

TABLE 1: PROJECTED INVESTMENT
IN AND INCOME FROM A CAMPESINO
FISH CULTURE UNIT

Investment (in \$ Colombian):	
Pond construction, with pick and shovel	\$ 800
Construction of inlet and drainage ditches	400
Cost of twenty-four cages, at \$40 each	960
Food plants	300
Unforeseen costs	540
Total Investment	\$3,000
Annual Maintenance Cost:	
(Including repair of cages)	\$1,500
TOTAL	\$4,500
Income	
Net Production per cage, first year	26 kg
Production of twenty-four cages, first year	624 kg
Value of harvest, first year (assuming a price of \$10/kg of fish)	\$6,240
Value of the harvest, second year (minimum of two harvests)	\$12,480
As of Summer, 1975, \$28.50 Colombian was the equivalent of \$1.00, U. S. Funds	

creased nourishment provided by the fish to the campesino family and to their livestock must be added.

DISCUSSION

Professor Patiño envisions that such ponds could be set up not only on campesino farms, but also "in grammar and high schools, in training schools, vocational agricultural institutes, in SENA, and even in the universities" where they would serve educational, scientific and recreational functions, as well as provide food. He suggests that the crop could be used in school cafeterias or shared among the students. "The development of fish culture should be conceived as a great crusade operating throughout the national educational system," he writes, "How much more useful and functional this type of activities and educational experiences would be than the bland and repetitive textbook instruction which is now given in our centers of education."

I can only add that the need for the type of education and action urged by Professor Patiño extends

far beyond Colombia. The lack of effective aquaculture programs in most of Latin America is obvious. Those few which have been proposed or enacted are mostly concerned with taking advantage of long growing seasons and cheap labor supplies to produce a product for export or sale to the relatively affluent, and confer economic benefit only to the entrepreneur and a handful of laborers. A few plans which have taken better aim at the important economic, nutritional and ecological problems have foundered for a variety of reasons — biological bottlenecks, lack of research funds, failure to approach the problem at a level meaningful to the campesino, etc. Professor Patiño has surmounted these problems to design and test a fish culture system that is ecologically and economically sound with great potential to alleviate some of the problems of Latin America.

— Anibal Patiño R.

Précis by William O. McLarney

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A New Low-Cost Method of Sealing Fish Pond Bottoms

In no part of the world is aquaculture less developed than in Latin America, despite its great potential there and the shortage of protein foods in much of the region. One of the constraints on the development of Latin American aquaculture has been the porosity of many of the soils — a problem which is by no means limited to Latin America. Such was the case with a 200 m² pond constructed in 1973 at Finca El Uno, located at Tirimbina, Provincia de Heredia, Costa Rica. Compaction of the soil alone was not enough to enable the pond to hold water. The soil at the pond site appears to contain quite a high percentage of clay, but there is a porous, sandy layer at a depth of 2-3 feet. Rainfall in the area is about 120 inches annually.

Similar problems have been solved in a variety of ways in the United States and other affluent countries. Bentonite clay is the most common sealing agent; when mixed with the pond bottom soil in the proper proportions it forms a colloidal seal. A similar effect may be achieved through the application of certain chemical salts. Many American fish farmers have lined their ponds with sheets of polyethylene, butyl rubber, and other synthetics, which are then buried. In extreme cases, small ponds may be cemented.

All the sealing methods mentioned so far share the characteristic of being expensive. This is a disadvantage anywhere, but in situations where capital is a major limiting factor, the expense can be prohibitive. We were able to circumvent this problem by applying a virtually cost-free method of sealing at Finca El Uno. The technique does not originate with us, but is of Russian origin and has not been well publicized. We became aware of it when Marsha Zilles of Santa Barbara, California, sent us a copy of an abstract from an architectural design journal briefly describing how Soviet scientists had sealed ponds by artificially inducing the formation of a "gley" or "biological plastic", as occurs naturally in bogs.¹ The process, as adapted for use in Costa Rica, proceeded as follows:

1. The pond bottom was completely cleared of debris, rocks, etc.
2. The bottom and sides were covered completely with wastes from nearby hog pens. Care was taken to apply the material to the vertical sides of the pond as well as to the bottom. This layer and each subsequent layer of material was added in

quantities sufficient to just cover the previous layer.

3. The hog pen waste was completely covered with freshly cut grass and banana leaves, plus a few discarded cardboard cartons.

4. A third layer, of soil taken from near the pond site, was added and tamped down firmly.

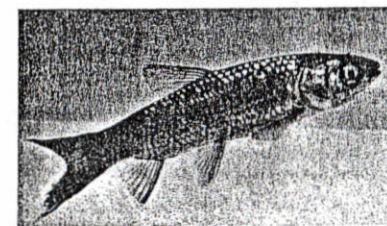
5. After between 2 and 3 weeks, the pond was flooded.

The pond retained water immediately upon filling, with no leakage whatsoever. The cost of sealing was limited to labor costs; the materials used were all "wastes" which would have been discarded in the course of normal farm operations.

The process involved in forming the seal is a bacterial one, which requires anaerobic conditions. It is possible that plastic and rubber pond liners actually act in the same way. While great care is taken to prevent punctures in the installation of such liners, it may be that their long-term effectiveness is, in fact, a result of the creation of anaerobic conditions underneath the liner. The suggestion is that a variety of waste materials, if properly applied, would seal porous soils, thus enabling the Russian method to be adapted for use practically anywhere.

So far as we know, the experience reported here is the first test of the gley formation method of pond sealing in the tropics, or anywhere outside the U. S. S. R. If its application turns out to be universal, as appears likely, the implication is that many areas of the world which, up to now, have been closed to aquaculture (except perhaps by large corporations or government agencies) can now be opened to this method of food production. We would very much like to hear about any experiences our readers may have with pond sealing.

— William O. McLarney
J. Robert Hunter



1. *The Journal of the New Alchemists* (1) p. 35.



Photo by John Cressy

Walton Two: A Compleat Guide to Backyard Fish Farming

by William O. McLarney and John Todd

Section 1

INTRODUCTION

Before we ask our readers to embark upon the noble art and science of raising fishes in their own backyards, it might perhaps be wise to explain ourselves. In these troubled times there no doubt will be those who think there are more productive or important pursuits. Nuclear disarmament, wise government and the reformation of institutions undoubtedly demand our finest energies. The needy, trapped by birth or circumstances in various kinds of hell, must be helped. We admit these problems demand the best minds.

We address ourselves to an equally relevant yet more distant reality - to some five to twenty years hence when the world may undergo rapid and unhappy changes caused by our long misuse of the earth's living mantle

and by the exhaustion of stored fuels. We don't believe the nuclear myth that claims that new powers will save us in the nick of time. In fact, we view the development of the atom to be humanity's folly; the spectre of the peaceful atom is as frightening in the long run as the existence of the nuclear military establishments.

New Alchemists are builders of "lifeboats" and "arks". It is our contention that they will be needed desperately, if humanity is to avoid famine and hardship, and manage to shift to modes of living which restore or rekindle our bonds with nature.

It is strange that such diverse sources as the Club of Rome, sundry ecologists and economists, and the American Petroleum Institute all concur that there is evidence of serious trouble ahead and there has been

minced sugar cane and table scraps, plus whatever the animal can forage. Such a diet is usually deficient in animal protein. Colombian campesinos cannot afford to make up this deficit by the use of concentrates, as is done in more affluent countries. Professor Patiño suggests that excess small cultured tilapia could fill this gap. For this purpose he recommends *T. mossambica*, which can be maintained without supplemental foods on plankton in fertilized ponds, and multiplies more rapidly than *T. rendalli*. The two species could be grown in polyculture, or a separate small pond could be set aside for *T. mossambica*. The pigs or chickens could be maintained near the fish pond so that the ponds can be fertilized with their manure.

Young *T. mossambica* were tested for acceptability as food for chickens and pigs. The tests on chickens were preliminary and established only that chickens prefer cooked fish. Tests with hogs were more extensive. These animals eagerly accepted whole, raw young *T. mossambica*. They had no difficulty with bones or fin rays.

One quantitative feeding experiment was conducted with hogs. Four one month-old Duroc Jersey hogs were divided into two pairs (one male and one female per pair). The control pair, which had a mean weight of 8.6 kg, was fed twice daily with cooked platanos (including peels) and minced sugar cane, in increasing quantities as the animals grew. The experimental pair, with a mean weight of 7.5 kg, received the same diet, plus a daily ration of whole, raw *T. mossambica* measuring up to 8 cm in total length. The daily tilapia ration was 100 g per hog at the start of the experiment and was increased to 250 g over the experimental period.

After four months, the hogs were weighed again. The mean weight of the control animals was 16.5 kg, that of the test animals 24.5 kg, or 33.1 per cent more, even though they had started the experiment being slightly smaller. The mean weight gain of the controls was thus 7.9 kg, or 48 per cent, while the hogs whose diet was supplemented by tilapia had a mean weight gain of 17.0 kg, or 69.4 per cent.

Professor Patiño does not consider the final weight of either pair of hogs satisfactory, due to irregularities in the feeding regime. Neither can his results be considered statistically significant. Nevertheless, the experiment indicates what might be achieved.

THE "CAMPESIÑO FISH CULTURE UNIT" AND ITS ECONOMICS

Based on the results of the experiments described here, Professor Patiño has drawn up a plan for a "Unidad Piscícola Campesina" (Campesino Fish Culture Unit), using *T. rendalli*, with the potential to accommodate additional species. The physical layout of such a system is illustrated in Fig. 1.

His plan for the UPC, as he calls it, includes the following instructions:

1. Select a pond site with the help of an expert. New Alchemy's new method of pond sealing could render site selection easier (McLarney and Hunter, see page 85).

2. Plant the area around the pond site with fish food plants. Professor Patiño suggests one hundred stalks of yuca, one hundred roots of bore, chayamansa and other suitable plants as available locally. These need occupy less than ½ hectare. It is important to plant before beginning pond construction, so that the plants are producing by the time the fish need food.

3. Build two ponds:

a. A nursery pond ("estaque criadero"), 5 m x 20 m x 1 m, connected by a ditch to a good water source, with another ditch for drainage. When filled, the nursery pond should be fertilized. When the water turns green, add five hundred to one thousand juvenile *T. rendalli*.

b. A growing pond ("estaque para jaulas") near the nursery pond, also provided with inlet and outlet ditches. The growing pond should be at least 3 m x 20 m, and 1.5 m deep. Plant this pond with aquatic plants and introduce twenty-four cages, each measuring 1 m x 1 m x 1 m, spaced equidistantly. Each cage should be equipped with legs to keep it 30 cm off the bottom.

4. When the tilapia start to grow, select individuals 6-8 cm in total length and stock them at 200 per cage. All the cages can be stocked at once, or stocking can be staggered to suit the culturist.

5. Feed the fish in the cages twice daily, in the morning and late afternoon, with leaves of the food plants. Feed as much as the fish will consume, but no more. If feasible, supplement their diet with wheat or rice bran.

6. Inspect each cage monthly to determine if health and growth of the fish are satisfactory. For this purpose, the cages may be lifted slightly so that the quantity of water in them is reduced. They should not be lifted completely out of the water or held up too long, as the fish will become very excited and subsequent losses due to jumping out may occur.

7. Harvest after five months, or when the fish have reached the desired size.

Using the costs reported by campesinos who have built ponds in the vicinity of Mateguadua, and the results of the experiments reported here, Professor Patiño makes the following economic projection (Table 1).

According to Professor Patiño's projection, in the first year, with only one harvest and all of the initial costs of construction, a profit of \$1,740 Colombian dollars could be realized. In subsequent years, with harvests up and expenses down, the projected profit would be \$10,980 Colombian, with only two harvests per year. To any such evaluation the benefit of in-

"God is said to have spoken to a fish, but never to a beast."

As in Frank Walton, *The Compleat Angler*, 1653

of useable vegetation.

4. They are tolerant of poor soils.

Professor Patiño suggests the consumption of aquatic plants by *T. rendalli* might be useful in weed control. I would like to suggest that in some instances they could be "pastured". In general, the provision of vegetable foods for tilapia should be left up to the individual farmer who best knows his local resources. If the leaves of a plant, such as yuca or banana, which can also provide the farmer with food or a cash crop, can be employed, so much the better.

CULTURE OF *T. RENDALLI* IN CAGES

The major problem in tilapia culture is overpopulation resulting in stunting. Three solutions have been applied.

