertain variability.

RESULTS

The 49-day-old fingerlings were cultured in the ponds an average of 44 days. Return ranged from less than 1% in 1 pond to over 100% in 2 ponds (Table 2). Striped bass fry in 1 low-density pond (pond 4) were not counted or included in the production figures because of the presence of 20,000 common carp (*Cyprinus carpio*) fry. Three adult carp entered the pond and spawned when a spring flood raised the water level in the kettle drains. (Two other adult carp similarly entered pond 8 but did not spawn.)

TABLE 2. Production data and size variability for striped bass fingerlings harvested from 0.02-ha ponds.

Fry stocked (No./ha)	Pond No.	Weight harvested (kg/ha)	Count (No./kg)	Weight[1] (g;$\bar{x}\pm$SD)	Length[1] (cm;$\bar{x}\pm$SD)	Production (kg/ha per day	Return (%)
250,000	4	215[2]	4543[2]	0.17±0.40[2]	1.9±0.1[2]	5.0[2]	-
250,000	8	108	2363	0.34±0.04	2.7±0.1	2.4	102.0
250,000	9	81	3995	0.22±0.06	2.3±0.2	1.8	130.0
500,000	2	48	3245	0.33±0.12	2.6±0.3	1.1	32.0
500,000	3	63	2394	0.39±0.08	2.8±0.2	1.5	30.3
500,000	7	52	2191	0.39±0.11	2.8±0.2	1.1	26.0
1,000,000	5	9	378	1.36±0.22	4.2±0.2	0.2	0.3
1,000,000	6	110	1909	0.64±0.20	3.3±0.4	2.5	21.1
1,000,000	10	121	1945	0.45±0.11	2.9±0.3	2.7	23.8
Average		74	2302	0.5	3.0	1.7	29.6[3]

1 - n = 20 fish per pond.
2 - Carp fry
3 - Number harvested divided by number supposedly stocked x 100.

The average returns from low, medium and high treatment ponds were 116, 29 and 15%, respectively. In the one high density pond with less than 1% survival (pond 5), losses were attributed to low DO (1.4 mg/l or less); however, in pond 6 21% of the fry stocked survived even though DO was as low as 1.5 mg/l. The average return from the eight 0.02-ha ponds was 181,000 fingerlings/ha, or 29,600 fish returned from 100,000 stocked (29.6% survival). Average weight and length, based on a sample of 20 individually weighed and measured fish per pond, were 0.5 g and 3.0 cm.

The largest striped bass fingerlings were harvested from pond 4, which contained the wild carp fry. Average weight and total length of 10 striped bass sampled from pond 4 were 2.24 ± 0.5 g and 5.0 ± 0.4 cm. The next largest striped bass, 1.36 g and 4.2 cm, were from a high density pond (pond 5) in which the return was 0.3% (Table 2).

Water Quality

Dissolved oxygen and Secchi disc visibility (Table 3) varied with stocking density, fertilization rate, and presence of wild carp. Dissolved oxygen at 0700 for low, medium,

TABLE 3. Water quality and production data for 0.02-ha continuously aerated ponds stocked with striped bass fry.

Fry stocked (No./ha)	Pond No.	Water inflow (liters/min per ha)	Secchi disc visibility[1] (cm;x±SD)	Dissolved oxygen[2] (mg/l; x±SD) Average	Minimum	Water temp[2] (C;x±SD)	Aquazine treatment (Date)	Days in Pond	Fish harvested (No./ha)
250,000	4	435	37±14	7.3±0.8	6.2	22.1±2.0	--	43	976,000[3]
250,000	8	282	48±18	7.1±1.3	4.1	22.2±2.2	--	45	255,000
250,000	9	472	95±49	5.6±2.0	3.1	22.3±2.1	--	45	324,000
500,000	2	1000	107±32	6.5±1.6	3.1	21.9±2.2	5-15-79	43	156,000
500,000	3	510	96±39	6.6±1.4	4.5	22.2±2.1	5-03-79	43	151,000
5000,000	7	815	109±48	6.8±1.2	3.6	22.1±2.1	--	44	114,000
1,000,000	5	360	113±28	5.2±2.0	1.4	22.2±2.1	--	44	3,400
1,000,000	6	472	120±26	5.0±1.8	1.5	22.1±2.1	5-11-79	44	210,000
1,000,000	10	285	104±37	5.0±1.3	2.5	22.4±2.2	--	45	235,000
Average		515	82	6.1	3.3	22.2		44	181,000[4]

