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A Fish-Rearing System Incorporating Cages, Water Circulation, and Sewage Removal[1]

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Cages now used for fish production permit all of the waste to be dissipated into the surrounding water. When such cages are used in a closed system, such as a hatchery pond, the carrying capacity is the same as, or somewhat less than, it would be if the fish were free in the pond. Even so, there are advantages to cages; for example, they permit localized disease treatment, localized aeration, and mechanized harvest. Further, since increased biochemical oxygen demand (BOD) and associated oxygen depletion is the first limit on a fish population that receives supplemental feed, cages that permit removal of solid waste as a means of controlling BOD may result in their use to increase the carrying capacity of a body of water. We investigated the design of cages that permit waste removal. Solid waste was collected from the cages and subjected to biofiltration; the water that contained the plant nutrients resulting from biofiltration was returned to the pond.

Methods and Procedures

The first system designed, used in preliminary tests conducted in 1970 and 1971, consisted of 14 cages attached to a floating dock that extended partly across one end of a 0.2-ha hatchery pond. Each cage had a pyramid-shaped bottom. A suction line located in the cage bottom was attached to a manifold connected to a centrifugal pump. Water was continuously drawn from each cage at a rate of 8.5-17 l/min with any solid waste that had settled to the bottom. The water carrying the waste and fresh well water (10.5-21 l/min) were permitted to flow down a grassy hillside, which served as a biofilter. At the foot of the hill, the water was collected in a sump, and 8.5-17 l/min were pumped back to the surface of each of the 14 cages; excess water was returned directly to the pond. Criteria for evaluating the system included determination of survival and rate of growth of the fish, and the carrying capacity of the pond.

On 8 May 1970 each cage in this system was stocked with 250 40-g channel catfish (*Ictalurus punctatus*). The fish were fed twice a day at a rate of 3% of their body weight per day. The waste removal pump operated continuously until 15 September, when it ceased to function, and most of the fish died as a result of oxygen depletion. All fish (live or dead) were weighed and the experiment was terminated.

On 14 April 1971 the cages in the system were again stocked with 250 fish each. Brood-size fathead minnows (*Pimephales promelas*) were stocked outside the cages; several yearling largemouth bass (*Micropterus salmoides*) were introduced into the pond by accident. The caged fish were fed once a day by automatic feeders at a rate of 3% of body weight per day. The waste removal pump operated continuously as before. The fish were harvested on 16 September 1971, after 155 days.

On the basis of information gained from the system used in 1970 and 1971, a second system was designed for operation in 1973. It consisted of 20 circular, wire mesh cages, each 1.8 m in diameter and 0.9 m deep, with a cone-shaped, fiber glass bottom that had a 23- cm removable plug through which the fish could be removed by "gravity harvesting." The plugs were adapted to fit over 4-cm nipples on a 15-cm manifold-type sewer line; each of two manifolds accommodated 10 cages. One end of each sewer line was equipped with a high volume, axial flow, centrifugal pump that continuously circulated water through the cages and out the bottom (Fig. 1). The pumps discharged into a cylindrical sedimentation tank, 3 m in diameter. The sediment was removed daily from the tank by draining it from a sump in the bottom of the tank. The overflow from the sedimentation tank discharged into a vegetated canal 1 m wide, 90 m long, and 25 cm deep, which functioned as a biofilter. From the canal, the water returned to the pond at a point 90 m from the location of the cages. The cages were suspended from a dock extending partly across one end of a 0.73-ha hatchery pond (Fig. 2). Enough well water was added to maintain the water level of the pond.

On 5 June 1973 these cages were each stocked with 400 31-g channel catfish. The pond outside the cages was stocked with 5,000 fingerling hybrid sunfish

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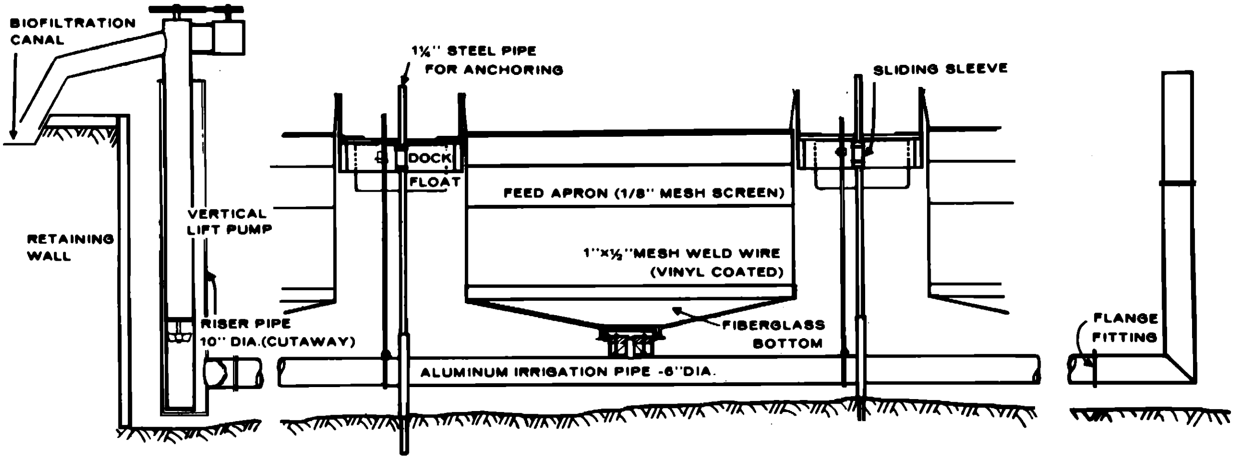

Fig. 1. Schematic drawing of a fish-rearing system that incorporates mechanisms for removing solid waste from cages.