1. Careful selection of only male fish for the culture pond.

2. Production of "monosex" hybrids — one hundred per cent male or nearly so.

3. Careful use of predatory fishes to thin, but not eradicate, the tilapia.

These techniques all require inputs of energy and managerial skill which cannot ordinarily be expected of the Latin American campesino embarking on a completely new food-raising enterprise. Cage culture solves the problem more simply. The eggs of all species of tilapia sink and are initially deposited in a nest dug in the bottom of the pond. When the fish are confined in wire cages suspended off the bottom, the eggs pass through the cage bottom out of reach of parental care. The pond in which the cages are placed or preferably, another pond, can be used as a natural "hatchery" in which tilapia are left to multiply virtually unmanaged. From time to time, stock can be selected from this pond for intensive culture to market size in the cages.

Other advantages of cage culture include:

1. Intensive culture with minimal labor and materials.

2. Technological and economic feasibility for the campesino.

3. Facilitation of feeding, inspection of the stock and harvest.

4. Continual harvest and replenishment of growing stock.

5. Rendering many types of water bodies useable for fish culture.

The first two cages constructed by Professor Patiño and the students were made of galvanized wire mesh and chanu or chano (*Humiriastrium procerum*) a local water-resistant wood. The cages, 2 m x 1 m x 1 m, were situated on legs which raised them 25 cm off the pond bottom. Later cages were constructed more economically by making four of the sides from such indigenous materials as cane. Wire was used for the bottom so that enough light could penetrate to permit the growth of oxygenating plants underneath the cage.

The cages were placed 1 m apart in one of the ponds, over a dense growth of *Elodea*. Each cage was stocked with 50 or 100 three-month-old *T. rendalli* with a mean weight of 22.5 g. Each cage received a handful of bore leaves twice daily. Two cages received an additional daily supplement of wheat bran. At the beginning of the experiment each cage was given ½ kg of bran daily. This was gradually increased to 1 kg/day.

The result was excellent growth and low mortality (four per cent). For the first month the young fish, which had been reared previously on commercial pelleted food, refused to eat the bore leaves. Subsequently they accepted the leaves and grew rapidly. After five months in the cages, when the fish were eight months old, the mean weight of the fish not receiving the bran supplement was 165 g. Those receiving the supplement averaged 200 - 250 g. Growth slowed considerably after five months, indicating the logical time to harvest.

After five months, the tilapia which did not receive the bran supplement had increased their weight by a factor of 7.33. The comparable factor for the supplemented fish was 8.89 - 11.11.

For purposes of comparison, Professor Patiño cites Kuronuma (1968) who describes the cage culture of various marine fishes in the fertile Inland Sea of Japan. Kuronuma considered an annual production of 29 kg/m² remarkable. These fish were fed a high quality dry food with a conversion ratio of 1.6. In Professor Patiño's experiments, the unsupplemented *T. rendalli*, stocked at 100 fish/cage, produced 28.5 kg/m² of pond surface in five months. While no attempt was made to determine the conversion ratio of bore leaves, it was undoubtedly much higher than 1.6. At New Alchemy East we have achieved a good conversion rate of 1.5 with *Tilapia aurea* and *Tilapia zillii*, and believe that part of our success is due to small amounts of animal protein (earthworms, insects, etc.) in their diet, particularly when the tilapia are small (McLarney and Todd, 1974).

"One-upmanship" in terms of weight/surface area data is an occupational disease of fish culture. Undoubtedly the production achieved by Professor Patiño could be bettered by using concentrated foods or by technological improvements. What matters is not competition among fish culturists, but the fact that his technique is inexpensive and does not require great sophistication on the part of the farmer, yet can result in the production of hundreds of kg of fish in a short time within a small area.

INTEGRATION OF FISH CULTURE WITH CULTURE OF HOGS AND CHICKENS

Professor Patiño points out that, while Colombian farmers commonly raise chickens and hogs for sale or their own use, growth of these animals is limited by their diet, consisting chiefly of corn, platano peels,

little effort in any segment of society to research and create alternatives within an ecological and self-renewing framework.

This apparent collective need to bury our heads in the sand has frightening portent. If reality is not faced there will be no option but to play out the drama against the backdrop of our time. It was this inaction, added to the practice of governments, businesses and universities of making a commodity out of genuine crisis that spawned the formation of The New Alchemy Institute. It seemed necessary to us to leave academe in order to pursue without compromise those problems facing humanity that seemed most important to us. We have not regretted our decision although finding support has proved difficult.

The authors of this manual began collaborating in the mid-1960's in Ann Arbor when we shared research space in the basement of an old university building which formerly had been a morgue. Our work was disparate but related; Bill was studying the behavioral ecology of stream fishes in southeastern Alaska,* and John was researching fish navigation and communication. We made several discoveries which helped unveil the mysteries of the fish's world. We found that catfishes navigate through a taste sense which is spread over their bodies,** and that some fishes have evolved chemical languages by which they communicate complex and intriguing social information.*** The aquatic medium was for us a strange and fascinating milieu, one to which we are still continuously drawn in order to learn of the workings of the world.

Several years later we worked together in San Diego to research the influence of environmental stress on the behavior of fishes. A laboratory exercise which had been set up to demonstrate to our students the effects of DDT on the social organization of fish proved a pivotal point in our lives. We discovered that, in some species, minute quantities of the poison could sever key social bonds, including those between parents and their young. On the other hand, several species were

not affected. We found the more highly the fish were evolved socially the more vulnerable they were to DDT. We became concerned that industrial societies might be triggering a natural selection process in lakes and oceans that could lead to the replacement one day of the more social and highly behaviorally organized creatures with organisms that would be more primitive socially. It seemed we were peering into an evolutionary process that was turning backwards as a result of mankind's insensitivity.

We established a research program to explore the inter-relationships among environmental stress, fish social behavior and the nature and stability of ecosystems. We wanted to learn whether behavioral studies would permit glimpses into the evolutionary past thereby enabling us to gain some understanding of the fate of a species exposed to pollutants and unstable environments. Subsequently the program was moved from San Diego to the Woods Hole Oceanographic Institution on Cape Cod.

After several years the first pieces of the jigsaw puzzle began to fall into place. We found that there are indeed linkages between the behavior of an animal, its environment and its vulnerability to stress. An environmental ethology theory was formulated to explore and map out this new area in biology.*

During this period, Bill was winding up the three-year task of writing, with two other noted ocean scientists, the definitive English language text** on marine and freshwater aquaculture, and had acquired during his travail extensive knowledge on the culturing of aquatic foods.

Neither of us liked the doomwatch aspect of our stress research, though it was fascinating. It had led us into a worldwide network of environmental scientists, most of them with nothing but bad news from their discoveries. Many were too narrowly focused and specialized to see the implications of their work, but a few did; it was not long before we began to discuss what creative and positive steps could be taken to

* McLarney, W. O. 1967. Intra-stream Movement, Feeding Habits and Population of the Coast-range Sculpin, *Cottus aleuticus* in Relation to the Eggs of the Pink Salmon, *Oncorhynchus gorbuscha*. Ph. D. Thesis, Univ. of Michigan, 131 pp.

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** Bardach, J. E., J. H. Todd and R. Crickmer. 1967. Orientation by Taste in Fish of the Genus *Ictalurus*. Science 155: 1276-1278.

*** Todd, J. H., J. Atema and J. E. Bardach. 1967. Chemical Communication in the Social Behavior of a Fish, the Yellow Bullhead, *Ictalurus natalis*. Science 158: 672-673.
Todd, J. H. 1971. The Chemical Languages of Fishes. Scientific American 224(5): 98-108.

* Todd, J. H., D. Engstrom, S. Jacobson and W. O. McLarney. 1972. An Introduction to Environmental Ethology: A Preliminary Comparison of Sublethal Thermal and Oil Stresses on the Social Behavior of Lobsters, and Fishes from a Freshwater and a Marine Ecosystem. Woods Hole Oceanographic Institution Technical Report, 72-42, 104 pp.

Todd, J. H., W. O. McLarney and M. Power. In Press. Environmental Ethology: A Comparative Study of the Relationships Between the Social Organization of Fishes and Their Ability to Withstand Thermal Stress.

Four additional component papers have been published or submitted as a result of the research.

** Bardach, J., J. Ryther and W. O. McLarney. 1972. Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. J. Wiley and Sons, 868 pp.

help an unhealthy planet. Twenty-first century pioneering was very much on our minds. In late 1969 New Alchemy was born.

We realized at the outset that the problems facing humanity were interrelated and could not be dealt with separately if lasting changes were to ensue. Energy, food, environmental health, land use, manufacturing, our estrangement from ourselves, each other, and the living world, and governmental crises were woven into the same tapestry.

This very interconnectedness is overwhelming, and most often inhibiting. Where is the forest and where are the trees? Yet only a wholistic approach to survival and reconstruction is appropriate if humanity is to avoid the agonies inherited from earlier social, economic or technical "fixes." For an individual, the only genuine way to approach wholism is to reduce the sense of scale to as much of the world as can be directly experienced and perhaps comprehended. The keys to the future seem to lie in a reduced sense of scale, and a wholistic kind of pioneering which could be at once exciting and creative, yet require little capital. Where to begin? That was very much the question then.

During our earliest discussions it was proposed that one approach to food crises, as well as alienation from nature, would be to have everyone to become a farmer. If people could spend part of their time culturing many of their foods in a manner that would be pleasurable and without heavy toil, could new notions of freedom and cooperation evolve?

It seemed, at first, a sick joke to entertain such fantasies. The facts were not in our favor. In conventional terms such notions don't usually work. Most people have neither capital nor resources to purchase land or equipment to farm. At the present there is little popular demand, even among radicals, for land reform. Nor is there a popular social or political vision of nations and regions as gardens. Eden is hidden from us. Besides, as the "realists" are so fond of pointing out, most people wouldn't want to farm. The country hick is still the lowest caste in our popular mythology.

Yet our idea wouldn't go away. We knew that the majority of families keep dogs or cats, tropical fish, birds, even alligators. Many tend lawns, cultivate house plants, prune hedges or garden. Psychically, people are drawn to living things, even when their pets are just caricatures of nature. There is something basic about the need in most of us for a relationship with non-human life — even in our plastic-fantastic society where nature herself is feared.

As humans, we want to be involved with life. Perhaps then it's not too great a step for us to transfer this drive to an involvement with creatures that can sustain us, and thereby enhance the living world beyond ourselves. This innate urge perhaps needs only to be cultivated, educated and extended for people to see why they must

begin to culture their own foods and become actively involved in developing deeper relationships between nature and human communities. Those who come to see the connection between their urge to be closer to life and the need to culture some of their own food would become, in spirit, farmers and stewards of the earth. Their fields could be as humble as boxes filled with earth, their forests a stand of trees against a brick wall, and their lakes small pools where life in great diversity could nourish and sustain them. Their efforts could become a vanguard followed by other restorative changes.

We began to see glimmerings of survival possibilities and, beyond these, transformations for society. In pragmatic terms these new beginnings would require little capital and small spaces to send down first roots. Miniature farms could be designed so that beautiful foods could be cultured and diets augmented everywhere. During hard times many people might be spared. We believed it would take an urban, as well as a rural agriculture to reverse the dynamic of industrial society and to create an ethic needed to restore countryside and landscapes.

The educational challenge need not be overwhelming; people could learn to grow foods, just as they learn to read or write or drive a car. Perhaps they need only to be convinced that the former can be exciting and mysterious as well as practical, and that food culture is as enlarging in its way as writing or reading, and has the added advantage of being a survival tool.

In moving from theory to practice, the first step we conceived was the backyard fish farm, a pool where most of the meat protein for a small group of people could be grown.

BACKGROUND TO THE BACKYARD FISH FARM

An anthropologist friend once told us a story about the Chinese in Malaysia many of whom have a unique custom which caught our fancy. In rainbarrels under the eaves of their houses, they keep fish intended for eating. The fish they select for culture are close to ideally adapted to the somewhat unorthodox environs of a rainbarrel. During hot days oxygen in the water is often depleted, but the resident fishes, members of a group of fishes called gouramis, have an accessory air-breathing organ, similar to a lung. They stick their heads out of the water and breathe air, thereby surviving the vicissitudes of life in a barrel. Their diets are simple and easy to obtain. They are primarily vegetarian and will happily eat foods humans reject, like gourds and the tops of tuberous plants. To their culturists they present the additional advantage of being both delicious and nutritious. Fish in a rainbarrel . . . funny, but ecologically sound, cheap, and perhaps potentially liberating from the company

To describe briefly the four species:

T. mossambica is omnivorous, but feeds mostly on phytoplankton and benthos. It is a mouthbreeder and multiplies very rapidly, which leads to overcrowding and sometimes enables it to out-compete valuable, but less prolific or aggressive species. *T. rendalli* is herbivorous by preference. Though not a mouthbreeder, it is, nevertheless, more prolific than either of the characins studied. Both species of tilapia are considered good food fishes.

