Cage Culture

— William O. McLarney

New Alchemy's newest aquaculture project is the rearing of fish in floating cages. The cages were placed in Grassy Pond, which borders on the New Alchemy farm. I had hoped to be able to write a glowing "success story" about our first experience in cage culture but it didn't work out that way, for reasons understood and otherwise. Instead of a success story with how-to-do-it instructions, this is a progress report essay on the art of cage culture and a commentary on the state of fish farming in North America.

Let me hasten to state that I have not lost faith in the concept of cage culture. Growing fish in floating cages is a more or less traditional technique in Cambodia, Java and other parts of Southeast Asia. More recently, it has been applied successfully in large scale commercial fish culture in Japan and the United States. More to the point is the recent success in small scale cage culture of bluegills *(Lepomis macrochirus)* and hybrid sunfishes in the Midwest where fish farmers have been able to raise up to 100 pounds of sunfish in 3'x3'x3' cages in a single growing season. (Ligler, 1971)

I think the potential of this form of fish culture as a family or small-scale commercial food source is obvious. The implication of successful fish culture in small cages is that anyone with access to unpolluted standing water could raise fish for the table and perhaps for sale. Not everyone has such access, but a lot of people do. In Massachusetts alone, for example, there are 151,739 acres of ponds and lakes. To apply the idea to a part of the country not so favored with natural lakes and ponds, there are 75,000 artificial "farm ponds" in the state of Illinois alone, which amounts to at least 50,000 acres of potentially productive water.

I have been asked how our cage culture work relates to the Back Yard Fish Farm and similar semi-closed fish culture systems for which New Alchemy has previously been known. (McLarney and Todd, 1974) Both are intended to produce fish at low cost in a small space and in quantities appropriate for homestead use. In both methods, the fish are confined in a very small space, which simplifies feeding, inspection, and harvesting. Those without access to a natural body of water or a site suitable for building an outdoor pond will have to resort to something on the order of our Back Yard Fish Farm in order to raise fish. But for those who do own a pond, or have access to one, or can build one, there are at least two advantages to cage culture:

1. The confinement of fish in a small volume of water, as in the Back Yard Fish Farm, necessitates recirculation and filtration of the water if substantial amounts of fish are to be grown. In a large outdoor body of water, these needs are eliminated, but the particular advantages of keeping the fish in a small enclosure are lost. Cage culture combines the best of both approaches by confining the fish in a small *space*, but not a small *volume* of water. That is, the water in the cage is continually being replaced by clean water from the surrounding pond. In fact, the fish through their normal breathing and swimming movements act as a "pump" to circulate their own water.

2. In many cases, fish which already inhabit the pond can be placed in the cages for intensive culture. In this way, ponds which are overpopulated or otherwise poorly suited for food fish culture can be used as natural "hatcheries", eliminating the expense and labor of purchasing or breeding stock.

Cage culture has the further advantage of being one of the few methods of fish culture which is compatible with the other values and uses of a pond. A pond like Grassy Pond, with its extensive shallows, brush and "weeds", irregular shoreline, natural fish predators, etc., viewed solely from a food fish production standpoint, is very "inefficient." But to convert it to a conventional, "efficient" fish culture pond would seriously compromise or destroy its value in terms of sport fishing and other recreational use, wildlife habitat, and esthetic pleasure. To use it for cage culture, on the other hand, modifies only a few square feet of the pond's surface. The cages may even enhance fishing; we find that bullheads, in particular, tend to congregate under the cages, fattening on morsels of food which slip by the caged fish.

We are by no means the first ones to perceive these advantages. The editors of Farm Pond Harvest magazine, in particular, have been active in promoting the use of cage culture and other methods to restore the American farm pond to its intended role as a food-producing resource (see addresses at end of article). However, their work, like that of most others in the field, has been heavily dependent on the use of commercial fish feeds. For those of you who have not been exposed to conventional American fish culture, I should point out that it is moving rapidly in the "agribusiness" direction. One of the clearest symptoms of this is the composition of commercial fish feeds. There are numerous manufacturers of dry feeds for trout and catfish, our two principal aquaculture crops. The first ten ingredients listed on the label of one brand of trout feed are: "fish meal, meat meal, soya bean meal, wheat germ meal, fish fiber and glandular meal, animal liver meal, corn gluten meal, dehydrated alfalfa meal, dried skim milk, dried whey products..... " The list goes on and concludes with no less than 13 synthetic vitamins and 6 added minerals.