(*Lepomis macrochirus* x *L. cyanellus*) and about 100 grass carp (*Ctenopharyngodon idella*). The fish in the cages were hand-fed at a rate of 3% of their body weight per day, 6 days per week for 104 days, and were harvested 17 September 1973.

During the 1973 growing season, oxygen and preliminary BOD values were determined periodically in the pond, at the outlet to the sedimentation tank, and at the inlet and outlet of the biofiltration canal. Oxygen values were measured with an oxygen meter (Yellow Springs Instrument Company, Model 54). Each oxygen determination in the pond consisted of an average of surface, midwater, and bottom readings taken at the end of the dock which supported the cages. Samples for BOD determination were collected at the surface at each of the sampling locations. The procedures used followed the standard methods of the American Public Health Association (1971), with the exception that an oxygen meter equipped with a BOD probe was substituted for the prescribed Winkler oxygen measurements. On five dates (13 and 16 July, 8 and 16 August, and 7 September) the 24-h accumulation of solid waste in the sedimentation tank was determined. The removal of solids required drawing 10 liters of water from the sump in the bottom of the sedimentation tank. The dry weight of solid waste collected in the sedimentation tank in 24 h was determined by filtering the waste drained from the tank and oven-drying the solids removed. On 8 August and 6 September preliminary values were also obtained for the solid waste removed in the canal. Canal waste removal was determined by filtering and obtaining the dry weight of suspended solids for a 50-liter sample at the inlet of the canal and comparing it with a similar sample taken at the outlet; the difference between the two values was accepted as the amount of waste removed in the canal.

Fig. 2. Floating dock and cage system positioned in rearing pond.

The procedure for mechanical harvest of the fish consisted of floating an individual cage to a position under an electric hoist mounted on an elevated track. The cage was then lifted and rolled to a position over a hauling tank on a truck. The 23-cm plug in the cage bottom was removed, allowing the fish to slide out of the cage. Such a system can be operated by one person.

Results

When the first trial was terminated on 15 September 1970, the cages contained 2,900 of the original 3,500 fish. Their total weight at harvest was 500 kg (2,470 kg/ha), with an average weight of 175 g. The pond contained 149 kg of fathead minnows, and eight 0.5- to 1-kg largemouth bass, giving a total standing crop of 3,248 kg/ha, including both the fish in the cages and those free in the pond. Food conversion of the caged fish was 3.0.

During the 1970 trial two of the cages had to be restocked because the original fish suffered an infestation of *Ichthyophthirius* . Two outbreaks of *Trichodina* required formalin treatment, on 10 June and 7 July.

During the 1971 trial the fish did not exhibit evidence of parasitic infestation, but on 19 August there was evidence of fighting in one cage, resulting in the loss of at least 18 fish. It was necessary to remove the fish and restock the cage. The experiment then continued without incident until 16 September, when the fish were harvested. The total harvest was 925 kg (4,556 kg/ha), and the food conversion was 1.82. The weight of fish outside the cages was not determined.

During 1973 an outbreak of *Dactylogyrus* required treatment with potassium permanganate. There was also one period of low oxygen, but neither of these problems caused loss of fish. Of 8,000 fish stocked, 7,675 were harvested. During the 104-day growing period the fish stocked at 30.8 g attained an average weight of 154.1 g. The total weight of catfish in the cages was 1,184 kg. Fish outside the cages included hybrid sunfish and a few escaped catfish weighing 387 kg, and 67 grass carp weighing 181 kg. Thus the total weight of fish in the 0.73-ha pond was 1,747 kg, or 2,399 kg/ha.

Dissolved oxygen in the pond showed a systematic decline after midsummer, reaching a low of 1.5 ppm on 5 September (Fig. 3). At the point where the circulated water entered the sedimentation tank, BOD values closely approximated those for the pond water, except immediately after the fish were fed (Table 1); in samples taken immediately after feeding, BOD values of the circulated water were higher than those in the pond. Although the BOD dropped to a level below that in the ponds after the water passed through the biofiltration canal, considerably more data would be required to determine whether the difference between the values was statistically significant.

The mean dry weight of solids removed in the sedimentation tank per 24 h was 24 g in mid-July, 88 g in the first and second weeks of August, and 65 g in September (when the fish had been reduced to half-ration). The average suspended solids removed by the canal in 24 h on 8 August and 6 September was 5,706 g dry weight.