1 - n = 38 daily (1110 ha) measurements per pond.
2 - n = 38 daily (0700) h) measurements per pond.
3 - Carp fry.
4 - Carp fry not included in average.

and high density ponds averaged 6.7, 6.6 and 5.1 mg/l, respectively and minimum DO levels of 3.1, 3.1 and 1.4 mg/l, respectively. Secchi disc visibility averaged 60, 104 and 112 cm for the 3 treatments--low, medium and high. The lowest average Secchi disc measurements (37 and 48 cm) were from ponds 4 and 8 which contained wild carp; in other ponds average visibility ranged from 95 to 120 cm. Thus, any correlation between water clarity and fertilization rate may be an artifact of increased turbidity resulting from the presence of carp in the low density ponds.

Water quality was analyzed in relation to total amount of hay fertilizer applied per pond and data from ponds with similar fertilization and stocking rates were averaged (Table 4). Total ammonia averaged 0.68, 0.61 and 0.67 mg/l, respectively, for the low, medium and high treatments. The highest total ammonia measured was 0.84 mg/l at pH 7.3 in a high density pond (pond 10) on 4 May. At the low density the highest total ammonia measured was 0.83 mg/l when pH was 7.2 on 22 May. Un-ionized ammonia calculated under these 2 conditions was less than 0.02 mg/l. The highest nitrite measured was 0.032 mg/l in pond 2. Maximum nitrates were 1.8 mg/l, and were the same for both low and high density ponds. Total iron ranged from 0.05 to 1.7 mg/l in the 9 ponds and averages of weekly samples ranged from a low of 0.26 mg/l in pond 3 to a high of 1.0 mg/l in pond 5. Average total hardness ranged from 68 mg/l in pond 3 to 92 mg/l in pond 5. Temperature averaged 22.2 C and varied only slightly from pond to pond (Table 3).

DISCUSSION

The total number of striped bass harvested after 44 days of pond culture was not greatly different for ponds stocked at the lowest and highest densities. However, the size

TABLE 4. Average water quality characteristics and striped bass fingerling production in ponds with low, medium and high fertilization and stocking treatments.

	Treatment			Average
	Low	Medium	High	
Total hay (kg/ha)	1120	2240	3360	3720
Pond No.	8,9	2,3,7	6,10	
Estimated fry stocked (No./ha)	250,000	500,000	1,000,000	593,000
WATER QUALITY				
Well water inflow (liters/min)	377	775	378	510
DO (mg/l)[1]	6.4	6.6	5.0	6.0
Secchi disc visibility[2] (cm)	72	104	112	96
NH_3-N (mg/l)[3]	0.57	0.51	0.56	0.54
NO_2-N (mg/l)[3]	0.004	0.005	0.002	0.003
NO_3-N (mg/l)[3]	0.3	0.3	0.2	0.3
pH[3,4]	7.3	7.0	7.2	7.2
Total iron (mg/l)[3]	0.38	0.31	0.46	0.38
Total alkalinity (mg/l)[3]	64	60	71	65
Calcium hardness (mg/l)[3]	60	58	68	62
Total hardness (mg/l)[3]	79	74	88	80
PRODUCTION				
Fish harvested (No./ha)	290,000	140,000	223,000	218,000
Total weight harvested (kg/ha)	94	54	116	88
Weight/fish (g)	0.34	0.40	0.52	0.42
Daily production (kg/ha)	2.1	1.2	2.6	2.0
Fry return (%)	116	29	22	55

1 - n = 38 daily (0700 hr) measurements per pond.
2 - n = 38 daily (1100 hr) measurements per pond.
3 - n = 6 weekly (0900 hr) measurements per pond.
4 - Arithmatic mean of pH values.

of fish harvested differed; average fish weight was positively correlated with stocking density and fertilization rate (Table 4). The correlation of stocking density and fish size at harvest may be an artifact of percent survival; had 100% of the fish stocked at the high density survived they would likely have been a smaller size. Daily production was slightly greater at the higher stocking densities, but survival (22%) was much less than at the lowest density (116%). Calculated numbers, 5100 and 6500, for fish removed from the 0.02-ha low density ponds were 2 and 30% greater than the estimated number stocked (5000). Since fry and fingerlings were not individually counted, this 2-30% difference in the estimates could be the result of underestimating the number of fry stocked and overestimating the number of fingerlings harvested. The 2-30% difference accounts for only fry recovered and would be even higher if survival were less than 100%.

