vitamin fortified Auburn No. 2 feed is satisfactory for intensive culture of catfish in raceways and cages where rates much higher than 4,000 per acre may be used in combination with water exchange and aeration.

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BIOLOGICAL FILTERS FOR INCREASED FISH PRODUCTION [1]

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INTRODUCTION

The production of fish in ponds is limited by several factors, among which are dissolved oxygen concentration and organic wastes in the water. Some wastes, particularly ammonia, are toxic to fish; while others contribute to the oxygen demand of the pond, reducing the oxygen available to fish.

Approximately 2,400 pounds of catfish per acre per year can be raised in ponds receiving supplemental feed (Prather and Swingle, 1960). The natural aeration and waste disposal systems of the pond are insufficient for larger crops and must be augmented by the fish culturist for larger yields. A flow of water through the pond is satisfactory if large volumes of suitable water are available and the subsequent pollution of the downstream environment is acceptable. Both the water used and downstream pollution are minimized if the water is purified and recirculated. Kuronuma (1968) reported harvests of common carp up to 30.3 kg/m^2 using mechanical filtration through coarse sand or small gravel and complete circulation every 2 hours. Other methods of purification need study. A biofilter, or trickling filter, is an efficient, widely used means of purifying sewage (Lohmeyer, 1957) which should be adaptable to the purification of water for fish. Chu and Greene (1967) grew goldfish (*Carassius auratus*) to a final weight equivalent to 18,330 lb/acre using small scale biofilters attached to aquaria.

This paper presents data on the use of biofilters to purify recirculated water for the culture of catfish. The general objectives of this research were to determine the potential production of a recirculating system with a biofilter; to determine the effects of the biofilter on water quality; and to compare the performance of channel catfish (*Ictalurus punctatus*) and white catfish (*I. catus*) in a biofilter system.

MATERIALS AND METHODS

All experiments were conducted in rectangular concrete ponds. The filters were boxes constructed of 2″ x 4″ pine boards spaced approximately ¾ inch apart, filled with two to four inch gravel and mounted over the ends of the ponds (Figure 1). The dimensions of the ponds and filters were:

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	Pond	Filter
Surface area	0.005 acre (20.2m^2)	15 ft^2 (1.4 m^2)
Depth	2.5 ft (.76 m)	4 ft (1.22 m)
Volume	4080 gal (15.3m^3)	60 ft^3 (1.7 m^3)

Circulation was approximately 650 gal. per hour or 3.8 times the pond volume per day. Water was pumped from the pond and sprayed continuously over the gravel. It trickled through the gravel and dripped into the pond.

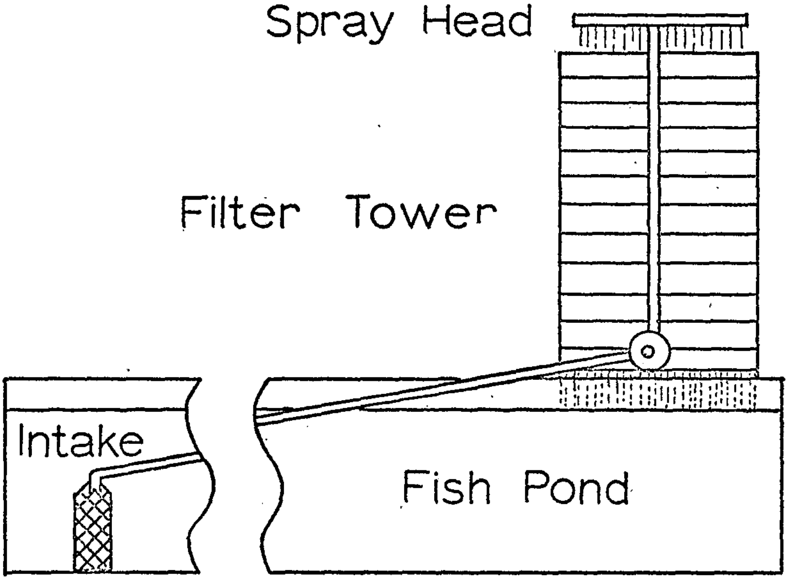

FIGURE 1. Diagram of biofilter mounted over 0.005 acre concrete pond

Channel and white catfish were obtained from the Auburn University Agricultural Experiment Station, and National Fish Hatchery in Marion, Alabama. In addition, channel catfish were obtained from a private hatchery in Yazoo City, Miss. The mean weight of fish stocked ranged from 0.02 lb (9 g) to 0.163 lb (74 g). Before stocking, the fish received prophylactic treatments of formalin, acriflavin and terramycin. If a significant number of fish died in a pond in the first 6 weeks after stocking, they were replaced. Fish dying after 6 weeks were not replaced.