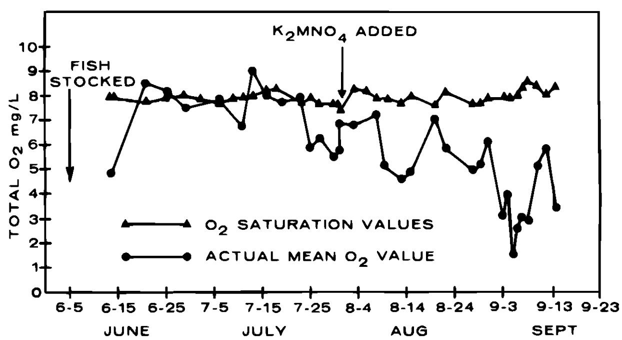

Fig. 3. Dissolved oxygen in a pond supporting a rearing system for caged fish. Readings were taken between 0900 and 1100 h in 1973.

Table 1. Biochemical oxygen demand (milligrams per liter) at four locations in a pond and associated biofiltration system used in nitrification of waste from fish confined in cages in the pond.

Date (1973) and time (h)	Pond	Location: Cage outlet	Sedimentation tank outlet[a]	Biofiltration canal outlet
16 July				
0930	2.5	1.6	2.5	1.5
2030	3.4	4.5[b]	4.2	2.6
23 July				
1000	3.0	2.9	2.8	2.6
1900	3.1	7.4[b]	5.4	2.8
3 Aug				
1000	2.5	2.0	2.8	2.2
5 Sept				
1500	6.8	5.2	6.2	2.4

[a] Beginning of biofiltration canal.

[b] Sample taken shortly after feeding.

Discussion

Most of our work to date has been directed toward perfecting the mechanical aspect of the system. The unit proved entirely satisfactory in terms of convenience in constructing the cages and assembling the system, in accessibility of the cages to care for the fish, and in handling the cages for mechanical harvest. Two changes in design appear desirable. The first is the use of a conventional type of biofilter instead of the canal. The second is the elimination of the sedimentation. tank, since the amount of solids removed by this process was trivial. A biofilter would provide greater flexibility in choosing a location for the installation, and better control of filtration and aeration.

The total cost of materials for the 20-cage unit, including the harvesting facility, was about $5,000. The principal expense was the cages, which had molded fiber glass bottoms that cost about $100 each; this amount might be reduced considerably if the cage bottoms were made in larger quantities. Operating cost for the two 3/4-hp motors was about $2 per day.

The biofiltration canal functioned satisfactorily, as indicated by the reduction of BOD values — even high values following feeding — to base values for the pond after the effluent passed through the canal. Furthermore, as previously mentioned, the canal removed a much larger quantity of suspended solids than did the sedimentation tank.

The maximum loading rate for the system was not determined. On the basis of observations made during development and design of the system, we believe that it will support 3,000 kg of catfish per hectare in cages, plus 1,000 kg of fish per hectare in the pond outside the cages.

One of the applications of the method identified during this study was its potential use for a type of polyculture. The procedure would consist of confining catfish in the cages and feeding them, drawing the sewage out of the cages, subjecting it to biofiltration, and returning the resulting plant nutrients to the pond to support a population of planktivorous fish. Such a system may prove attractive for the production of caged catfish in combination with the golden shiner (*Notemigonus crysoleucas*) or fingerlings of various species. It is also possible that planktivorous fishes produced outside the cages could be used as forage for the caged fish.

The outbreaks of *Ichthyophthirius* and *Trichodina* in 1970 resulted in poor food conversion. It is evident that, as in any high density system, prophylactic control of parasites and diseases may be required.

Our overall assessment is that the system has potential for increasing production in ponds, avoiding loss of caged catfish to oxygen depletion, and permitting certain types of polyculture that would not be feasible if large catfish were mixed with small fishes.

Reference

American Public Health Association. 1971. Standard methods for the examination of water and wastewater, 13th ed. American Public Health Association, Inc., New York, N.Y. 874 pp.

Black and Bigmouth Buffalo Spawn in Brackish Water Ponds

Young-of-the-year black buffalo (*Ictiobus niger*) and bigmouth buffalo (*I. cyprinellus*) were found in brackish water ponds which had been stocked with adult fish at the Rockefeller Wildlife Refuge, Grand Chenier, Louisiana. Sixteen 19-cm fingerling black buffalo were recovered from a 0.04-ha pond originally stocked with 10 2-yr-old buffalo (1.18 kg average) and 15 21.6-cm channel catfish. In another 0.04-ha pond stocked with 10 2-yr-old bigmouth buffalo (1.24 kg average), 139 15.2-cm fingerlings were recovered. Fish were removed from both ponds on 15 October 1974, 197 days after the adult fish were stocked.

Salinities for the two ponds ranged from 1.6 to 1.8 ‰ in the pond with black buffalo and from 1.4 to 2.0 ‰ in the pond with bigmouth buffalo.

Spawning of buffalo in brackish water ponds has not (to my knowledge) previously been reported; however, laboratory studies by Hollander and Avault (1975) indicated that eggs hatch in up to 9 ‰, fry survive in 9 ‰ and fingerlings survive approximately 12 ‰ salinity.

Reference

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— W. Guthrie Perry, *Louisiana Wildlife and Fisheries Commission, Grand Chenier, La. 70643.*