The bocachico is economically the most important fish in the Cauca valley. It feeds on algae and detritus, obtained by sucking up mud and periphyton. In the Cauca valley, it may compete with *T. mossambica*. The bocachico lives mostly in standing or slow-moving waters, but requires running water to breed.

The jetudo, in nature, is entirely a creature of swiftly flowing waters. It feeds primarily on algae attached to rocks and river bottoms and is described as having a "delicate" flavor.

Professor Patiño has only begun to investigate the possibilities of culturing the two native species, but he has raised two important questions:

1. What is the behavior of the jetudo when confined in standing water?
2. What is the effect on growth of the bocachico in ponds when combined with *T. mossambica* or *T. rendalli*?

With respect to the first question, it was demonstrated that the jetudo will survive and grow in standing water. This is also true of another edible characin, the machaca, *Brycon guatemalensis*, which occurs naturally only in flowing waters (McLarney, 1973b). Sixty-four jetudo, with a mean weight of 69.3 g, were introduced into one of the ponds. Over a period of twelve months they grew to a mean weight of about 115 g. Only four died. Prior to the introduction of the fish the pond was fertilized with commercial 14-14-14 fertilizer and planted densely with *Elodea canadensis* to maintain high levels of dissolved O₂. The lowest concentration recorded during the experiment was 6.8 ppm. This experiment was disrupted somewhat by the accidental introduction of some young *T. mossambica*, which may have competed for food with the jetudo.

Two ponds were used in the tilapia - bocachico experiments. One was stocked with 150 juvenile bocachico with a mean weight of 34.7 g and 100 *T. mossambica* with a mean weight of 6.0 g. The other pond received an identical lot of bocachico plus 80 *T. rendalli* with a mean weight of 47.6 g. (It should be noted here that a possible limiting factor in culture of the bocachico is its delicacy with respect to handling. Mortality of bocachico during capture, transport and stocking was thirty-five per cent, that of tilapia less than five per cent.) Prior to stocking, both ponds were fertilized with 14-14-14 at the rate

of 1 kg/pond; at the time of stocking the water in both was light green. The *T. rendalli* pond was densely planted with *Elodea canadensis*. Three months later, *Elodea* was placed in the *T. mossambica* pond as well, to aid in oxygenation.

Periodic examination of the stomach contents of sample fish showed that there was more overlap between the feeding niches of the bocachico and *T. mossambica* than between bocachico and *T. rendalli*. While the ponds differed in such respects as size and reproductive rate of tilapia, dissolved O₂ concentration, provision of supplementary food (leaves of various plants supplied daily to the *T. rendalli*), and abundance of aquatic plants, the evidence suggests that the combination bocachico - *T. rendalli* is complementary, while the combination bocachico - *T. mossambica* - is not.

This conclusion is more strongly supported by the relative growth rates of the bocachico in the two ponds. After twelve months the bocachico confined with *T. mossambica* had reached a mean weight of about 94 g, while those in the *T. rendalli* pond had reached a mean weight nearly double that - about 175 g.

If bocachico or jetudo are to be used in practical fish culture, they must be bred in captivity. This has not been done to date, but Professor Patiño does not foresee this as a serious problem. He thinks that the process of pituitary injection, which has been successful in inducing many other typically rheophilic South American fishes to spawn in standing water (de Menezes, 1966), is likely to succeed with these species also.

The remainder of the work was carried out solely with the two *Tilapia* spp. Some of this work has further implications for polyculture.

USE OF AGRICULTURAL WASTES OR WEEDS AS FISH FOOD

A variety of terrestrial and aquatic plants were tested for acceptability for food for *T. rendalli*. Fifteen, including the aquatics *Elodea canadensis*, *Potamogeton crispus* and *Chara* sp. were consumed readily. Ramos (1971) and Huet (1970) offer additional lists of plants accepted by herbivorous tilapia. Hickling (1971) states that *T. rendalli* will accept a daily ration of 15% of its weight in yuca leaves (*Manihot esculenta*) or 33% in *Colocasia*. The difference reflects the water content of the leaves.

Of the plants tested, Professor Patiño recommends yuca, bore (*Alocasia macrorrhiza*) and chayamansa (*Cnidioscolus chayamansa*), an edible euphorb shrub indigenous to Mexico. He lists four advantages of these plants:

1. Their leaves are high in protein (17.2 per cent, 23.25 per cent and 24.2 per cent, respectively).
2. They are easy to grow and can be propagated vegetatively.
3. They grow rapidly and produce large amounts

Cultivo Experimental de Peces en Estanques

PREFACE

While one of the roots of New Alchemy lies in the disenchantment some of us feel with the framework of institutional science, we do not wish to present the attitude that there is little of value in the work being done in universities and research stations of the world. Science and technology do make important contributions and from time to time we shall describe some of the work which seems especially relevant from a New Alchemy point of view.

Such an editorial effort is handicapped by the impossibility of keeping up with all the scientific literature in even one field. We are indebted to Sr. Alberto Donadio, of Medellin, Colombia, for bringing to our attention the work of Prof. Anibal Patiño R. of the Universidad del Valle, Cali, Colombia.

Professor Patiño's work is especially gratifying to me, since he has arrived independently at many ideas similar to my own for the development of tropical aquaculture (McLarney, 1973a), and has demonstrated that they will work — biologically and economically.

The following account, which should be of interest to anyone involved in tropical ecologies or economies, is excerpted and paraphrased, with Professor Patiño's kind permission, from his paper "Cultivo experimental de peces en estanques", which appeared in *Cespedesia*, Vol. II, No. 5, pp. 75-127. For information on obtaining the original paper (in Spanish), write Cespedesia, Jardin Botanico del Valle, Apartado aereo 5660, Cali, Colombia.

INTRODUCTION

Professor Patiño's work parallels New Alchemy schemes for tropical aquaculture in four respects:

1. He advocates polyculture of certain species of *Tilapia* and local fish species.
2. The primary foods for the fish, apart from those produced by fertilizing the fish pond, are weeds, agricultural wastes or various plants which can be cultivated with a minimum of effort.
3. Selected fish are grown to market size in cages. The remainder are left, essentially unmanaged, in a pond which serves as a hatchery.
4. Excess small fish are fed to other farm livestock, such as hogs and chickens. The wastes from these animals are used to fertilize the pond.

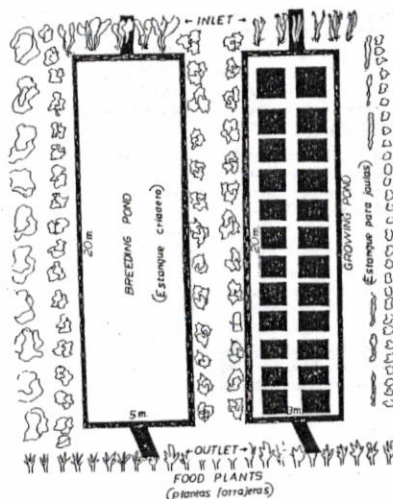
Professor Patiño has demonstrated the economic feasibility of this approach for the campesino (small farmer). He has also outlined plans for the implementation of this sort of fish culture in the countryside.

We shall discuss these features of Professor Patiño's work in the order listed above. All of the work described

was carried out in four ponds fed by the Rio Tulua in El Jardin Botanico del Valle, Mateguadua, Colombia. The ponds, each 10 m x 30 m x 1.2 m, were lined with polyethylene and fertilized with cow manure. Professor Patiño and four students from the Universidad del Valle accomplished all of the work from the construction of the ponds with pick and shovel to the conclusion of the experiments in a year and a half.

POLYCULTURE

Four species were chosen for the initial studies: *Tilapia mossambica* Peters, *Tilapia rendalli* Boulanger (= *Tilapia melanopleura*), and two native characins, the bocachico (*Prochilodus reticulatus magdalenae* Steindachner) and the jetudo or patalo (*Ichthyoelephas longirostris* Steindachner). The two *tilapia* were chosen because of the ease with which they may be cultured, and because of their different feeding habits. As both species are already established in the Rio Cauca drainage, which includes the Rio Tulua, there are no ecological objections to the use of these exotics. The native species were chosen because both are valuable food fishes currently threatened by environmental change, and because they might fill ecological niches complementary to the *tilapia*.



stores... fraught with possibilities.

Thus we were inspired to delve into intensive fish culture. But the tropics of the Far East are faraway and edible gouramis are hard to come by. Besides, rain-barrels freeze in Winter.

As ecologists, with an orientation towards the development of self-sustaining human communities, we disagreed with most of what we knew about intensive fish culture in North America and Japan. Most western aquaculture is high technology - high capital cost, people-displacing stuff. There are weird systems in Germany and Japan where fish are held in tiny aquaria like chickens in batteries and force-fed high protein foods. They are so crowded their bodies are sometimes not fully covered with water. (Bardach, Ryther & McLarney, 1972)

As one would expect the energy component, based upon electricity from fossil fuel or nuclear plants, is high. A lot of power is required to run pumps, lights, heaters, filters, feeders, sterilizers and other kinds of paraphernalia associated with the trade. There is also a lot of energy wrapped up in the construction of the technology itself.

The energy component of most fish farms is not the worst offense. The foods that are fed to trout, salmon and catfish represent a form of agricultural imperialism and make little sense in the long run. The feeds given these fish include: anchovies from Peru, herring meal, a variety of grains, soybeans, minerals and vitamins. As in feedlot cattle, foods that could be used directly by humans are lost in being converted to animal feeds. It represents an inefficient use of the world's food resources and will ultimately prove economically shaky. Soybean and grain prices are skyrocketing and may stay high. Aquaculture, as we saw it several years ago, was suffering the same malaise as afflicts agriculture, and was even competing with it for dwindling resources.

Industrial toxins such as mercury, lead, pesticides and PCBs fall with the rains and enter food webs on the ground. Animals eating contaminated plants or preying on other animals tend to accumulate poisons. We suspected that many cultured fishes had concentrated these toxins in their tissues as well. Fishes we tested from "wild" Cape Cod ponds had very high levels of DDT and its derivatives, especially in their fatty tissue. We knew we would have to look beyond orthodox aquaculture for our inspiration if we were going to develop the backyard fish farm idea.

Algae as the Primary Food in an Ecologically-Derived Fish Farm

Natural ponds, especially shallow ones, often turn green as the result of the immense proliferation of millions of tiny algae suspended in the water. If a pond is fertilized, algae blooms can be so dense as to limit visibility to a few inches below the water surface. In

such instances the production of plant matter is incredible.

Most North American fish farmers do not like algae growing in their ponds and many spend considerable time and money on poisons in attempting to eliminate them. But one of the beauties of a pond is that it is a three-dimensional space, and all of this space, in theory at least, can be used to culture foods for the fishes that reside therein, provided algae, the basis for most aquatic food chains, are allowed to flourish. We reasoned that somehow algae should become the foundation of our miniature fish farms, as they can purify wastes by using them as a nutrient source. *Algae we thought might be used as a direct source of feed, if fish that can eat algae could be found. A biologically sound form of aquaculture based upon algae would be inexpensive and available to anyone who wanted to try his hand at it. Since they are abundant in even the smallest ponds, we felt that algae might prove easy to grow.

Algae-Eating Fishes

When the great god Pan came to dispensing fish into the lakes and streams of North America, he neglected, for some capricious reason, to give us vegetarian fish large enough or sufficiently good-tasting to eat. The fish he gave us that we consider edible feed upon other fishes and small animals. Trout, perch, bass and catfish are mainly flesh eaters. We had to turn to other continents in our search for a herbivorous fish that would thrive on algae yet be tasty.

For centuries the Chinese have been doing incredible things with their ponds and lakes, and have developed fish farming to its highest state. (Figure 1 illustrates a Chinese polyculture pond). They are able to produce



Fig. 1 Chinese Carp Culture

Multi-tier and feeding niches of the principal species in classical Chinese carp culture: (1) Grass carp (*Ctenopharyngodon idella*) feeding on vegetable tops. (2) Big head (*Aristichthys nobilis*) feeding on plankton in midwater. (3) Silver carp (*Hypophthalmichthys molitrix*) feeding on phytoplankton in midwater. (4) Mud carp (*Cirrhinus moliorellus*) feeding on benthic animals and detritus, including grass carp feces. (5) Common carp (*Cyprinus carpio*) feeding on benthic animals and detritus, including grass carp feces. (6) Black carp (*Melopharyngodon piceus*) feeding on mollusks.

