UTILIZATION OF RAINBOW TROUT, *SALMO GAIRDNERII* RICHARDSON, IN A DOUBLE-CROP FISH CULTURE SYSTEM IN SOUTH GEORGIA

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ABSTRACT

Techniques were investigated for growing rainbow trout, *Salmo gairdnerii* Richardson, from fingerlings to market size during the winter months in a recirculation, flowing water fish culture system where channel catfish, *Ictalurus punctatus* (Rafinesque) are grown in summer. Trout stocked having a mean weight of 0.1 lb had a mean weight of 0.7 lb in approximately 100 days with a feed conversion ratio of 1.29 to 1. Survival of the fish was 82%. Water quality parameters and control of parasite infestations during the culture period are also discussed.

INTRODUCTION

Rainbow Trout, *Salmo gairdnerii* Richardson, have traditionally been grown in areas where cold water is available on a year-round basis. In nature, trout require an abundance of clean, cold, well-aerated water and where these conditions are duplicated artificially by man, trout usually flourish.

Raceways have been utilized for trout culture for a number of years both in Europe and the United States. Most of the raceways in which trout are grown are of the open system type where water flows through and downstream without being recycled.

In 1969, closed flowing water systems were first introduced in Georgia by the Soil Conversation Service for the primary purpose of culturing channel catfish, *Ictalurus punctatus* (Rafinesque). In this type installation, the water is stored in a reservoir, routed through raceways containing fish and back into the reservoir. A facility consisting of eight 100 ft raceways, a 500 ft deep well, and a 5 acre reservoir was constructed at the Coastal Plain Experiment Station, Tifton, Georgia, in 1971. The primary purpose for the facility was for researching the culture of channel catfish in flowing water.

Temperatures of impounded water recorded during the winter of 1970-1971 at this station indicated ranges favorable for trout survival and growth. The object of this investigation was to evaluate the biological feasibility of utilizing rainbow trout in the winter in a double-crop fish culture system in South Georgia.

MATERIALS AND METHODS

The raceways used in this study have the same basic design and are similar in construction and size to those described by Chapman, *et. al.* (unpublished)[4], but with some modifications. The design and construction of the aeration devices are the most distinct differences. These are discussed by Chesness, *et. al.* (1972).

Rainbow trout fingerlings were obtained from a private hatchery in North Georgia on December 10, 1971. The fingerlings ranged from 6 to 8 inches in length and had a mean weight of 0.1 lb. A total of 14,000 fish were stocked in the eight 100 ft. raceways. Efforts were made for the stocking rates to be the same for each raceway, but from observing the fish when feeding, it was apparent that some raceways were more densely stocked than others.

A commercially prepared floating trout feed approximately 6 mm in size was used throughout the experiment. The feeding schedule is given in Table 1. The fish were fed two equal rations daily at about 8:30 a.m. and 4:00 p.m. Feeding adjustments were made weekly based on samples of weighed fish and expected weight gain from feed consumed during the previous week.

The rations were weighed in the laboratory into paper bags for each raceway. The feed was distributed the length of the individual raceways with a small feed scoop and was usually vigorously consumed in 10 min. or less.

Harvest of the trout was accomplished by seining with a 30 ft. nylon seine with ½ inch mesh and a 4 ft. bag. Also, a catching box 2 ft. x 2 ft. x 8 ft. covered with ½ inch galvenized hardware cloth was placed on the lower side of each crosswall as the individual raceways were drained. Some of the trout passed through the drains with the water flow into the box and were then taken out with dip nets. The water flow was maintained through the system during the entire harvest procedure.

RESULTS AND DISCUSSION

Water temperatures determined to a great extent the amount of feed which the trout consumed on a given day. When the water temperature remained above 52° F the food consumption was good, but when water temperatures were below 50° F, the fish fed sparingly.