All fish were fed Clarks trout feed at 3 per cent of their body weight daily 5 days per week. If fish were observed in distress from low oxygen in a pond, that pond was not fed for two days. The daily ration was adjusted every 3 to 4 weeks when growth estimates were made from seining samples.

At the end of each experiment the ponds were drained, and the fish were counted and weighed to the nearest 0.1 lb.

Analyses were performed on water samples from each pond. Dissolved oxygen was determined by the sulfamic acid modification of the Winkler method and with a YSI oxygen meter. Procedures given in Standard Methods (APHA, 1965) were used with minor modifications for carbon dioxide, alkalinity, total hardness, ammonia, and organic nitrogen. Turbidity was measured with a Hach Turbidimeter. The pH was measured with a Photovolt Model 126 pH meter. Nitrate and nitrite were measured using the procedures given by Strickland and Parsons (1968). Carbon was determined on a Beckman carbon analyzer. Samples for carbon analysis were acidified below pH 2 with H_2SO_4 and washed with nitrogen bubbles to remove inorganic carbon before analysis. In addition, dissolved carbon samples were filtered through a 0.45 micron Millipore filter previously washed with 0.05 N HCl. Some total carbon values were calculated from COD values by the equation $C = 2.3204 + 0.3970$ COD [2], since the large particles in the samples clogged the injection needle. Winkler determinations of dissolved oxygen were made immediately upon sample of collection. Measurements with the oxygen meter were made *in situ*. Measurements of pH, alkalinity, and total hardness were performed within 5 hours of sample collection. Measurements of ammonia, organic nitrogen, nitrate, nitrite, and turbidity were made within 24 hours of sample collection. Samples for carbon analysis were acidified within 24 hours of collection, but analysis was delayed as long as 6 weeks. Tests showed no measurable change in carbon during sample storage.

Samples for O_2 analysis were collected by bottle train sampler (Swingle and Johnson, 1953); other samples were collected initially with a 3-foot vertical water sampler, but later by submerging a 500 ml bottle to a depth of 4 to 6 inches.

1968 EXPERIMENT

Introduction. Since costs of operating the filter system are the same regardless of the weight of fish, economical operation requires that the maximum weight of fish compatible with good growth and food conversion be stocked. This experiment was designed to test the effect of two stocking rates on growth, food conversion and maximum production. In addition, the effectiveness of a settling basin in series between the pond receiving feeding and the filter was tested. Tests of the effects of the filter and the settling basin on water quality were also made.

Design. In four ponds the pump intake was at the end of the pond opposite the filter (Figure 1). In four other ponds the pump intake was in an adjacent pond (settling basin) containing no fish. The connection between the fish pond and the settling basin was at the end opposite the filter. In two aerated control ponds with the same circulation as the filter ponds, water was sprayed into the pond rather than onto a filter. One of the control ponds also had a settling basin in series.

Of each group of four filter ponds two were stocked with 2,000 lb/acre (low rate) and two with 4,000 lb/acre (high rate) of catfish. The two controls were stocked with 2,000 lb/acre each.

Stocking. The filter ponds were stocked with channel catfish on May 10, 1968, the control ponds on May 17. An epizootic of ich (*Ichthyophthirius multifiliis*) in eight ponds killed enough fish to require total restocking of three ponds and replacement stocking in five. Since sufficient channel catfish were not available, white catfish were restocked in three ponds on June 11 (Table 1).

Results and Discussion. The production parameters are shown in Table 1. Two filter ponds and the aeration control pond suffered heavy mortality on Aug. 10 when a burned-out fuse caused the pumps to be off overnight. The production data on these ponds are omitted because of this mortality.

The surviving control pond had the lowest net production (7,540 lb/acre), 4,750 lb/acre below the mean of the comparable filtered ponds with settling basins and low stocking rate.

The mean net production of the high rate ponds was 16,460 lb/acre compared to 11,580 lb/acre for the low rate ponds. Thus the higher rate was more efficient in producing fish. The mean daily gain in weight is a better indicator than the net production because it takes into account the shorter growing period of two of the high rate ponds. The high rate ponds produced a greater weight of fish per day (117 lb/acre/day) than the low rate ponds (73 lb/acre/day) and hence provided more efficient use of the circulating water. Higher stocking rates would probably be more efficient since growth estimates indicated a logarithmic growth

[2] Unpublished data in Fisheries Research Annual Report (1967), Auburn University Agricultural Experiment Station, Auburn, Alabama.