*R. Anderson & B. R. Howell, 1973. The effects of algae on the water conditions in fish rearing tanks in relation to the growth of juvenile sole, *Solea solea*. *Aquaculture* 2(3), 281-288.

enormous amounts of food from standing bodies of water. Eight thousand pounds of high quality fish per acre is not uncommon (Bardach, Ryther & McLarney, 1972.)

Chinese aquaculture is eminently biological and is based upon the careful selection of a variety of native fishes. Herbivorous species predominate. Fish farmers do all they can to encourage algae growth including building latrines over ponds as a source of fertilization. The algae in their ponds provide the bulk of the food consumed by several favored species of fishes. In our opinion Chinese aquaculturists have a lot to teach the world about raising foods using the strategies of nature. The present Chinese regime has extended the tradition, and we have been told that their total production of freshwater foods is staggering.

Tilapia

It was an algae-eating fish with African origins that caught our fancy as a candidate for the backyard fish farms. This fish, called tilapia or St. Peter's fish, is common throughout Africa and parts of the Middle East. It was the fish sought by fishermen in the Sea of Galilee in Christ's time and legend has it that this was the fish he fed to the multitudes.

Tilapia have a lot going for them. They are relatively peaceful and, unlike many of the Chinese fishes, very easy to breed and transport. They can be grown in dense associations. Tilapia, depending upon the species, feed mainly on algae or aquatic vegetation and have a reputation for being superb tasting. They have had the added advantage of being cultured experimentally in several places in the southern United States. We thought they might be available for our use.

There remained a major obstacle to our culturing tilapia, namely, the fact that they are a tropical fish and require warm water for growth and reproduction. They would be unable to survive in the wild in North America except on the southern end of Florida or in the lower reaches of Texas and the Imperial Valley in California where they are already feral. From an environmental point of view this inability to survive in the wild was an asset as we would not be responsible for introducing an exotic fish that would enter lake ecosystems and upset natural ecologies, as the carps from Europe have done over the last hundred years.

The temperature sensitivity would have seemed to rule out tilapia, but we were becoming interested in researching non-polluting sources of energy, like the sun and the wind, and wanted an excuse to use them where possible. If we could trap the sun's heat and store it in ponds, we might be able to create a "tropical" environment for enough of the year to raise at least one and perhaps several generations of tilapia. During the cooler months, the solar-heated

ponds might be suitable climates for growing plants and perhaps even one or two cooler water fish species. The decision to use tilapia and to try to duplicate their requirements in our ponds turned out to be a happy one. In 1971 we built our first little dome-covered pond in the woods not far from the sea on Cape Cod.

BASIC OBJECTIVES OF NEW ALCHEMY'S BACKYARD FISH FARM RESEARCH

A number of guidelines were established at the outset to ensure that we continued to work towards our ultimate objective of building and testing low energy, low cost, ecologically-adaptive culturing systems for fishes. These miniature farms were to be suited to the needs of individuals or small groups with little in the way of monetary or land resources. They were to be survival tools for urban people who might find themselves without access to good foods during crisis periods. It was further hoped their development might introduce into food culture, and perhaps the public consciousness, ecological concepts of recycling, energy conservation and biological diversity and stability. The small-scale food farm would be in some respects an image of the plant itself, providing a means of teaching stewardship and an understanding of the workings of the natural world.

Objective 1: Food Source for Urban Areas

A fish culturing complex was to be developed to provide high quality fish to fill the protein needs of a small group of people. Our initial goal was to produce about one hundred pounds of tilapia annually, during the warmer months from June through September, in the northeastern part of the United States. Longer term plans called for much larger yields and the introduction of a diversity of cultured organisms.

Objective 2: Costs

Initial construction costs were to be low. Subsequent electricity cost would be necessary to run a small water-circulating pump. Eventually we planned to eliminate electricity from the systems altogether, using wind-mills for pumping and increasing internal biological self regulation. There would be no-cost foods for the tilapia and labor would be kept minimal.

Objective 3: Self Regulation

The fish farms, designed so that they would not require constant surveillance, could be left unattended for several days on end without harming the fishes.

Objective 4: Space

We wanted to establish a fish farm in as little a space as 25' by 25', suited to cities, suburbs, alleys, rooftops or vacant lots.

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- Publications with some materials on intensive fish culture. None of these are directly applicable, but many issues contain very valuable information.
 - Aquaculture* An international journal of aquatic food research. Quarterly. Cost Dfl 84.00 or approximately \$28.00 U. S. from Elsevier Scientific Publishing Company, P. O. Box 211, Amsterdam, The Netherlands.
 - Aquaculture and the Fish Farmer*: A bimonthly publication with a considerable emphasis on biologically sound fish farming methods. P. O. Box 1837, Little Rock, Ark. 72203. \$5.00/year.
 - Catfish Farmer and World Aquaculture News* - Bimonthly @ \$6.00 per year, 530 Tower Building, Little Rock, Arkansas 72201.
 - F.A.O. Aquaculture Bulletin* - Quarterly published at the FAO offices of the United Nations, Via delle Terme di Caracalla, 00100 Rome, Italy. It is a good publication, but the editor of the Quarterly is so tight with it, that despite years of aquaculture research, we have been unable to receive a copy at N.A.I. Some universities have it. Their distribution policy should be changed so that culturists can have access to the findings of others.
 - Farm Pond Harvest* - A quarterly publication focusing upon ponds. Available from Farm Pond Harvest, 372 South East Avenue, Kankakee, Illinois 60901. \$3.00 per year.
 - The Progressive Fish Culturist* - A quarterly journal published by Bureau of Sport Fisheries and Wildlife. U. S. Government Printing Office, Washington, D. C. 20402. \$2.50/year, plus 75 cents if foreign postage.

some of his time crafting small fish farms, and in his private hours wander down to the edge of streams to cast a line or reflect upon the mysterious bounties of nature.

The world is very much with us now, and at this time as millions already die from hunger, these tiny life rafts belong everywhere.

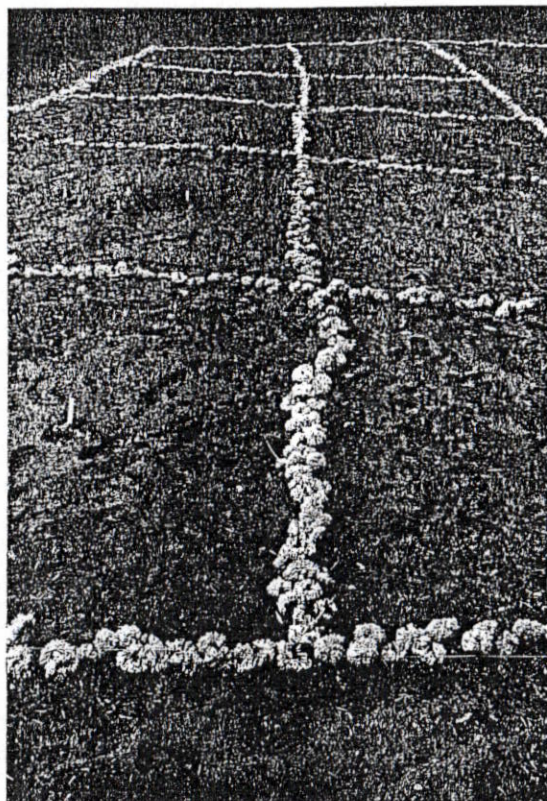


Photo by Alan L. Pearlman

Objective 5: Energy Conservation

The backyard fish farm should not be dependent upon fossil fuel or nuclear power sources. Ultimately, the primary energy inputs would be exclusively the sun and the wind, which would regulate the internal climate and transport water through the system.

Objective 6: Feeds for the Fishes

Ninety per cent or more of the feeds for the tilapia were to be algae and aquatic plants grown right in the ponds with the fishes themselves, and the supplemental animal foods were to be derived from inter-connected food chains utilizing wastes and requiring little space.

Objective 7: Filtering of Growth-Inhibiting Fish Wastes

We wanted to develop filtration and other biological techniques for the transformation of toxic, growth-inhibiting wastes to chemical substances which not only do not arrest growth, but are directly utilizable by the algae and other aquatic plants as a major nutrient resource. Intensive fish culture necessitates the removal of growth inhibitors, and our strategy was to do so in such a way that the breakdown products would be a new energy source within the system.

Objective 8: Taste

We hoped that the fish would be of the highest quality, acceptable to gourmet fish cooks. New world

pioneering or hard times hopefully should not involve neglecting one's taste buds.

After several summers' experimentation we have come a long way toward reaching many of the above goals. Installation costs have been kept down. Even our newest backyard fish farm was not expensive despite the fact that it includes a big windmill, a solar heater for water circulation and climate regulation, and some greenhouse capacity, and is constructed of long-lived materials including cement, glass and lumber.

We have been able to grow algae beyond the ability of the fish to consume them, and we have had some success developing adjunct supplemental animal food cycles. The fish farms are not temperamental and can be ignored for days on end, except for venting on the hottest days to lower temperatures within the pools.

Biological filters have been built that have enabled us to go a long way toward eliminating growth-inhibiting wastes. Consequently we have been able to grow edible size tilapia (8-10 oz.) in as short a period as ten weeks. The fish are delicious. The food editor of THE NEW YORK TIMES, John Hess, described them as the best-tasting farm-raised fish he had experienced. (Photo 1 - Tilapia)

We still have a long way to go before the full potential of the backyard fish farm is close to being tapped. Tilapia produce large numbers of young before growing

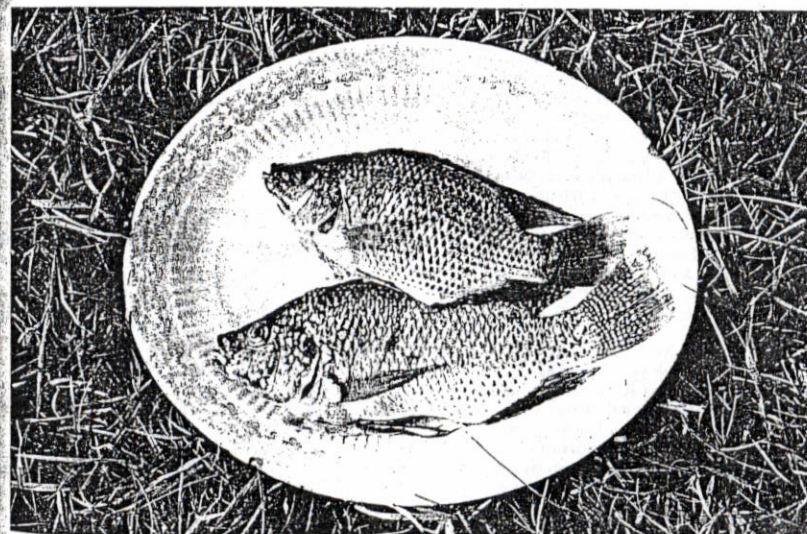


Photo 1 - Tilapia

Photo by John Cressy

to an edible size and we have yet to be able to regulate the population within the ponds and so end up with hundreds more fishes within the system than is optimal. Our yields are half what we originally hoped for. We are trying to solve population problems by introducing predators into the systems at the point when the growing tilapia become reproductively mature. We expect to locate a predator that will crop the new-born tilapia effectively while leaving the parents alone.

In the future we intend to increase the complexity of the food webs within and adjacent to the culture ponds, so that several mutually-complementary edible organisms can be cultured together. This polyculture will increase the stability and ultimately the overall productivity of the little fish farms.

Already we have found another benefit of closed system aquaculture. It provides a suitable and stable climate for adjacent greenhouses. The article describing our proposed "ARK" in another section of the Journal explores this possibility.

Despite the limitations of our efforts to date, we feel we have reached a point when it is time to chronicle our experiences and prepare a guide to backyard fish farming. We feel it would not be wrong to encourage others to begin as well. A collective effort may just make a difference during this time when food prices are soaring and the quality and future availability of foods is increasingly in doubt.

TILAPIA CULTURE AND THE BEGINNER

Tilapia culture can be easy for the uninitiated. Nevertheless there is some information that is essential to be successful at intensive fish farming along ecological lines. Tilapia, if neither allowed to be chilled nor placed in cold water, are fairly tolerant of human foibles and inexperience, and the beauty of their culture is that one can get started without an accumulated body of knowledge. In the summer tilapia culture can be as simple as digging a hole in the ground, filling it with water and adding a little manure. If the pond holds water and the water temperatures are in the sixties or seventies, tilapia will survive. They might even breed and, with a little luck, grow. With a transparent pond cover acting as a thermal trap, the tilapia pond will be more effective, and the growing season extended.