Scientifically inclined readers may be appalled at the energetics of formulating such a feed. Others will question the appropriateness of feeding fish on potentially useful human food. Still others will criticize the ethics or politics of using inexpensive fish from the coasts of South America to make expensive fish for the North American table. The least debatable drawback to such prepared feeds is the expense. Each of the ingredients costs, and these costs are rising. I know of one case where a fish farm, with the help of an economist, formulated its own low cost, high growth feed for a particular species of fish; the cost of this feed has increased by a factor of 6 in as many years. It is hard to grow fish inexpensively with an expensive food.

The prepared feeds are effective; at the present time we cannot say "Feed this and that and your fish will grow as well or better than they will on a prepared commercial feed." This is because, given the nature of American business and agriculture, virtually all the research that has been done on fish nutrition has aimed toward the development of "complete" prepared diets. It is assumed, not proven, that natural or fresh foods cannot compete economically.

I therefore conceived that it would be useful to grow fish in cages in Grassy Pond, feeding some on prepared diets at conventional rates and others on "natural" foods we could provide at very low cost and without competing with our own diets. For reasons which we do not fully understand, we failed to produce significant quantities of edible size fish on either diet. However, I think the work sheds some light on both the relative value of both types of diet and on the problems and techniques of cage culture. It is therefore reported here.

We began with only 3 cages, due to a lack of funding for the project. The mesh material for the cages was Vexar, a nylon made by DuPont specifically for use in fish cages. Fish cages have also been made of plastic coated wire, but fish farmers report this has not been as reliable as Vexar. Imagine the disappointment of the fish farmer who pulls up his year's crop — and watches it fall through the bottom of the cage. It has happened. The past winter, in Colombia, I observed some beautiful and durable cages made from strips of guadua, a type of bamboo, but I know of no indigenous North American material with similar qualities. Whatever type of cage material you choose, to maximize water circulation and minimize the need for cleaning, use the largest mesh size that will contain the fish. Ours was one quarter inch.

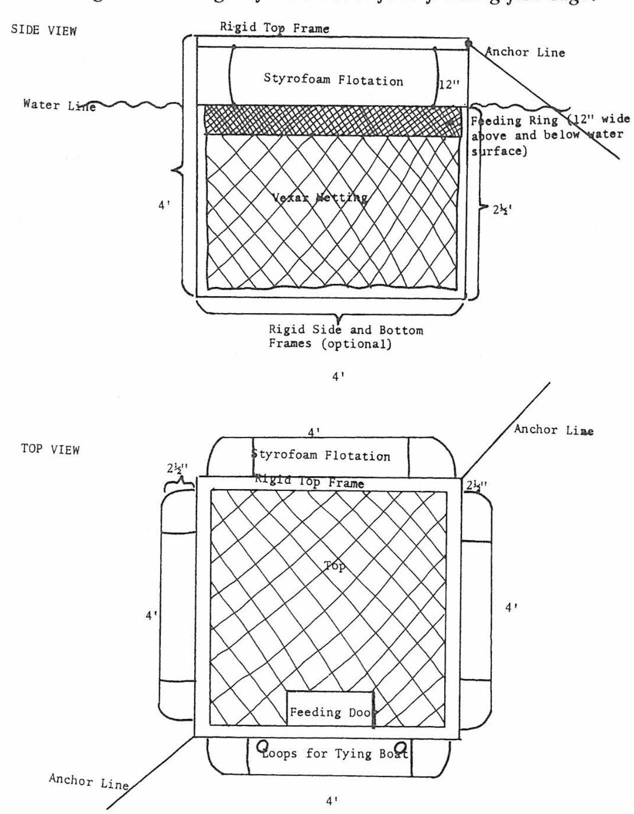
Our cages were provided with a rigid wooden frame at the surface, but were otherwise unsupported. They were constructed by sewing together sections of Vexar netting with nylon line. Commercially manufactured cages have a rigid frame on all sides, and we found out why. The unsupported cage walls tended to buckle slightly, not enough to deform seriously the cages, but enough to begin forming cracks in the Vexar. In one cage, these cracks eventually opened, forming holes large enough to permit the escape of fish.