The recirculating pond water was used exclusively during the trout culture period with three exceptions. They are identified by footnotes in Table 2. On each of the three occasions indicated, the fish refused feed when offered to them. In each instance the water temperature was less than 50° F in the raceways. The pond water flow was reduced and a similar amount of 70° F well water was added so that the water temperature in the eight raceways was maintained above 50° F. This resulted in a water temperature of near 60° F coming into Raceway 1. Since more of the circulating water was exposed to the air, atmospheric temperatures influenced the water temperatures in the raceways more than they did the reservoir water temperatures. Each 100 ft. raceway lost approximately 1° F of heat when atmospheric temperatures were below 20° F. When the weather moderated and the pond water temperature rose above 50° F, the pond water alone was utilized.

[4]Paper prepared by S. R. Chapman, J. L. Chesness and R. B. Mitchell; Biologist, Soil Conservation Service, Athens, Georgia; Associate Professor, Department of Agricultural Engineering, University of Georgia; and Assistant State Conservation Engineer, Soil Conservation Service, Athens, Georgia; respectively and presented by Chapman at the joint meeting of the Southeast Region, Soil Conservation Society of America, and Southeast Region American Society of Agricultural Engineers, at Jacksonville, Florida, January 31-February 3, 1971.

Table 1. Feeding Schedule for Rainbow Trout in Raceway Experiment for Growing Season 1971-1972, Coastal Plain Experiment Station, Tifton, Georgia.

Raceway	Dates	Number of Days	Pounds Fed	Number of Days	Feed Consumed	Percentage of Total Feed	Feeding Rate Percent Biomass
1-8	Dec. 10-16	6	266				2.5
1-8	Dec. 17-29	12	650				2.5
1-8	Dec. 30-Jan. 7	9	450	27	1,366	17	2.5
1-8	Jan. 8-23	15	1,232				3
1-8	Jan. 24-28	2a	321				2.5
1-8	Jan. 29-Feb. 8	11	880	28	2,433	29	2
1-8	Feb. 9-24	14b	1,276				2
1-8	Feb. 25-Mar. 2	7	700				2
1-8	Mar. 3-7	5	724	26	2,700	33	2
1-8	Mar. 8-12	12	700				2
1-8	Mar. 13	1	150				2
1-7	Mar. 14	1	135				2
1-6	Mar. 15	1	115				2
1-5	Mar. 16	1	95				1.5
1-4	Mar. 17-20	4	340				1.5
1-3	Mar. 21-22	2	120				1.5
1-2	Mar. 23	1	40				1.5
1	Mar. 24-26	3	60	26	1,755	21	1.5
		107	8,254		8,254	100	

a/ Feed withheld for 2 days (January 26-27) because fish were stressed.
b/ Feed withheld on February 18 because fish were stressed.

Table 2. Maximum and Minimum Temperatures (°F) in Raceway 1 for Trout Growing Season 1971-1972, Coastal Plain Experiment Station, Tifton, Georgia.

Date	Max.	Min.	Date	Max.	Min.	Date	Max.	Min.
1971			1972			1972		
December 10	62	58	January 16	64	52	February 22	56	52
11	62	60	17	50	44a	23	57	53
12	68	64	18	62	58b	24	60	58
13	68	64	19	60	57	25	62	62
14	68	66	20	60	57	26	64	60
15	68	64	21	60	56	27	64	62
16	68	65	22	56	54c	28	64	60
17	69	67	23	59	58	29	65	63
18	69	64	24	62	58	March 1	67	64
19	68	64	25	60	58	2	64	62
20	65	59	26	58	52	3	65	62
21	63	60	29	60	58	4	64	61
27	61	58	30	64	58	5	63	60
28	61	58	31	63	59	6	62	59
29	64	62	February 1	58	56	7	63	60
30	63	60	3	56	52	8	64	62
31	65	63	4	52	47a	9	62	59
			5	60	57b	10	61	60
1972			6	61	57	11	61	59
January 1	64	61	7	52	50c	12	64	61
2	64	62	8	54	50	13	65	63
3	63	59	9	50	47a	14	67	64
4	63	60	10	62	52b	15	67	66
5	64	60	11	62	60	16	69	66
6	61	56	12	61	60c	17	69	67
7	58	54	13	55	53	18	68	66
8	56	53	14	61	55	19	69	66
9	58	54	15	62	59	20	69	65
10	60	56	16	62	59	21	70	67
11	65	60	17	62	59	22	70	66
12	65	60	18	53	50	23	71	66
13	66	62	19	53	50	24	71	67
14	64	64	20	51	48	25	71	68
15	64	60	21	52	50	27	72	66

a/ Fish did not feed because of low water temperature.
b/ Well water mixed with pond water.
c/ Well water turned off and pond water alone utilized.