The biological and technical skills to which this guide is addressed will enable you to have more fun and grow the tilapia faster and at less cost. At the same time you will be drawn into the fascinating milieu of an aquatic ecosystem which in itself is an image of the larger realm. Despite its pragmatic origins, working with the backyard fish farm may provide some keys to stewardship in a larger context. As you orchestrate the whole, learning its strengths and weaknesses, you begin to appreciate the larger

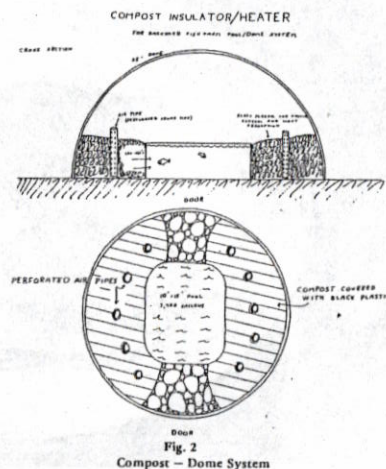
world which sustains us. Like the Karmayogis who find their way by working, yet thinking beyond it, you will be influenced by working with these microcosms. Food culture should become an element of the larger experience, and tilapia culture, like a vegetable garden, is an excellent way of beginning.

Section 2

Constructing Backyard Fish Farms: Three Possibilities

There are a number of ways to establish a backyard fish farm, and a diversity of techniques for constructing and heating the culture pools to temperatures required by tilapia for growth and reproduction. Any strategy that insures that the pond temperatures will be maintained in the seventies or low eighties for at least three months of the year will, in theory, provide an environment for raising an annual crop of tilapia. A well designed system in a favorable climate may enable one to culture two or three tilapia crops each year. In southern parts of the country less energy is required to trap and store heat within the ponds. No doubt there is a northern limit to the area where it is feasible to readily heat a pond for a period long enough to complete a single tilapia growing season.

We like to use the sun as our energy source for the ponds and have employed a variety of techniques for trapping its heat. On Cape Cod pond temperatures reach into the seventies towards the end of April and early May when a solar heater is used in conjunction



The backyard fish farms described herein are capable of producing meat protein of very high value for consumption by a small group. Already they are operational life rafts for people in need of growing their own foods who desire relatively poison-free animal proteins.

We would like to extend the backyard fish farm concept beyond its apocalyptic sense into new approaches for caring for ourselves and the planet. Their productivity and stability should be increased. It is our wish that eventually small, well-tended backyard fish farms and arks could support those who tend them. If yields increase as the lives of the tenders become more self-sufficient, then this dream may yet be realized.

In order to achieve these ideals a lot of research and study will be needed and many people should become involved. We have mapped partially the course we hope to follow.

i. We hope to incorporate a variety of ecological, no-cost tactics towards increasing yields. Already two species of tilapia with slightly different food requirements have been cultured together in a simple polyculture arrangement. We intend to increase the number of species in the system slowly and observe their impact on the whole. Crayfish, European carp, white amur or grass carp, bluegills and gouramis are all potential candidates for highly diverse fish farms.

ii. We intend to select and breed those tilapia which are most vigorous and grow most rapidly in the unusual environments within our small aquatic ecosystems. We can help these fishes adapt to their new environments. The single sex hybrids from matings between two different tilapia species should be tested. Hybrids currently being used in tropical tilapia culture are all male offspring of two species crosses. Comparable techniques in our ponds might help solve over-population problems.

iii. The research utilizing native and tropical species of predators will continue as an alternative strategy to population regulation. Tied to this work will be studies evaluating optimal densities within a given system. For example, two hundred *Tilapia aurea* may prove an optimal tilapia density for a backyard fish farm, or mini-ark, but a population of five hundred fishes of a variety of species might do equally well, and produce proportionately more. This type of information is critical to further evolution of the concepts we have discussed.

iv. Food webs to sustain the fishes have had little study or analysis. We are still determining which organisms can survive and reproduce within the ponds. We need to know, as an example, if five or ten species of tiny herbivorous insects and crustacea can thrive on the algae, without cropping it so hard that they limit algae production and therefore reduce fish production. If algae, invertebrates and fish can co-exist,

the small invertebrates might supply the animal protein needs of the fishes without harming the overall system.

v. There are many mysteries that need exploring in these miniature ecosystems. Their chemistry fascinates us, and a study is now underway to elucidate chemical changes at the various stages and locations within the fish culture complex. To know what filters and plants do to purify water is to let us in on the chemical nature of the restorative process.

vi. The structures which house the ponds need improving and further refining of their solar-trapping and heat-conservation components. It is likely that they could be built more effectively without appreciably increasing construction costs.

vii. There is also the matter of scale. We are designing the backyard fish farms and mini-arks to be tended by people. Mechanization or expensive installations are avoided as a point of principle. They are people-oriented places, exciting to work in and around. We should still like to know if larger food-raising complexes would be much more productive and stable. If so, can they be designed to be tended by three or four or more individuals and still provide some income as well as subsistence? Scale is important since many are interested in taking part in cooperative ventures. If the Ark research is funded, we will be able to gain some comprehension of scale because of its larger size. We suspect that climate, stability and self-regulation will improve as the size of the food culture complex increases, but only to a point that stops short of requiring exotic and expensive technologies. A sensitive balance between technology and biology will be the outcome of this dialogue with materials and Nature.

viii. There is the question of self-sufficiency for those who tend the arks. If their shelter were also part of the food-culturing complex, then living costs might be reduced. In other words, even though incomes might not be high, The New Alchemists are curious to find ways of using the backyard fish farms as the climate base for attached living structures. These would be arks in the true sense, whole microcosms, reflecting the larger world. Though we have a long way to travel, we now believe it will be possible to create structures in temperate regions that will house, sustain and help support those who inhabit them.

Caring for arks will take a kind of knowledge and knowing much needed in these times. With these, perhaps a new awareness will arise that could grow toward stewardship on behalf of our fellows and the planet.

This incomplete Compleat Guide is in a strange way linked to the legacy of Izaak Walton, the seventeenth century gentleman who authored "The Compleat Angler." Were he alive today he might spend

ten weeks, approximately one-third of the edible size fish from this pond were harvested during the last week of August and September by hook and line (using worms or trout chow for bait). The majority of individuals fished out before harvest were *T. aurea*, but accurate species records were, unfortunately, not kept. Harvest occurred shortly after the Dome-Pond.

EDIBLE SIZE FISH					
Species	No. fish	Total weight (kg)	Mean weight (kg)	Mean length (cm)	Length range
<i>Tilapia aurea</i>	29	6.59	0.23	22.2	18.0-27.0
<i>Tilapia sp.</i>	11	1.52	0.14	20.5	18.5-23.1
<i>Tilapia zillii</i>	0				
Fish harvested during growing season, species not known	21	4.20	0.20		
TOTAL	61	12.31	0.20	21.8 (forty fish only)	18.0-27.0 (forty fish only)

SMALL FISH					
Species	No. fish	Total weight (kg)	Mean weight (kg)	Mean length (cm)	Length range
Species not determined individually	531	4.76			3.0-14.2
GRAND TOTAL	592	17.07			

TABLE 5

Total production of this system, over a one hundred and forty-two day growing season, reckoned in the same way as for the Dome-Pond, was 17.07 kg (approximately 37½ lbs.) minus 4 kg = 13.07 kg (approximately 29½ lbs.). The conversion ratio was 0.86:1. This figure is of course theoretically impossible. If allowance were made for these factors: 1) that here we are dealing with a dry weight/wet weight ratio; 2) that there is no part of trout chow which is not consumed; and 3) that no allowance is made for the role of algae and incidental foods, the actual conversion ratios in the two ponds would probably be found not to differ greatly.

If dressing loss for these fish is assumed to be the same as for fish from the Dome-Pond, the Flat Top pond produced a total of 5.95 kg of fish in edible form. Total production from the two ponds was thus 36.06 kg of fish, with 23.94 kg of edible size fish, and 14.63 kg of fish in edible form.

Some of the difference in the data from the two ponds is undoubtedly also due to differences in species composition and numbers of fish, but there is no way, based on the present experiment, in which this can be analyzed. In general, it could be said that the characteristics of the two systems are similar. The most significant difference is in feeding. While the cost of trout chow in a system as small as ours was certain-

ly not prohibitive, it would of course increase with the amount of fish to be fed, whereas a diet of the sort fed to the Dome-Pond fish could remain essentially zero cost. There is, of course, a labor factor favoring the commercial diet. Ecologically, the non-commercial diet is clearly preferable, both because of the composition of trout chow, and because of the integration of aquaculture and agriculture it represents. We would like to encourage backyard fish farmers to make use of diversified, non-commercial diets insofar as their time, ingenuity and resources permit.

Temperature Data

Maintenance of a suitable water temperature is critical for maintenance and growth of tilapia, hence the greenhouse structures and solar heaters. Both structures were provided with vents to prevent the water from becoming too warm. Some venting was necessary from May 20 to September 4; the vents were always closed at night. The relative effectiveness of the two systems is compared in Table 6.

Month	Mean Max. & Min. Air Temperatures	Dome-Pond Max. & Min. Water Temperatures	Flat Top Max. & Min. Water Temperatures
May - 15 on	17 - 13	31.0-28.0	31.0-25.0
June	24 - 15	31.5-26.0	32.0-25.0
July	27 - 18	34.0-27.5	32.0-25.0
August	27.5 - 18	data lost	30.0-25.0
September	22 - 12	32.5-23.0	31.0-22.0
October - (up to Oct. 22)	16.5 - 7.5	25.5-21.0	25.0-19.5

Table 6

The dome was a slightly more effective heat trap throughout the season; the most probable explanation for this seems to be that it received much more of the morning sun.

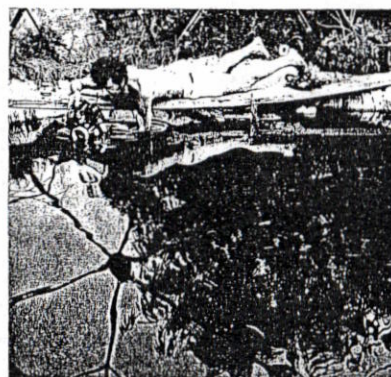


Photo by John Cressey

FALMOUTH, MASSACHUSETTS MONTHLY AVERAGE MAXIMUM & MINIMUM TEMPERATURES, MONTHLY MEAN & PRECIPITATION 1973

Month	Mean	Max.	Min.	Rain"
January	29.65	37.9	21.4	1.61
February	29.	36.3	21.7	2.98
March	40.85	47.8	33.9	3.39
April	47.3	54.8	39.8	7.38
May	54.5	61.5	47.5	4.31
June	67.6	75.8	59.4	4.55
July	71.4	79.45	63.35	6.37
August	72.2	80.6	63.8	3.41
September	61.6	70.5	52.7	3.15
October	53.2	61.35	45.06	5.63
November	42.66	50.16	35.16	2.29
December	37.5	46.5	28.5	8.44
1974				
January	31.1	39.87	22.35	4.10

TABLE 1

with covered ponds, even though the temperatures outside drop to near freezing at night.

There are other ways to heat a pond besides the sun, but we urge you to consider only those sources of heat that are derived from wastes, or renewable sources, or are free for the trapping. Some folks with a woodlot might want to have a wood stove in a combined aquaculture-greenhouse complex like the Ark or Mini-Ark. Others may decide to use a clear dome over an above-ground pool and surround the pool with an active compost heap. The compost heap in this case will impart some of its heat into the adjacent pond thereby stabilizing and elevating pond temperatures. Such a proposed scheme is shown in Fig. 2. There is a twofold benefit in this system as composting would proceed more rapidly because of the higher temperatures and moist conditions within the dome.

These are just two possibilities we have yet to test and no doubt there are many others that might work better. Here we want to describe three backyard fish farms which we have developed and worked with at New Alchemy on Cape Cod. Our climate has been a major consideration in the methods we have employed. Table 1 gives the mean, maximum and minimum temperatures for our area.

The tilapia growing season is not year-round. The fish are not overwintered in the culture systems, as too much energy would be required to maintain pond temperatures in the seventies. The tilapia are grown like any annual crop, set out in the spring and harvested approximately three months later when they reach an edible size. We expect that our newest tilapia culture system,

the Mini-Ark, with its solar collector will extend the growing season on Cape Cod to about six months, allowing two crops. Under ideal conditions we might one day culture three crops annually, especially if the first generation of tilapia placed in the ponds are partially grown young which have been overwintered indoors. It should be pointed out that we overwinter several hundred young tilapia in refrigerator liners placed next to a basement furnace. The water in the liner-aquaria is filtered to prevent the build-up of wastes. People without access to winter holding facilities can solve the supply problem by housing three or four adults in aquaria. Tropical fish stores have the paraphernalia to help you. The success of your backyard fish farm will be to a very large degree dependent on the quality of the pond and associated complex. A well-conceived and constructed system will more than pay for itself.