Flotation for the cages was provided by 4 pieces of styrofoam 36" x 9" x 1", attached near the top so that 1 foot of the total cage height of 4 feet was above the surface. We felt this eliminated the necessity for tops on the cages, though if one were growing a species of fish more given to jumping than sunfish, tops would be necessary. The floats were enclosed in canvas bags so that the styrofoam, should it break, would not float away.

The cages were anchored in the pond by means of cinder blocks attached to two of the corners with nylon line. They were set in water deep enough that the bottoms of the cages were clear of the pond bottom at all times.

Figure 1 is a sketch of one of our cages, with a wooden frame added on all sides. Another feature we want to add next time is some sort of snap arrangement, so that a boat can be quickly and snugly fastened to the side of the cage.

Figure 1. Design of a 64 cubic foot floating fish cage.



For those who do not want to go to the bother of building their own cages, I have appended the addresses of a number of commercial cage manufacturers. One of them, Inqua Corporation, also offers a $1 booklet entitled "Profitable Cage Culture", (Neff & Barrett, 1975) which goes into the why and how of growing fish in floating cages in much greater detail than I can here.

Each cage was stocked with 200 "hybrid bluegills", a cross between male green sunfish, *Lepomis cyanellus* and female bluegills. The use of these fish is not essential to cage culture, which can be applied to most species which can be cultured at all. I chose the hybrid because it is supposedly a particularly fast growing fish which combines all the desirable characteristics of the bluegill with a mouth nearly as large as that of the green sunfish, so that it is easier to feed.

Each of the 3 cages was stocked on May 14 with approximately 200 young fish weighing a little over 2 grams each. The cages were designated A, B and C. For the first 15 weeks of the experiment, the fish in Cage A received only natural foods, while those in Cage B were fed daily except Sundays with 1/8 inch Silver Cup floating trout feed in an amount equivalent to 2% of the estimated total weight of fish in the cage. To form an idea as to the importance of foods which entered the cages naturally, the fish in Cage C were not fed during this time.

There were three principal components of the natural food diet:

1. Earthworms: This is of course the archetypal fish bait, and for good reason. Fish, including our sunfish, love them. Earthworms have another advantage for the fish farmer in that good methods have been developed for raising them (see Book Review – page 29) though fish farmers have not taken advantage of this. We started a small earthworm culture this year, but the bulk of our worms were gathered from compost or leaves. Worms were fed to the fish by placing them on a perforated styrofoam float. They were eaten one by one as they worked down through the holes.

2. Flying insects: These were captured with the aid of ultraviolet "bug lights." We had an old style bug light with an electric killing grid, which was donated several years ago by Gilbert Electronics of Jonesboro, Arkansas, and this was used. But this year we received the generous donation of two "Will-O'-the Wisp" bug lights from Hedlunds of Medford, Wisconsin (see list of addresses). These lights are manufactured expressly for use in fish culture. The insects are attracted to the light, sucked in by an impeller fan and blown down into the water. Due to a lack of electrical wire, we were unable to install ours over the cages, but instead had to attach a bag to collect the insects. Certainly the trap's effectiveness was reduced, but on good nights we harvested as much as a quarter pound of insects, mainly midges and moths. On bad nights the harvest was virtually nil, even during June, our peak "bug season." I imagine these lights would be more effective consistently in the Midwest or South where hot, sultry summer nights prevail, rather than on Cape Cod where windy nights are the rule. Nevertheless, the cost of providing high quality fish food in this manner was less than a nickel a day using conventional electric power. Were we to succeed in developing a U-V bug light powered by a wind-charged battery, that would be as close to a free nocturnal lunch for fish as one could get.

3. Midge larvae: Cage C was provided with a 2' x 6' burlap sheet of these larvae every other day; their culture is described in previous issues of *The Journal of the New Alchemists* (McLarney, 1974; McLarney, Levine and Sherman, 1976).