TABLE 1. Summary of fish production data in 1968 filtration experiment with three ponds omitted because of mortality due to power failure

Treatment *	Date	Stocking Pounds per acre	Species	Days in experiment	Harvest lb/acre	Net production lb/acre	Feed conversion	Mean daily gain lb/acre
F + SB	6/11	4,000	W. Cat	129	23,020	19,020	1.37	148
F + SB	5/10	4,000	C. Cat	165	14,620	10,620	1.92	64
F + SB	5/10	2,000	C. Cat	160	13,700	11,700	1.12	74
F + SB	5/10	2,000	C. Cat	160	14,880	12,880	1.19	80
F	6/11	4,000	W. Cat	128	23,760	19,760	1.33	154
F	5/10	2,000	C. Cat	157	12,180	10,180	1.23	64
A + SB	5/17	2,000	C. Cat	150	9,540	7,540	1.54	50

* F = Filter, SB = Settling basin, A = Aeration spray.

TABLE 2. Mean water quality parameters in 1968 filtration experiments

Treatment *	Stocking rate lb/acre	O_2 ppm	Ammonia ppm N	Organic nitrogen ppm	Dissolved carbon ppm	Total carbon ppm	Turbidity JTU
F + SB	4,000	8.2	0.40	5.7	40.5	73.8	14.3
F + SB	2,000	8.1	0.38	7.1	74.8	114.1	15.2
F	4,000	7.6	0.62	8.9	25.5	72.1	32.7
F	2,000	6.7	0.41	6.9	17	103.5	42.2
A + SB	2,000	6.0	0.32	5.4	44	73.5	11.3
A	2,000	8.6	0.55	10.4	45	113.5	19.0

* F = Rilter, SB = Settling basin, A = Aeration spray.

rate in all ponds which continued until draining (except in one high rate pond stocked with channel catfish).

The low rate ponds with settling basins had higher net fish production (mean = 12,280 lb/acre) than the low rate pond without a settling basin (10,120 lb/acre). The settling basin had a negligible effect on fish production in the ponds stocked at 4,000 lb/acre with white catfish. Thus at the high stocking rate it would appear more efficient to eliminate settling basins.

The mean water quality parameters are shown in Table 2. Data from all ponds are included. Hardness ranged between 37 and 77 ppm, and pH between 7.6 and 9.0.

The only statistically significant difference in water quality was that in filtered ponds the presence of a settling basin reduced the turbidity (plankton and detritus) (p less than 0.05). The same general effect is seen in the two aerated ponds.

1969 EXPERIMENT

Introduction. In the 1968 experiment the two species of catfish responded differently to the same treatment and stocking rate. The 1969 experiment was designed to determine if this was a true difference between species. In an attempt to reach maximum production the fish were stocked earlier to give a longer growing season. More intensive sampling for chemical analysis was also performed to try to detect effects of filtration on water quality.

Design. Eight ponds with filters were set up as in 1968 without settling basins (Figure 1). Four ponds were set up for aeration as in 1968. Four of the eight filter ponds were stocked with 4,000 lb/acre of white catfish, the other filter ponds and the aeration ponds were stocked with 4,000 lb/acre of channel catfish. All ponds were stocked March 7 and 12 but losses from diseases (*Columnaris* and *Aeromonas*) in March and a parasite (Ich) in April forced restocking of seven ponds. The final stocking dates are in Table 3. Each of the three ponds stocked with white catfish on May 30 received 4,800 lb/acre because that was the estimated weight in the other white catfish pond on that date. The pumps were turned on April 15 (May 30 for the 3 ponds stocked on that date).

Results and Discussion. The production parameters are shown in Table 3. Data from one catfish pond which suffered 60 per cent mortality from a pump failure in August, is omitted. Two other white catfish ponds suffered 95 per cent mortality when the pumps were inadvertently turned off overnight on Sept. 3 after 97 days in production. They were drained the next morning and the dead fish included in the production data. In the fourth white catfish pond a persistent algae scum killed 29 lb of fish (5,800 lb/acre) in the 5 weeks prior to harvest; these fish are included in the production figures.