BACKYARD FISH FARM ONE: A DOME COVERED POND

Our first backyard fish farm was comprised of a geodesic dome covering a three thousand-gallon swimming pool. It was situated in an opening in an oak-locust woods not too far from the sea. It had the air of

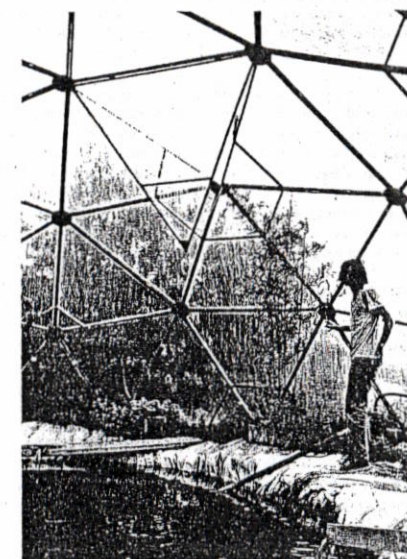


Photo 2 Photo by Alan L. Peariman

a tiny visitor from space, yet it blended happily with its surroundings. Since that time we have had a somewhat irrational attachment to the geodesic dome as a solar trap and pond cover. There is no other structure that is as much fun to sit in on moonlight nights listening to the water tumbling back into the pool from the filter, and afternoon light does exquisite things to the surface of a pond in a dome. It's possible that the one thing domes are good for is a component of miniature fish farms. In this situation it doesn't matter if they leak, as almost all do, and the fact that they are difficult to regulate climatically can be forgiven in view of the steadier nature of the pond which oscillates more slowly, never reaching the climatic extremes of the dome. The dome is a good solar trap.

Equally important, at least in the early days of our work, was the fact that geodesic domes seemed to symbolize a new confidence and a sense of mastery. Neither were fully justified, but still the dome was tied to the enthusiasms of Buckly Fuller and a pioneering spirit that was in the air. They were "New Age" tools, and somebody had to find a use for them.

We started with an 18', double-skinned Sun Dome*, and the following year moved up, and built two 25' diameter, single-skinned domes of the same design. These last two blew away or disintegrated within months of their initial construction. One late afternoon when the Cape was struck with an intense tropical storm of near-hurricane velocity, we watched as one dome was picked up and scattered over close to half a mile.

Well, the next year we built another twenty-five-footer of the same design, and it was beautifully built with reinforced components. It was skinned with a heavy vinyl and survived the growing season in grand style. But a few months later the vinyl turned opaque and began to fall apart. Apparently, the wood preservative we had lovingly applied to immunize the structure against decay, ate into the vinyl and destroyed it. So much for a long-lived structure. But the real crunch came shortly thereafter. A snow and sleet storm piled a snow load that approached eight pounds per square foot on several of the sections, and the top of the structure collapsed.

The story hasn't ended there. Undaunted by new-age engineering, Bill McLarney insisted that we have a new dome, because as he put it, "domes belong over ponds." So we have just completed a new dome and we like it. It's big and the frame is tough, comprised of 2 x 4's with hubs of heavy metal pipe. The 30' structure is held together with the same metal strapping we use on the windmill towers. (See Marcus Sherman's windmill article). The frame can be walked upon and relatively heavy objects such as fish nets and flower pots can be suspended from the ceiling. This time we painted the dome with a white primer that contained B-I-N, which we are told prevents resins and other

chemicals from leaving the wood and attacking the plastic. The design is the Pacific Dome** described on pages 20 through 24 in DOMEBOOK 2. Earle Barnhart suggests that potential builders also read page 136 of SHELTER*** - carefully.

The dome is temporarily covered with 10 mil vinyl. When we can afford it, it will be covered with more permanent materials including insulated plywood panels with reflective surfaces on the north side and fiberglass or glass materials on the more southerly exposures.

Materials are very important and we are acquiring some pretty strong opinions about those one should or should not use to build with. We use a lot of polyethylene, vinyl and other products of the same ilk, but we don't like them. Poverty dictated that we use these "cheap" substances but we are beginning to realize that there was a lot of false economy involved. Plastic is relatively cheap but it is forever being replaced and after a few years one begins to conclude that one would have been much further ahead to use materials that last a life time, or longer.

Vinyl and polyethylene are manufactured from petroleum. Some of the life extenders put into plastics are amongst the most toxic and persistent chemicals known to man. Plastic rips and is in constant need of repair. We are forever picking up the scattered bits that litter the landscape. As children, many are conditioned by cheap plastic toys to believe that impermanence is progressive, maybe even essential. This subtle but insidious commercial violence has often gone unnoticed but has been very real and has wrought considerable damage.

We are making an effort to shift to working with more permanent materials such as cement, stone, wood and glass. We believe that our children should not be forced as we have been to build from the rubble of a wasteful and ungraceful civilization. They should have a chance to build upon our shoulders. This can only happen if we build such things as tiny fish farms to function for generations. Perhaps then an ethics of permanence and diversity will evolve and our use of the planet will become more subtle and beautiful.

There is an even more immediate reason for making the shift. Petroleum will be in short supply within a few decades and must be husbanded for tasks for which there are no easy substitutes. The sands, stones, field crops and forests are more reliable allies in building for the future.

* Sun Dome: Popular Science Magazine, 355 Lexington Avenue, New York, New York 10017. Plans cost \$5.00

** Domebook 2, edited by Lloyd Kahn. Available from Shelter Publications, P.O. Box 279, Bolinas, California 94924 or through bookstores. \$4.00

*** Shelter, edited by Lloyd Kahn and Bob Easton. Available from Shelter Publications - or more easily through bookstores. \$6.00

Section 4 Early Findings

A COMPARISON OF DOME AND FLAT TOP BACKYARD FISH FARMS: THE FIRST YEAR'S RESULTS

Stocking

Dome-Pond: The Dome-Pond was stocked May 15-19 with one hundred and forty tilapia ranging from 43-160 mm in total length. Total weight of the fish stocked was 2.32 kg for a mean weight of 16.5 g. The species stocked consisted of *Tilapia aurea*, *Tilapia zillii*, and an unknown species henceforth to be referred to as *Tilapia* sp. Numbers of each species stocked were not recorded, since most of the fish had been overwintered in refrigerator liners and the bleaching effect of a long period of time against a white background rendered identifying marks all but invisible. Species composition was determined at harvest time.

The Flat Top Pond was stocked on June 5 with sixty tilapia of all three species. These fish weighed a total of 4.00 kg for a mean weight of 15.0 g. Species composition was determined at harvest time.

Supplemental Feeding

Dome Pond	
Animal Foods	
Earthworms	6.16 kg
Flying insects	1.10
Amphipods	(weight unknown, probably not quantitatively significant)
Midge larvae	(weight unknown, probably not quantitatively significant)
Total Animal Food	7.26 kg (8.0% of total)
Plant Foods	
Purslane	47.43 kg
Soy meal	24.71
Marigold blossoms	4.41
Vetch	3.14
Carrot tops	2.83
Filamentous algae	0.40
Sheep sorrel	0.30
Oats	0.02
Total Plant Food	83.24 kg (92.0% of total)
GRAND TOTAL	90.50 kg (equals approximately 199 lbs.)
Flat Top	
Commercial Trout Pellets	11.24 kg (approximately 25 lbs.)

TABLE 3

Production

On October 23 the Dome-Pond was completely drained and all the fish harvested. Edible size fish were retained for use as food (with the exception of a few kept for display or breeding purposes), while smaller fish were overwintered. (Edible size fish were con-

sidered to be all those 16.0 cm long and over. Of the one hundred and forty originally stocked, one hundred and thirty-one or 93.6%, were harvested at edible size.)

EDIBLE SIZE FISH

Species	No. fish	Total weight (kg)	Mean weight (kg)	Mean length (cm)	Length range
<i>Tilapia aurea</i>	33	4.22	0.13	18.6	17.1-20.8
<i>Tilapia</i> sp.	94	13.13	0.14	20.6	16.0-23.1
<i>Tilapia zillii</i>	4	0.59	0.15	18.4	18.0-19.0
TOTAL	131	17.94	0.14	19.7	16.0-23.1

SMALL FISH

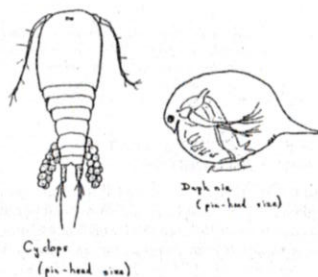
Species	No. fish	Total weight (kg)	Mean weight (kg)	Mean length (cm)	Length range
Species not determined individually	662	7.37	—	—	4.5-11.1
GRAND TOTAL 793		25.30	—	—	—

TABLE 4

Total production of the system, over a one hundred and sixty-one day growing season, reckoned as the total weight of fish harvested (25.30 kg) minus the weight of fish stocked (2.31 kg) was 22.99 kg (approximately 51 lbs.). Dividing this figure into 90.50 kg (the total weight of supplemental food given) gives a conversion ratio of 3.94:1, which is very good for fish receiving a 92.0% vegetable diet. This figure is more impressive when one realizes that conversion ratios cited in the aquaculture literature are usually based on prepared dry diets and are thus a ratio of dry weight input to wet weight output. Of the foods we used, only the soy meal was dried, thus our data represent a ratio of wet weight to wet weight. Further, there is considerable solid waste in fresh foods, as opposed to dry foods which are consumed in their entirety. For example, the stems of plants are not eaten; a considerable amount of soil is inevitably introduced with earthworms, etc. Allowing for these factors, and discounting the contribution of planktonic algae, which is provided at essentially no expenditure in money or labor, the dry weight/wet weight conversion ratio in our system is probably around 1.5:1.

Dressing loss of a sample of the edible size fish was determined to be 51.6%, so that a total of approximately 8.68 kg of fish in edible form was produced. Fish wastes are chopped up and fed to our chickens, so some of the dressing lost is "returned" as eggs. Dressing loss could probably be reduced to 40-45% if smaller lots of fish were dressed at one time, so that more care could be lavished on the process.

Flat Top: Similar data for the Flat Top pond follow. As the fish grew to an edible size in approximately



as they look, from the side, like pot-bellied, long-nosed hunchbacks with flapping arms and no feet. The Cyclopids are the next major group and can be recognized by their long antennae, a "single eye", and often bags hanging out on each side of their tails. These bags are the female's egg pouches.

These are the good guys and their numbers can skyrocket in your ponds if conditions are right. In the absence of fish and other predators, within several weeks swarms of them will appear in the ponds as their generation times are short and the numbers of offspring prodigious. Their numbers may expand to the point where they will become a significant food source for the tilapia.

In nature, food limitations and the "bad guys" keep the good guys' numbers in check, balancing populations and resources in many subtle, partially understood ways. Predators upon the Daphnids and Cyclopids will be present in your sweeps as well and will need to be removed from your catch. These predators are almost without exception weirder-looking than their prey. Think of dragons and more than likely a number of them will appear. These are the predatory nymphs of dragonflies, mayflies and damselflies and they will crop the animals you want to culture if given a chance. There are also the water bugs, an odd-looking crew, which are predators of many small aquatic animals.

Separating Out the Beneficial Organisms: It is easy to separate the predators from the grazers you want to culture. Empty the creatures you have collected, a few ounces at a time, into the white pan. Take a turkey baster (a glass tube with a big rubber bulb at the other end for sucking up juices) and squeeze the bulb with the tip in the pan. Most of the time the animals you want are swept into the baster and the nymphs and water bugs avoid the current and are not caught up. This ultra-simple system works because the Daphnids and Cyclopids, being well brought-up grazers, flow into the baster with the current you create. They are not powerful swimmers, whereas predators have a well-developed ability to counter currents, and are able to flee and avoid the baster.

Management and Culture: Our experience has been limited to culturing Daphnia in glass carboys, and to growing a variety of organisms collected from local ponds on Cape Cod. Despite our relative lack of experience, we are encouraged by the large populations of zooplankton present in the Mini-Ark.