Average striped bass fingerling production from 7 continuously aerated ponds (Table 4) was 2.0 kg/ha per day which was considerably less than the 3.1 kg/ha per day reported by Baker (1976). These differences in results may be attributed to differences in experimental design such as age of fry stocked, number of days in the culture ponds,

fertilization rates, aeration, etc. More typically striped bass fingerlings are produced under conditions similar to those reported by Baker in which ponds are not continuously aerated and daily fertilization rate is about 24 kg of hay and 1.4 kg of inorganic fertilizer.

Striped bass survival and production seemed to be a function of low DO and not other water quality characteristics. Low DO, due to heavy hay fertilization and a week of cloudy days, was probably the cause for loss of fish in pond 5 and may have been a factor in ponds 6 and 10. Fresh water inflow into the ponds varied from pond to pond as a function of leakage rate from the pond (Table 3). Inflow was apparently not correlated with either DO or fingerling production but may have influenced Secchi disc visibility by flushing nutrients from the ponds and reducing planktonic blooms. Un-ionized ammonia was safely below the 0.08 mg/l reported toxic to salmonids (Liao and Mayo 1972) and was probably not responsible for the low survival of striped bass in pond 5. The maximum value for total iron was less than half the LC_{50} level, 40.0 mg/l, reported for striped bass larvae by Hughes (1973); however, the highest level of iron was found in ponds where survival was lowest. The highest iron level in ponds with 100% return was 0.52 mg/l; in ponds with 30.3 and 26% returns, the maximum level was 0.6 mg/l. Average total hardness was less than half that considered optimum (200 mg/l) for striped bass (Bonn et al. 1976); however, differences in returns could not be attributed to observed differences in water hardness.

Net algae, was a serious problem requiring chemical control during the study in ponds 2, 3 (2 of the 3 low production ponds), and 6; it was present to a limted degree in all ponds. Some fry were undoubtedly lost as they became entangled in the net algae. The gill netting of striped bass fry in net algae has been observed both in our ponds and in the laboratory. The two ponds, 4 and 8, with wild common carp were relatively free of filamentous algae at harvest and control of filamentous algae with common carp deserves further investigation. Conversely, stocking grass carp (*Ctenopharyngodon idella*) for control of filamentous algae in striped bass fingerling ponds has not proven effective (Reeves and Germann 1971).

The spawn of wild common carp with a density at harvest of 976,000 fish per hectare indicates that high densities of fingerling fish of this species can be produced in aerated and fertilized ponds. The large striped bass produced in ponds 4 and 5 where survival was less than 1%, indicates that striped bass growth rates in the other ponds were sub-maximum. In ponds 4 and 5 low survival decreased competition for available food and in pond 4 the few surviving striped bass could have fed on the carp fry.

Judging by the size and numbers of fingerlings harvested from ponds stocked at different densities, it appears that the larger fish may have been feeding on other striped bass in the high density ponds. Cannibalism has been observed in the laboratory but was not verified in the ponds. The largest fingerlings were produced in ponds where survival was the lowest.

The number of fingerlings produced per hectare was 2.4 times greater (181,000 fish/ha) than that commonly achieved in conventional pond culture indicating that continuous aeration and heavy fertilization may increase return of striped bass fingerlings. Increased stocking densities did not result in a proportional increase in the number of fingerlings produced, but larger fish were produced in ponds initially stocked at the highest density. One airlift pump per pond maintained DO above 3 mg/l in ponds initially fertilized with 1120 kg of hay per hectare. However, 2 airlift pumps per pond did not prevent isolated instances of low DO in ponds initially fertilized with 2240 kg of hay per hectare. Dissolved oxygen was a limiting factor at the highest fertilization and stocking rate. Additional research is needed to establish striped bass fingerling production when (1) carp fry are cultured as forage, (2) carp are used to control filamentous algae and (3) DO is maintained near saturation in heavily fertilized ponds.

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