The mean net production of the aeration control ponds was 4,520 lb/acre compared to 19,300 lb/acre for the filtered ponds with channel catfish and 13,480 lb/acre for the filtered ponds with white catfish. Feed conversion and mean daily gain of the two species were similar in the filtered ponds. Based on 1969 data channel catfish gave greater production than white catfish. However, the mean daily gain of the two white catfish ponds which were in production only 97 days was 136 lb/acre/day. If they had continued to grow at this rate for another 55 days until the end of the growing season they would have gained another 7,500 lb/acre making them comparable to the channel catfish ponds.

When the data from both 1968 and 1969 are combined there appears to be no real difference in production between channel and white catfish. The maximum standing crop of both species in filtered ponds was about 23,300 lb/acre, with a net production of about 19,300 lb/acre.

The filters improved the quality of the water in the ponds (Table 4). In the aeration ponds there was significantly (p less than 0.05) more ammonia, organic nitrogen, total organic carbon, nitrite, and turbidity than in the ponds of the filter treatments. There were no significant differences between treatments in oxygen, dissolved carbon, nitrate, pH

TABLE 3. Summary of fish production data in 1969 filtration experiment with 1 pond omitted because of mortality due to pump failures

Treatment *	Date	Stocking Pounds per acre	Species	Days in experiment	Harvest lb/acre	Net production lb/acre	Feed conversion	Mean daily gain lb/acre
F	3/12	4,000	C. Cat	210	22,300	18,300	2.3	88
F	3/12	4,000	C. Cat	210	26,480	22,480	1.9	108
F	3/ 7	4,000	C. Cat	210	20,100	16,100	2.2	76
F	4/ 8	4,000	C. Cat	178	24,340	20,340	1.7	114
Mean					23,300	19,300	2.0	96
F	5/30	4,800	W. Cat	97	18,320	13,520	1.1	140
F	5/30	4,800	W. Cat	97	17,620	12,820	1.1	132
F	4/ 8	4,000	W. Cat	204	18,100**	14,100	2.4	69
Mean					18,010	13,480	1.6	102
A	3/12	4,000	C. Cat	210	9,700	5,700	4.2	28
A	3/12	4,000	C. Cat	209	4,080	80	309.8	0.2
A	4/ 8	4,000	C. Cat	204	6,700	2,700	11.9	14
A	4/ 8	4,000	C. Cat	204	13,600	9,600	3.3	48
Mean					8,520	4,520	6.2	22

* F = Filter, A = Aeration spray.
** Includes 5,800 lb/acre killed by low oxygen in 5 weeks prior to harvest.

TABLE 4. Annual treatment means of water quality parameters measured in 1969

Treatment	O_2 ppm	Ammonia ppm N	Organic nitrogen ppm	Dissolved carbon ppm	Total carbon ppm	NO_3 ppm N	NO_2 ppm N	Turbidity JTU	pH	Hardness ppm $CaCO_3$
Aeration	3.7	1.69	22.2	40.5	150	0.36	0.27	56.1	7.8	94.4
Filter (C. cat.)	4.3	0.65	9.5	38.7	69	0.78	0.11	17.9	7.6	77.5
Filter (W. cat.)	4.7	0.41	8.2	22.3	44	0.31	0.06	13.7	7.7	64.9

or hardness. However, the oxygen difference of 0.6 to 1 ppm probably represents a real difference even though it is not statistically significant because fish died of oxygen deficiency in three aeration control ponds but

SUMMARY AND CONCLUSIONS

1. Recirculation and biofiltration of the water in fish ponds yielded a net production of catfish of over 19,300 lb/acre.
2. Channel catfish and white catfish responded similarly to the filtered water system.
3. Filtration improved the water quality in the pond by reducing ammonia, organic carbon, nitrite and turbidity and possible increasing dissolved oxygen.
4. At high stocking rates (4,000 lb/acre) a settling basin in series with the filter had no effect on the fish production but did cause a 20.6% increase in production at low stocking rates (2,000 lb/acre).
5. As a result of crowding of the fish, diseases and parasites were a major problem.

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CHANNEL CATFISH VIRUS DISEASE IN SOUTHERN UNITED STATES

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ABSTRACT

Channel catfish virus disease is caused by a specific virus which has been isolated from 23 epizootics reported from nine different states. This paper gives clinical signs, mortality patterns and susceptibility of different age and size fish to channel catfish virus. Recommended practices for controlling the disease are presented.

INTRODUCTION

Channel catfish virus is the etiological agent of channel catfish virus disease (CCVD) and is the only known virus disease that results in high mortalities in warmwater fish of North America. The virus appears to be limited to the Southern United States where mortalities as great as 95% have been reported from epizootics affecting cultured channel catfish, *Ictalurus punctatus* (Rafinesque).