Occasional tidbits of other live or fresh foods were added, but not in significant amounts. It was more difficult to quantify accurately the natural foods than the dry feed. The amount of insects caught by the lights, in particular, was out of our control. The quantity of midges fed also varied from feeding to feeding; assuming our production rates are essentially the same as in previous years, the average feeding amounted to about 100 grams. The quantity of worms fed was more amenable to regulation, being a function of the amount of labor expended. However, since the primary goal was to develop a feeding system which would be practical for a homesteader or small farmer, the total amount of natural foods used was limited to what could be gathered in an hour. Thus, on some days, particularly later in the season, the combined dry weight of the three types of natural food fell short of the total weight of dry food fed. The approximate proportions (dry weight) of worms, flying insects and midge larvae in the natural foods diet were 75%, 20% and 5% respectively.

About every two weeks a sample of 30 fish was taken from each cage and weighed. This figure was used to estimate the total weight of fish in the cage, which was in turn used in preparing new feeding rates. Comparison with the actual weight of all the fish in a cage, on the three instances when such a comparison was made, showed that our estimates ran about 10% low.

The feeding and sampling regimes just described were followed throughout the study, with the following changes:

1. On June 29 it was determined that the fish in Cage C had ceased growing altogether, and perhaps had started to lose weight. The mean weight of the sample fish on that date was 2.2 grams; on June 14 it had been 3.3 grams. From June 30 through September 1, they received the same dry feed as the fish in Cage B, but in daily amounts equivalent to *3%* of the total weight of fish in the cage.

2. As the daily feed rations became larger, it became less certain that all the food was being consumed. On

August 4 we therefore began feeding twice a day.

3. Sometime between August 31 and September 11 a hole was formed in Cage B, permitting the escape of about 75% of the fish. When this was discovered, the remainder of the fish were removed, weighed and redistributed between Cages A and C. From then on the experiment was altered as follows: Cage C was fed with dry food at the 2% rate, Cage A received the same *plus* 100 worms (approximately 60 grams dry weight) and an average of 2.5 grams (dry weight) of flying insects daily.

4. Our first killing frost occurred on October 12; this coincided with a drastic drop in the water temperature. This was reflected in a marked reduction in feeding by the fish. It was thus decided to make the final harvest on October 19.

We had aimed at producing ¼ lb. (114 gram) fish by the end of October. Assuming 100% survival and no escape of fish, this would have given us 600 sunfish weighing a total of 150 lbs. (68,100 grams). Our actual final harvest was 367 fish weighing 14.4 lbs. (6,525 grams) or 9.6% of our goal. The mean weight of these fish was 0.04 lb. (17.8 grams) or 16% of the target weight. From a production point of view, a failure; but there is something to be learned from the experience and it has not caused me to lose faith in the potential of cage culture as a means of producing food fish on Cape Cod or elsewhere.

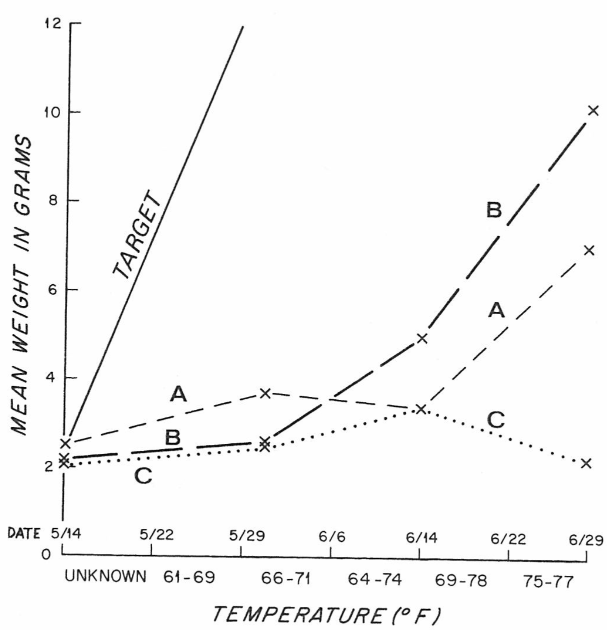


Table 1. Growth of Caged Hybrid Sunfish, May 14-June 29

Cage	Initial total wt. of fish (May 14)	Initial mean wt. of fish	Est. total wt. of fish (June 29)	Mean wt. of sample fish (June 29)	Per cent growth (based on mean wts.)
A	513 grams	2.5 grams	1420 grams	7.1 grams	184%
B	457 "	2.2 "	2040 "	10.2 "	325%
C	440 "	2.1 "	480 "	2.4 "	14%
Total	1410 "	2.3 "	3940 "	6.6 "	187%

In an attempt to analyze where we went wrong and to illustrate what we have perhaps learned, let me offer a series of graphs and tables illustrating the estimated total and mean weights of fish in Cages A, B and C, and their rate of growth during 3 portions of the study period.