Since feed consumption of the trout was related to water temperatures, rate of growth was also temperature dependent. Data contained in Table 3 show the growth of the fish based on periodic sampling. The weights are recorded in grams and the lengths in millimeters so that the small growth increments could be readily identified. The trout gained an average of 270 g and increased approximately 100 mm in length during the 107 day growing period.

The comprehensive growth curve in Figure 1 indicates that fish grew rapidly during most of the culture period. However, when the periodic weight increases were calculated as percentages of the total weight gained, and superimposed

Table 3. Growth of Rainbow Trout in Raceways During the 1971-1972 Growing Season, Coastal Plain Experiment Station, Tifton, Georgia.

Date	Cumulative Number of Days	Number Fish	Cumulative Mean Weight Grams	Mean Gain Grams	Percent-age Gain	Mean Length mm	Mean Increase mm
December 10a		100	45			165	
16	6	40	53.2	8.2	3	171	6
23	13	821	78.1	24.9	9	200	29
January 10	31	630	100.0	21.9	8	210	10
19	40	886	122.1	22.1	8	224	14
26	47	653	139.0	16.9	6	232	8
February 9	61	400	145.0	6.0	2	233	1
16	68	34	170.1	25.1	9	238	5
22	74	89	195.2	25.1	9	245	7
March 1	82	97	214.7	19.5	7	250	5
8	89	80	243.0	28.3	10	252	2
14b	95	200	285.6	42.6	16	257	5
22	103	100	315.8	30.2	11	262	5

a/ Fish stocked.
b/ Harvest begun.

over the temperature ranges of the water (Figure 1), it was evident that growth was much reduced during the colder days. If the capability for adding warm well water to the system had not been present, growth of the fish would have been considerably less during the periods when the pond water temperature was below 50° F. A longer growing season would probably minimize the effects of the lower temperature periods upon the fish.

A sample of trout, usually 6 or 8 fish, was checked each week for parasites. The fish were carried to the laboratory alive where slides were prepared from gill tissue and external scrapings from the bodies of the fish. The only parasites found on the fish were the monogenetic trematode, *Gyrodactylus*, and the protozoan, *Trichodina*. They were seen both externally on the fish and on the gills for the first time January 3, 1972. The infestation increased gradually during the following 3 weeks. As a result, a formalin treatment of 30 ppm was administered January 21 with the water flow in the raceways stopped for 1 hr. The one treatment was effective in controlling the parasites and no others were necessary.

No disease problems were evident with the trout during the culture period. Water soluble tetracycline hydrochloride was added to the feed of the fish at the rate of 4.5 g per 100 lbs of fish as a precautionary measure for 10 days after stocking.

Water quality parameters measured were dissolved oxygen, free carbon dioxide, pH and total hardness. Davis (1965) stated that trout should not be held for any length of time in water with an oxygen content less than 5.0 ppm. The oxygen measurements shown in Table 4 were well above 5.0 ppm. A low of 6.4 ppm was recorded in Raceway 8 on December 30 which was 1 wk after ¾ lb of copper sulfate per acre was used to treat the reservoir pond for excessive plankton growth. The lower dissolved oxygen readings on that day were attributed to the oxygen demand of the dead plankton.

Degradation of the water as it flowed through the raceways was evident with the extreme high and extreme low for each date shown in Table 4 recorded in Raceway 1 and Raceway 8, respectively. The dissolved oxygen content of the water was increased as it passed over the aerator between each raceway, but not to its original concentration. Therefore, the dissolved oxygen measurements were lower in each successive raceway.