Zooplankton, including the Daphnids and Cyclopids, are cultured in the two upper pools as well as in the main tilapia culture pond. They feed upon the algae or "green soup" grown within the system, but their diet has not been limited to the green phytoplankton. They also grazed down the filamentous algae which were choking the aquatic plants in the second chamber of the uppermost pool. In the 1920's and early 30's, before brine shrimp were introduced into the tropical aquarium trade, Daphnids were widely cultured as a fish food. The most successful culturists added a few ounces of ground soybean meal into their ponds or tanks every few days to keep the water exceptionally green. Some added small amounts of brewer's yeast with comparable results.

We have tried both techniques and recommend using soybean meal ground very finely. However, very little should be added at any given time or the pond's vital oxygen supply might become depleted. A few ounces is all that is required. It is, incidentally, fairly easy to grow soybeans in small plots or unused places around the fish farm. Allow the soybeans to mature and dry on the vines and harvest only after the first frosts.

Management: Add the zooplankton in the spring, about a month and a half before the water is warmed up enough for the tilapia. If predators are eliminated from the sample, populations of Daphnids and Cyclopids will zoom upward until the pond teems with animal life. These animals will be the initial source of animal protein for the young tilapia upon their introduction to the system. They will be used as food at a time when animal protein needs are highest in the tilapia diets. Within a week all the tiny zooplankton will be consumed. However, the populations in the upper and intermediate pools will be large at this point. Every few days the pools are siphoned, or partly drained, into the tilapia pond and large numbers of the Daphnids and Cyclopids are swept in. Enough should remain behind to trigger another population outbreak and when the numbers build up again the process is repeated.

We have not as yet harvested our first crop of tilapia grown this way, although the fish appear to be thriving. Since algae is not limited in our backyard fish farms, it is our tentative conclusion that such beneficial animals as Daphnia can be cultured with tilapia even though the diets of zooplankters and the fish are similar, and that the former may provide some, perhaps all, of the animal protein needs of the tilapia.

A polyethylene dome cover usually lasts three or four months. We have had a vinyl cover last three years. Fiberglass panels are supposed to survive longer, but we have been told that their light-receiving characteristics change over time, so that they would become progressively less useful. Glass is beautiful and can last for generations; but it is also heavy and might be ill-suited for use on lightly-built domes. Domes might be designed around glass as a covering material, but the problems may prove so severe that it will be necessary to conclude that domes are not among the more useful structures of the future, even as fish pond covers. Nevertheless, one of our fantasies involves a glass dome with the north face composed of stained-glass panels.

Additional Heating for the Dome

Because of all their angles, domes are virtually impossible to insulate with night blinds or other heat-conserving devices. A double skin improves the internal climate and makes a better heat trap, but there may be cheaper ways of achieving the same ends. Figure 3 shows several simple solar heaters that could be installed inside a dome. The water would pass through the heaters on its way to the filter.

SOLAR WATER HEATERS

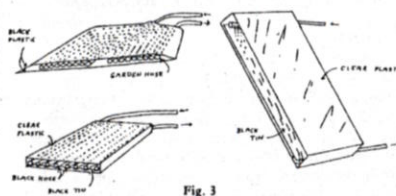


Fig. 3

Another possibility might be a vertical coil of black hose winding around the inside of the dome and held against the edge of the structure by wooden stakes. It would be connected to the filter pump. Such a heating coil might be capable of trapping considerable heat.

We have tried an internal umbrella made of wood and plastic as a second cover for the pond when the weather began to cool in the fall. The umbrella was made of six legs attached to a central hub and covered with plastic which just fitted over the pool. One of the plastic sections could be quickly uncovered for feeding and observing the fish. The umbrella was removed to harvest the fish.

Ventilation

During the hottest days in the summer, pool temperatures can rise to above ninety degrees reaching the

danger zone for the fish. Then venting is essential to cool the system. Ventilation is also necessary frequently, if only briefly, for plants in domes in order to reduce the probability of a disease outbreak. A venting arrangement is shown in Fig. 4.

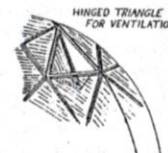


Fig. 4 - Ventilation

Pond Filtration

Inside the dome-pond complex are three biological filter tanks arranged like steps; water is pumped to the uppermost tank and from there flows by gravity from one level to another through the filter tanks, then into a trough through which it is returned to the pond. The process of biological filtration transforms toxic, growth-inhibiting substances, given off by the fish, into chemicals which can be readily used by the algae for growth. Through a review of the aquaculture literature, and by comparing notes with other small-scale fish farmers, we have become convinced of the need for some sort of recirculating filter system for backyard fish farms. All three of ours employ slightly different methods of filtration.

The filters in the dome-pond are bacterial and operate on the same principle as the sub-sand filters familiar to aquarium hobbyists. Water passes out of the pond into a settling tank, then through a bed of oyster shell or some other calcium-bearing substance and back into the pond. The settling tank and filter bed collect particulate matter, and the calcareous filter material serves to buffer pH, but the most important function of the filter is the removal of growth-inhibiting chemicals produced by the fish themselves. Under natural conditions, the growth rate and total production of fish in a small system is limited by these metabolites. Growth may be rapid and more or less uniform up to a point, but when the concentration of these growth inhibitors becomes too high, growth of all or most of the fish virtually ceases, no matter the availability of food. Such a situation may, of course, be alleviated by increasing the size of the growing enclosure, but obviously this approach soon reaches a limit of feasibility, particularly in a backyard. Fortunately, a similar effect can be achieved by increasing, not the actual volume of water available to the fish, but the effective volume. The latter may be increased simply by continually recirculating and renewing chemically the pond water.

This method was first put into practice in the culture of food fish by Dr. A. Saeki of Tokyo University and Mr. I. Motokawa of Maebashi City, Japan, in 1951.* Recirculating water systems based on their design are now widely used in commercial culture of carp and eels in that country. An experimental adaptation of Saeki and Motokawa's invention at the Max Planck Institute, Hamburg, Germany, has been used to culture carp at densities which must be seen to be believed. In the United States, the recirculating principle has been applied in hatcheries operated by the Bureau of Sport Fisheries and Wildlife, and by a few commercial catfish and trout farmers. More recently, Life Support Systems of Albuquerque, New Mexico, has begun to market complete closed systems, based on the Japanese model, for culture of trout and other fish on any scale from a modest one-family tank to a large-scale commercial operation.

Most commercial fish farms are rather sophisticated technologically and consume large amounts of conventional electric power. None of them are fish culture systems which use algae as the primary food source for the cultured organisms and therefore in some respects their design is not applicable. Much of the theory and experience involved is useful, and those of you who are interested in the chemistry and biology of closed systems should consult Spotte (1970) for a thorough introduction to the subject.

The system within our dome is simpler and has the advantage of permitting the algae to flourish rather than filtering them out. Ideas for its design have come from a number of people. The "upside-down" filter idea was contributed by Ken Lomax. (Lomax and Harman - 1971.)

Our filter tanks are made from refrigerator liners (old refrigerators, available free anywhere, are easily patched with silicone caulking to render them watertight and make excellent large water tanks for any purpose) in which a perforated fiberglass sheet is supported about a foot off the bottom (Fig. 5). The area under the fiberglass constitutes the settling basin, which may be provided with a drain so that accumulated particulate matter can be removed and applied to plants. On top of the fiberglass rests the filter bed, in our case, a two-foot deep layer of broken clam shell pieces averaging about 1½" in diameter. The shells serve as a substrate for the growth of bacteria which are the agents of chemical decomposition of the growth-inhibiting metabolites. The filtered water is allowed to overflow the tank and then splash into the next filter tank or, at the end of the cycle, into the pond. Splashing helps by adding oxygen.

Our filters differ from most others in the size of the particles comprising the filter bed. Most biological

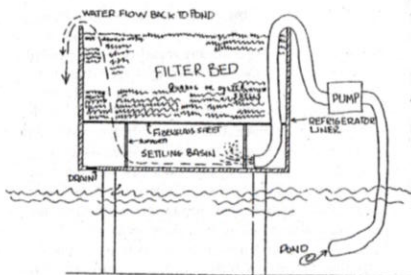


Fig. 5 - Filter

filters of this sort contain crushed oyster shell, with pieces averaging perhaps one-eighth inch in diameter. The use of such small particles is justified since most fish culturists who employ recirculating systems are raising fish which do not derive any significant portion of their nourishment from planktonic algae. Thus, it is of no concern if the filter removes algae particles physically. The situation is different with tilapia, which must have "green water" if they are to do their best. Last year we achieved effective biological filtration with beautiful algal blooms. Cal Hollis of Houston, Delaware, has been equally successful and he attributes his effective filtration and algae production to the use of 14" dolomite which makes up his filter bed.

The water is circulated through the filters by a one-quarter horsepower, 1725 rpm, continuously-running electric motor which drives a centrifugal pump. A continuous flow of water through the filters optimizes the detoxifying ability of the filter and protects the bacteria from fatal anaerobic conditions. If oxygen within the filters is depleted, the detoxifying bacteria are replaced by anaerobic bacteria which do not eliminate growth inhibitors.

We are not entirely happy with the filtration system within the dome-pond fish farm for one reason. It draws upon a fair amount of conventional electric power to operate the pump continuously. At present we are trying to resolve the energy dilemma within another system, which we call the Mini-Ark, subsequently described.

BACKYARD FISH FARM TWO: A THREE TIERED, FLAT TOP FISH RAISING COMPLEX

The second backyard fish farm was built as an 'alter ego' to the dome-pond. (Photo 3) We employed different tactics in constructing the complex and in raising the fish. We reasoned that the most critical variables in backyard fish farming would be

probably go unmolested by the tilapia. Males and young guppies would tend to hide around the edge of the pond, and with the aid of a small amount of plant cover, a few males would probably survive for reproduction. At least some of the young would mature amongst the plants and later become available for the tilapia.

There are no doubt many unknowns we have yet to identify. It may be wise to combine the filter culture method (2) with the polyculture scheme (4) to ensure a continuous supply of livebearers in the system. Competition for food between tilapia and livebearing fishes could occur when the two are grown together. However, algae production is not a limiting factor in the tilapia ponds, and tilapia eat mainly phytoplankton (single-celled, suspended algae), whereas livebearers consume mainly benthic or attached algae and detritus. Competition is likely to be most keen for high quality protein foods, such as insects, worms, or soy meal. What is significant is the fact that the livebearers would add more to the system in the form of food for tilapia, than they would take in competing for some of the feeds. The benefits of polyculture and overlapping niches more than outweigh the drawbacks of food competition.

There may be one further complication in the use of poeciliids as food for the tilapia. The predator species introduced to control tilapia over-populations may consume either breeders or young of the livebearers intended as food for tilapia. However, if predators were added to the system only when the tilapia have reached maturity, then a simultaneous reduction in the numbers of both baby tilapia and livebearers might not prove harmful to overall tilapia production. Fortunately mature tilapia require less supplementary animal protein than the young.

In summary, we suspect that livebearing fishes have a place as an additional food for tilapia in the backyard fish farms. We hope soon to obtain quantitative data on livebearer production, and determine whether these tiny and prolific fishes can indeed provide the animal food required by tilapia.

Postscript

Sometime after writing the above I found several references to the piscivorous nature of *Tilapia* species. Adults of *T. mossambica* (Peters) and *T. bornorum* (St. Amant, 1966) have been observed to prey on poeciliids. Further, adult *T. aurea* (McBay, 1961) and *T. melanopleura*, but not *T. mossambica* (Wager and Rowe-Rowe, 1972), have been recorded as consuming tilapia fry.

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Wager, V. A. and D. T. Rowe-Rowe. 1972. The effects of *Tilapia rendalli* and *T. mossambica* on aquatic macrophytes and fauna in five ponds. So. African J. Science 68: 257-260.

SUPPLEMENTAL FEEDING: PART 3 - CULTURING ZOOPLANKTON

Within the Miniature Ark we are culturing an array of tiny planktonic animals collected from local ponds. The objective is to culture supplemental feeds within, or adjacent to, the system thereby making it more autonomous or whole in a biological sense in addition to reducing the amount of time required to provide the fish with their animal protein needs.

Collecting the Organisms: Before becoming a great hunter-gatherer, you will need to learn when collecting from ponds how to determine amongst these very small aquatic animals which are the good and which are the bad guys. This knowledge is critical and not hard to acquire.

You will need a ten-times magnification hand lens and a good field guide to freshwater organisms. There are several. The one we use is "A Guide to the Study of Fresh-Water Biology" by James G. Needham and Paul R. Needham. It is published by Holden-Day, Inc., 728 Montgomery Street, San Francisco, California. The cost is about \$4.00. We don't have an exact price.