Graph/Table 1 covers the period from stocking (May 14) through June 29; feeding commenced May 18. The first thing one notices from the graph is that we got off to a bad start. While in the latter part of the period (June 14 to 29) growth was satisfactory, it was certainly not so prior to that time. It may be that both the 1/8" pellets and the natural foods were too large for the fish, and that they were forced to derive a significant part of their nutrition from plankton entering the cages naturally. That this is possible is shown by the curve for Cage C, where the fish realized some growth during the period May 14 to June 14, although they were not fed.

Graph/Table 2 covers the period June 30 to September 11, during which time all three cages were being fed. Although the fish in Cage C were receiving 3% of their estimated body weight in dry food, while those in Cage B received only 2%, there is no apparent difference in growth rate except during the first two weeks of the period, which was the first time Cage C was fed at all.

The abrupt decline in mean weight of Cage B fish in the last two weeks of the period is apparently connected to the escape of 157 fish of a total of 208 during that time. Had individual fish actually lost weight at the rate indicated by the curve, it would certainly have manifested itself in poor physical condition of the fish, which was not noted during the September 11 harvest. For the sake of facilitating comparison, data from the August 31 sampling rather than the September 11 one are presented in Table 2.

Graph/Table 3 covers the final 6 weeks of the study, during which time both cages received dry feed, while Cage A also received a natural foods supplement. Growth, while very poor in both cages, was somewhat better in Cage A. The loss of weight in the last 2 weeks is associated with a sharp decline in water temperature during that time. During October most of the fish refused to accept dry feed, although natural foods were accepted whenever they were offered.

The superior growth rates of the fish which received dry feed may reflect not so much any superiority of that diet, but the difficulty of providing an adequate amount of natural food. It is virtually inconceivable that a diet composed of live earthworms and a great variety of fresh insects could be deficient in proteins or vitamins, but it may have fallen short of the fishes' carbohydrate needs. We could, of course, increase the total weight of natural foods and therefore the amount of carbohy-