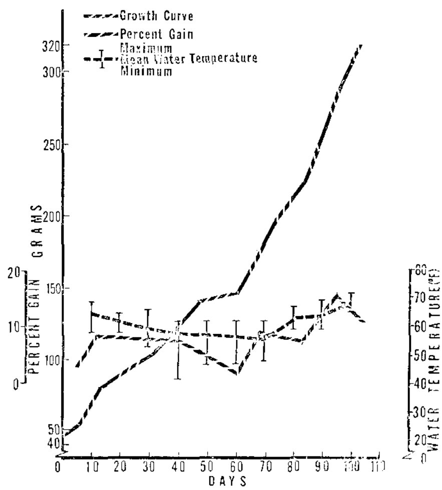

Figure 1. Growth curve of rainbow trout and percent gain in relation to water temperature, 1971-1972.

Free carbon dioxide was not measured at a concentration greater than 2.0 ppm. Total hardness was 90 ppm and pH was 7.0, 7.2 and 6.8 when checked on December 13, January 14 and February 25, respectively.

Table 4. Means and Extremes of Dissolved Oxygen in Raceways During Trout Culture Period, 1971-1972, Coastal Plain Experiment Station, Tifton, Georgia.

Date	Time	Mean O2 PPM	O2 PPM Extremes
December 13	10 a.m.	9.4	9.8-9.0
30a	9 a.m.	7.7	8.9-6.4
January 3	3 p.m.	9.3	9.6-8.8
4	1 p.m.	8.6	9.0-7.8
13	2 p.m.	10.3	11.4-9.4
14	2 p.m.	10.4	12.2-9.4
25	2 p.m.	9.6	10.0-9.0
February 3	2 p.m.	9.9	11.3-9.3
4	2 p.m.	11.0	11.4-10.1
16	1 p.m.	10.0	10.3-9.7
March 2	9 a.m.	9.3	9.7-8.7

a/7 days after treatment with Cu SO4 for excessive plankton bloom.

Harvest of the trout was begun March 14 and completed March 29. Numbers, total weight and mean weight of fish taken from each raceway in order of harvest are given in Table 5. Survival, including those which were purposefully sacrificed when examined for parasites, was 82 percent. Mortalities shown in Table 6 were insignificant for any one day except for losses sustained on January 26 and 27. Those two days accounted for 93% of the losses, whereas the additional 7% which died were distributed throughout the other days.

The fish were stressed at feeding time on the morning of January 26 with most of them crowded under the aerators or in the shallow water at the edges of the raceways. Brockway (1950) cited combinations of various water quality parameters which resulted in mortality of fish. Similar combinations may have been responsible in this instance even though water quality determinations failed to reveal any parameter which should have caused such behavior by the fish.

About 100 lb of the stressed trout were dressed and salvaged for food. While eviscerating the fish, it was observed that all of their stomachs were full of undigested food consumed the previous afternoon. Some unknown factors caused the digestive system of the fish to not function properly, thus resulting in an exhibition of stress symptoms on the part of the fish. Feed was withheld and by late afternoon the fish were back down in the water, but 2,223 dead trout were picked up by the following afternoon. A similar stress syndrome occurred on February 18 but no mortalities occurred.

The trout which were harvested at the conclusion of a culture period ranging from 95 to 107 days had a mean weight of 0.69 lb. and a mean length of 11 inches. The average daily increase in biomass for the entire population was 59.8 lbs.

The fish consumed 8,254 lbs. of feed while gaining 6,398 lbs. for a feed conversion ratio of 1.29 to 1, which is excellent for trout. Schmittou (1969), reported experiments with caged catfish and observed that feed efficiency is a reflection of the interaction between the fish, the feed and the environment. These results indicate that a flowing water closed raceway system provided a favorable environment for rainbow trout.

Table 5. Numbers and Weights of Trout Harvested from Raceways, March, 1972, Coastal Plain Experiment Station, Tifton, Georgia.