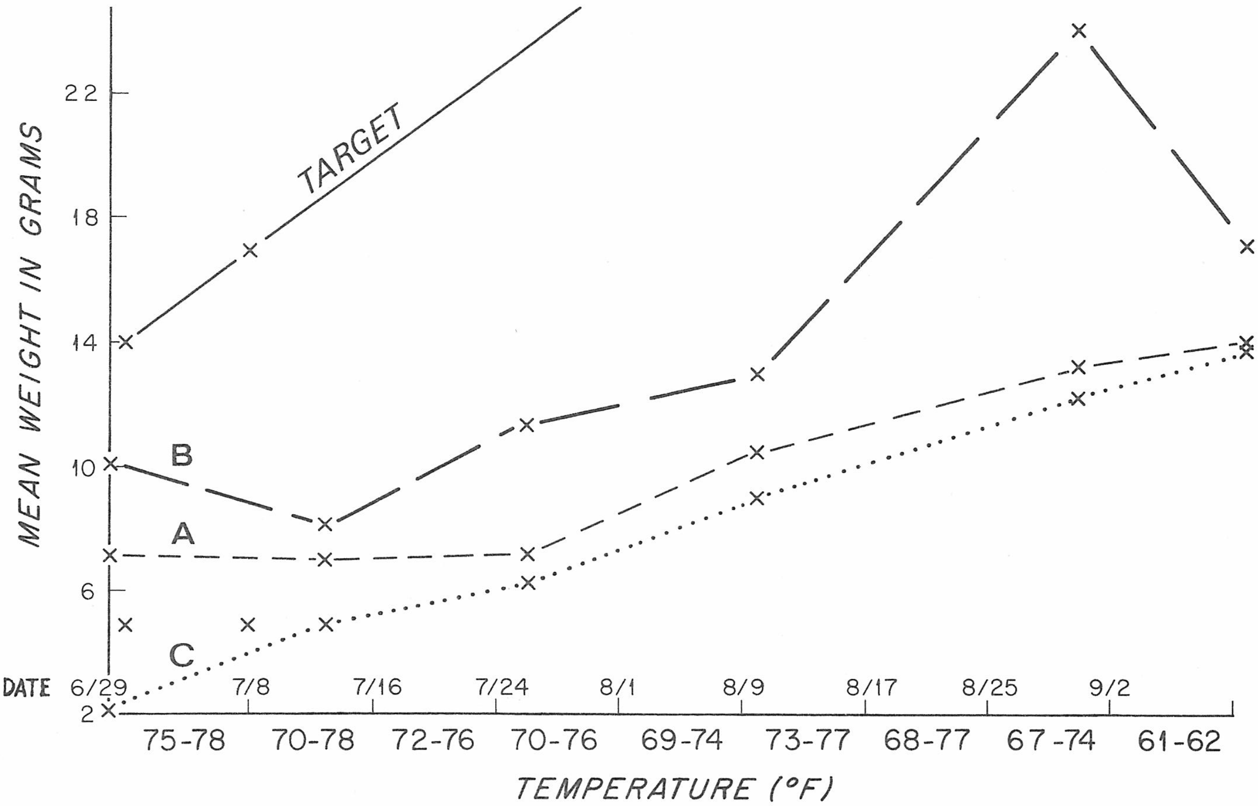


Table 2. Growth of Caged Hybrid Sunfish, June 30-August 31

Cage	Est. total wt. of fish (June 29)	Mean wt. of sample fish (June 29)	Est. total wt. of fish (Aug. 31)	Mean wt. of sample fish (Aug. 31)	Per cent growth (June 30-Aug. 31-based on mean wts.)	Per cent growth (May 14-Aug. 31 - based on mean wts.)
A	1420 grams	7.1 grams	2640 grams	13.2 grams	86%	428%
B	2040 "	10.2 "	4820 "	24.1 "	136%	995%
C	440 "	2.4 "	2460 "	12.3 "	413%	957%
To-tal	3940 "	6.6 "	9920 "	16.5 "	151%	617%

drates reaching the fish by improving the efficiency of our worm culture or by adding additional types of food. But we should also consider a compromise feeding strategy. Carbohydrate is relatively easy and inexpensive to supply in dry form; the cost of prepared fish feeds is largely due to the protein components. On the other hand, protein and vitamins are present in high proportions in most natural foods. It may be that the "ideal" fish diet would be a dry feed made of cheap grains, plus a smaller quantity of live or fresh food of animal origin.

Comparison of the different diets aside, the harvests from the cages were uniformly disappointing. One factor which may have contributed to this has already been mentioned — use of food particles too large for the small fish in the first month of the study.

There may also have been some problems with water quality. Periodic testing of dis-

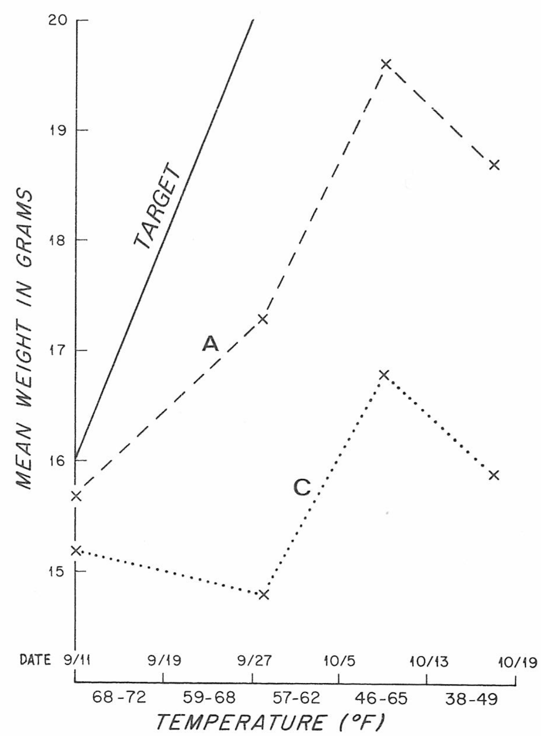


Table 3. Growth of Caged Hybrid Sunfish, September 12-October 19

Cage	Est. total wt. of fish (Sept. 12)	Mean wt. of sample fish (Sept. 12)	Total wt. of fish (Oct. 19)	Mean wt. of fish, (Oct. 19)	Per cent growth Sept. 12-(Oct.19 - based on mean wts.)	Per cent growth May 14-(Oct.19 - based on mean wts.)
A	3535 grams	15.7 grams	4020 grams	18.7 grams	19%	———
C	3430 "	15.2 "	2505 "	15.9 "	5%	———
To-tal	6965 "	15.3 "	6525 "	17.8 "	16%	674