Raceway	Number of fish	Pounds of fish	Mean Weight
8	1277	846	0.66
7	1741	1,063	0.61
6	1308	966	0.74
5	1324	889	0.67
4	1173	852	0.73
3	1477	1,046	0.71
2	1255	912	0.73
1	1823	1,224	0.67
Totals	11,378	7,798	0.69

Table 6. Mortalities of Rainbow Trout in Raceways, 1971-1972, Coastal Plain Experiment Station, Tifton, Georgia.

Dates		Number of fish	Cumulative Mortality
December	12-18	79	79
	19-25	1	80
	26-January 1	2	82
January	2- 8	9	91
	9-15	2	93
	16-22	7	100
	23-29	2,223	2,323
	30-February 5	4	2,327
February	6-12	14	2,341
	13-19	19	2,360
	20-26	11	2,371
	27-March 4	17	2,388

CONCLUSIONS

Results of this study indicate that the potential for utilizing rainbow trout as a second fish crop following production of catfish in a flowing water system is good. Water quality parameters measured during this investigation indicate that the carrying capacity of the raceways may be increased without expecting deleterious effects.

Further experiments are needed to determine the optimum stocking rates for cultures of this type. Also, stocking the fish in early November to take advantage of a longer growing season sould be considered. Additional water quality parameters should be monitored including ammonia, turbidity and BOD.

Periodic grading of the fish to remove those of harvestable size should be advantageous. Experiments for determination of grading mechanics and feasibility are also needed.

Data and observations indicate that parasites may be a limiting factor in intensive culture of fish. However, the relative ease and low cost of treatment per unit of production in flowing water culture may minimize the detriment caused by parasites.

LITERATURE CITED

Brockway, D. R. 1950. Metabolic products and their effects. Prog. Fish-Cult., Vol. 12, pp. 127-129.

Chesness, J. L., J. L. Stephens and T. K. Hill. 1972. Gravity Flow Aerators for Raceway Fish Culture Systems. Ga. Agr. Exp. Sta. Res. Rept. (In Press).

Davis, H. S. 1965. Culture and diseases of game fishes. University of California Press, Berkeley and Loss Angeles. 332 p.

Schmitton, H. R. 1969. The culture of channel catfish, *Ictalurus punctatus* (Rafinesque), in cages suspended in ponds. Proc. Twenty-third Ann. Conf. Southeast. Assoc. Game and Fish Commrs. 23:226-244.

INVESTIGATION OF POND SPAWNING METHODS FOR FATHEAD MINNOWS[1]

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ABSTRACT

For transfer of fingerling fathead minnows *(Pimephales promelas)* from spawning ponds to growing ponds, the optimum combination of brood-fish population density and sex ratio in the spawning pond was 19,200 fish per surface acre and five females to one male. Fingerling production from this combination amounted to 1,524,500 fish. Fathead minnows utilized spawning boards placed up to 5 ft deep, and they also utilized boards placed without reference to the substrate. Larger nest sites encouraged larger egg deposits. Nests were crowded together as effectively by restricting available nest sites as by providing visual isolation or territorial markings. Post-spawning mortality of adults ranged from 20% to 91% with higher survival of females than males.

INTRODUCTION

As long ago as the early 1930's, certain areas of the United States began to experience a decline in natural populations of bait fishes (Radcliffe, 1931; Hubbs, 1933; and Markus, 1934a). The problem was solved temporarily by pond culture of bait minnows. Though early attempts were inefficient and production was low, with accumulated knowledge and experience, bait minnow culture became more intensive and productive. At the same time, though, popularity of warmwater sport fishing increased due to construction of reservoirs, larger human populations, more leisure time, and greater human mobility. Demand for bait minnows increases concurrently with the popularity of warmwater sport fishing. Therefore, to serve the large market and yet control increasing costs, bait minnow culturists must seek highly intensive propagation techniques to produce maximum yields of salable fish with minimum space and expense.

The fathead minnow is a small, hardy, easily propagated minnow that is probably second to the golden shiner *(Notemigonus crysoleucas)* in importance as a commercial bait fish. Adults usually become sexually mature the second