solved oxygen concentration and pH in the cages and in the open pond always revealed near-optimum levels. No differences were observed between the two environments. But there may have been other problems we were unequipped to detect. Due to unusual hydrological conditions which prevailed in 1976, the volume of water in Grassy Pond was well below normal and the channel which ordinarily connects it with a larger pond dried up. This combination of circumstances may have contributed to a build-up of sulfur compounds or other harmful substances which would normally have been flushed out or diluted. (The presence of sulfur was obvious to anyone wading in the pond.)

Time of feeding may have been more important than we at first surmised. Initially the fish were fed only in the morning; later a late afternoon feeding was added to the schedule. Feeding during the full heat of the day was avoided, but a strict schedule was not kept. At first, the fish fed enthusiastically whenever food was offered; but, as the season progressed, they became more reluctant to accept the dry feed. Late in the season a few feedings were done very near dawn or dusk, and the fish appeared much more enthusiastic. It seems as though better food utilization might have occurred if we maintained a strict dawn/dusk feeding routine.

Of course, the total weight of fish obtained in the final harvest was reduced by the loss of some individuals. I have mentioned the loss of the majority of the fish from Cage B. At various times during the year, 15 fish were lost due to diseases or accidents. At the final harvest, 16 other fish were missing from Cage A and 68 from Cage C. It seems unlikely that these fish could have escaped, but neither is there any other apparent explanation for their disappearance.

There is another possible reason for the low production of our cages which should be considered. I may have chosen the wrong fish. Hybrid sunfish are a new idea in aquaculture, and a good one; but in my excitement over them I neglected to consider carefully the character of the environment I chose to work in. At least 12 species of fish inhabit Grassy Pond. Among them are two sunfishes, the bluegill, one of the parent species of our hybrids and the pumpkinseed (*Lepomis gibbosus).* Neither grows rapidly nor attains large size frequently in Grassy Pond, although both species do well in nearby ponds. The brown bullhead *(Ictalurus nebulosus)*, on the other hand, does better in Grassy Pond than in most ponds in our vicinity. The brown bullhead is a fine food fish with omnivorous feeding habits and generally hardy; it should do well in cage culture. In 1977, funds permitting, we shall test both sunfish and bullheads with a variety of diets incorporating both prepared dry feeds and fresh natural foods.

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Neff, G. N., and P. C. Barrett. 1976. *Profitable Cage Culture.* Inqua Corporation, P. O. Box 1325, Homestead, Florida 33030. 30 pp. $1.00.

ADDRESSES OF SUPPLIERS OF EQUIPMENT AND INFORMATION CITED:

Farm Pond Harvest. Professional Sportsman's Publishing Company, Box AA, Dept. C , Momence, Illinois 60954.

Manufacturers of cages and materials for making cages:

Astra Pharmaceutical Products, Inc., Framingham, Massachusetts 01701. (Cages)

E. I. DuPont de Nemours and Co., Inc., Film Department, Wilmington, Delaware 19898. (Vexar netting)

Inqua Corporation, P. O. Box 1325, Homestead, Florida 33030. (Cages)

Panduit Corporation, 17303 South Ridgeland Avenue, Tinley Park, Illinois 60477. (Ties for fastening netting to cage frames)

C. E. Shepherd Company, P. O. Box 9445, Houston, Texas 77011. (Cages and coated wire for making cages)

Manufacturers of "bug lights"

Environmental Systems, Inc., RFD 1, Peterborough, New Hampshire 03458.

Gilbert Electronics, Inc., 3113 East Nettleton Avenue, Jonesboro, Arkansas 72401.

Hedlunds of Medford, Inc., P. O. Box 305, Medford, Wisconsin 54451.

Ken's Channel Catfish - Hybrid Bream Hatchery and Fish Farm. Route 1, Alapaha, Georgia 31622.