Preliminary identifications of algae, protozoans, rotifers, molluscs, crustaceans, insects and fishes can be made using the keys in the book. You may also need an "old-fashioned" introductory zoology or biology text to learn enough about the structure and morphology of each taxonomic group to be able to "see" the animals swimming in your collection tray. Most modern texts don't give you this nitty-gritty necessary for developing as a skilled naturalist and observer, being more oriented to the abstract, concepts, DNA-RNA, systems and the like.

Seek out an enriched or polluted pond in your area as the organisms there are well-adapted to the environs of a backyard fish farm. Arm yourself with a fine mesh net (can be obtained from an aquarium store), a coffee can with a lid and a shallow white tray. The tray has to be white if you are to see the animals you will collect.

Remember, they are tiny. Look before you sweep. When your eyes become adjusted, you may see tiny, brownish dots moving about in huge numbers. If you see these small moving "dots", you have found your quarry. These animals, which graze on minute plants and bacteria, are members of the class Crustacea, like the crayfish and the lobster. Several groups are easily recognized and fortunately they are the ones you want. The Daphnids are top-priority organisms for your fish farm and can be recognized quite easily

*Kuronuma, K. 1966. New Systems and New Fishes for Culture in the Far East. F. A. O. World Symposium on Warm Water Pond Fish Culture. FR. VIII-IV/R-1.

for Backyard Fish Farms. We hope to fill this gap in our knowledge.

Plant feeds: It is easier to determine the amounts of supplemental plant foods. As with cattle or goats the feeding rate is determined by the rate of consumption, and consumption can be determined by observing the remaining edible plants floating on the surface. Haity vetch, for example, continues to remain in good condition and actually thrives floating in a pond until it is eaten. Don't feed on any given day much more plant feeds than was consumed the previous day. Overfeeding can harm the pond.

Postscript to Supplemental Feeding: Part 1

We have listed a great variety of supplemental feeds and it might seem to the reader to be a time-consuming chore to provide them. Except for gathering worms from a worm bed, IT ISN'T. We simply gather vetch, weeds or carrot tops as part of our other activities or while on walks. Supplemental feeding need not be a hassle, but we do urge you to acquire inexpensive scales sensitive enough to weigh the feeds. The weight data are invaluable for determining both rates of feed conversion and the overall success of your operation. Besides, one of you may find the plant elixir for tilapia, and without weights it will be almost impossible for you to prove your case and benefit others.

SUPPLEMENTAL FEEDING - PART 2

Livebearing Fishes: An Inexpensive and Easy Way to Culture Supplementary Food for Tilapia in the Backyard Fish Farm
— by Stewart Jacobson

Small fishes of the tropical family *Poeciliidae*, which includes guppies and mollies common to home aquaria, bear their young alive and have a prodigious capacity for reproduction. These fishes are a promising supplementary food source for tilapia grown in backyard fish farms.

Recently, I established in a greenhouse dome a fifty-gallon observation tank with several *Tilapia aurea* ranging in size from 4.5 cm to 7.5 cm. A similar tank was used to raise guppies (*Poecilia reticulata*) and mollies (*Poecilia sphenops*). I was fortunate to observe that the tilapia would eat adult miniature male guppies (less than or equal to 1.6 cm in length) placed in their tank but not larger female guppies or mollies of reproductive size. Male guppies are much smaller than the females, so from my observations it seems likely that the tilapia will feed selectively upon the mature male guppies and immatures of both sexes.

These preliminary observations, while potentially valuable, need to be expanded and perhaps extended to other tilapia species, especially under conditions more closely approximate to those of tilapia culture.

However, we are encouraged from a number of observations in aquaria that small fishes can be grown with tilapia and may provide their supplemental animal protein needs.

The guppies may lend themselves most readily to integration within backyard fish farms. I observed that guppies, but not mollies, grew and reproduced with attached algae or detritus as their main food source. They were fed only small amounts of trout chow twice a week or less to balance their diet. This occasional feeding of outside foods would probably not be necessary if livebearers were cultured in the tilapia systems.

Possible Culture Systems

Livebearing fishes could be grown as food for tilapia in at least four different ways. None would be difficult or time-consuming.

1. Culture in Separate, Shallow, Solar-Heated Pools.

Small wading pools or lily ponds covered with storm windows would be ideal for growing guppies or mollies. The pools would be drained periodically and the fish netted and fed to the tilapia. The larger fish would be screened out and returned as brood stock.

2. Culture in the Biological Filters.

A second approach would involve the spatial separation of the livebearers from the tilapia, and entail growing them in the filters adjacent to the pools. Since tilapia do not have access to the filter, the livebearers would harvest the algae, detritus, and small animals otherwise not available as food for tilapia. The livebearers would be flushed periodically into the tilapia pond. A screen of appropriate size could be placed over the drain from the filter to the pond allowing only smaller fish, which would include most males, to enter the tilapia pool. The screen would provide the advantage of retaining large females capable of producing many young.

3. Cage Culture.

Guppies, and other livebearers, could also be grown directly in the tilapia pool in screened cages. Smaller fishes could leave the cages to be preyed upon, whereas the mature females and some of the larger of the males would remain protected.

4. Polyculture in the Tilapia Ponds.

An intriguing approach to supplemental feeding might involve growing guppies and tilapia together in a simple polyculture arrangement. In the past we found that by no means all the algae in the pools is utilized by the tilapia, and other species including guppies might be able to take advantage of some of the unconsumed planktonic algae and benthic algae, if present.

It has been observed in natural streams that large female guppies swim in open water. If they exhibited the same behavior in the culture pond, they would

identified most rapidly by using this approach. As it turned out we unleashed a dynamic that quickly turned into the Great Tilapia Race between the two systems. As the season developed and the competition became intense, veiled threats of nocturnal fish raids were heard, and accusations of sneaking unweighed food to the fishes were not uncommon. It went so far as to reach the point where insidious whispers were heard in the early, bleary-eyed hours of the dawn, about the introduction of some nasty fish with spines into the ponds that would "unzip" the liners and drain the ponds dry. Yet outwardly the behavior of the participants remained impeccable and they were often to be seen happily chatting about their respective strategies, sprinkling their conversation, of course, with just enough false leads. At the end of the season, when the dust settled, it was concluded that they had produced fish equally well and the race was pronounced a draw. Everybody won, or partially so..... and along the way, we learned a lot about raising tilapia in small, solar-heated ponds.

Tactics

In the Dome-Pond more efficient filters with a relatively powerful pump were used, whereas in the Flat Top a single filter, a small pump and an algae-growing pool were used to detoxify fish metabolites.

As a management strategy the water in the Flat Top was changed frequently. The drained water was used to irrigate garden crops. Fresh water was added to the upper pool and allowed to warm and "age" on its way through the shallow upper and middle pools to the bottom pool which was used for culturing the fish. The Dome-Pond water was drawn off in lesser amounts.

The dome system was a more effective heat trap, so towards the end of the summer the Flat Top was provided with a small solar heater and heat conservation and light reflection devices to aid in warming the ponds and increase the algae production.

The Dome-Pond fishes received only organically-raised natural foods cultured or trapped within the dome or in the gardens. In the Flat Top or "Alter Ego" the fish subsisted mainly upon the algae grown within the ponds, but their diets were supplemented by small amounts of commercial trout feed.

The systems performed more or less equally well. We were able to conclude that more frequent water changing could substitute for relatively sophisticated filtration, if and only if, appropriate growing temperatures in the upper seventies or low eighties were maintained. The costs of the Flat Top and Dome-Pond were comparable, although less skill was required to construct the Flat Top. The Flat Top was not as pleasant inside because space was limited to a crawl area on the nor-

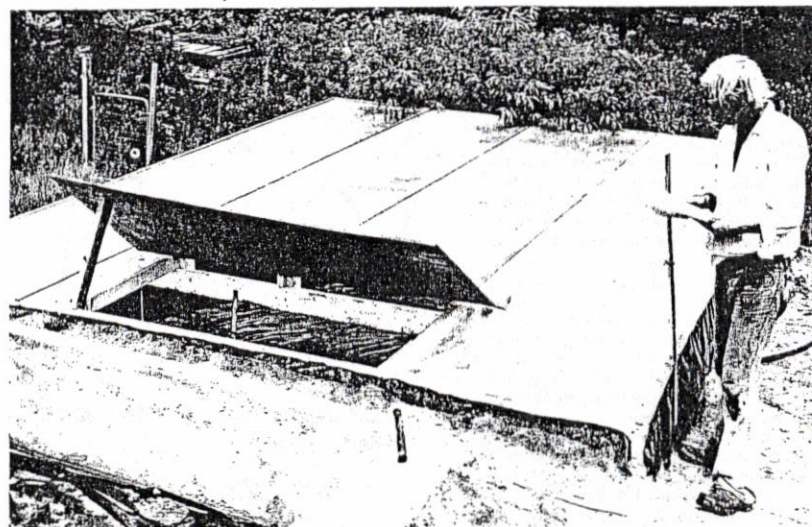
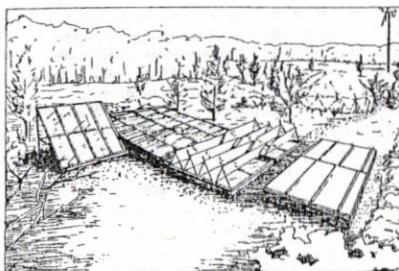


Photo 3 — Flat Top Backyard Fish Farm

Photo by Alan L. Pearlman



N.A.I.'s 5,000 Gallon Fish Rearing Complex
Adapted To Northern Climates

Fig. 6

thern side. Production in the two ponds was comparable, proving that tilapia can be grown when their diet is supplemented with worms, insects and a variety of local plants like vetch, purslane, carrot tops and ground soy beans, instead of expensive commercial feeds that might have had some contaminants.

Unfortunately in either system we were not able to regulate the numbers of tilapia. The populations in both climbed to such a high density that overall production was less than we had hoped for our first complete growing season.

The Flat Top was definitely the less dramatic of the two backyard fish farms. Photo 3 shows it during the hottest days of summer with a topped open middle pool and a single layer of fiberglass over a frame raised up above the culture pool. By late September the Flat Top took on the air of a worthy competitor to the Dome-Pond in a technical sense. Figure 6 shows it with solar heater, double roof, reflective panels and night blinds. With these more sophisticated additions the Flat Top was somewhat better adapted to northern climates than the Dome-Pond with its internal umbrella.

Figure 7 depicts temperatures in degrees centigrade within the pond on three separate days between October 16 and October 21 during varying weather conditions. By November 1, with freezing weather outside, water temperatures inside the Flat Top were approximately 68°F (20°C) and no longer suitable for growing tilapia. A few fish were left in the pond to determine how they would fare. On November 22 the pond temperature dropped to 50°F (10°C) during a cold snap and half the fish died. By December 22 the remaining tilapia had succumbed.

The small Flat Top backyard fish system was capable of trapping and storing enough heat from the sun to allow a five-month growing season (May 15-October 15) under Cape Cod conditions. Although we grew only a single crop to edible size in 1973, we believe it possible to culture two crops annually, especially if the young

held over from the previous fall are stocked in the pond in the spring.

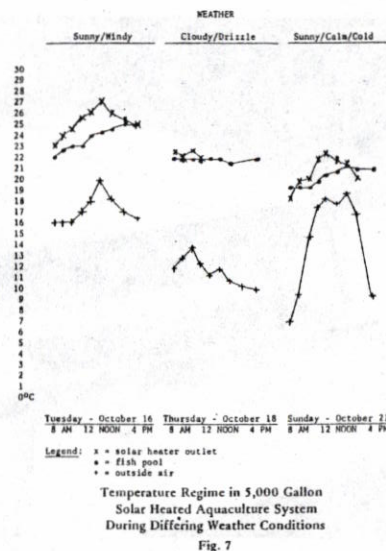
The growing season in the Dome with its internal umbrella was not quite as long as within the Flat Top. However, in more clement or sunnier parts of the country the choice between the Dome and Flat Top becomes a matter of taste. A double-skinned 2" x 4" x 30' dome might perform equally well or better. The only clear advantage of the Flat Top over the Dome lay in its upper cement pools which provided holding places for tilapia and reservoirs of enriched "green" water when the lower large pool had to be drained to patch leaks in the plastic liner. Comparable cement pools could be incorporated into a dome system and would be especially useful if troublesome plastic liners were used in the main pond.

Constructing the Flat Top Backyard Fish Farm

The construction of this small system is extremely simple, well within the capabilities of the most inexperienced carpenter.

Upper Two Pools

The Flat Top is comprised of two shallow pools located above the tilapia culture pond. The uppermost pool is used to filter the water pumped up from the lower pond and the intermediate pool is used for



great, and other sources are not abundant.

Amphipods or "Beach hoppers": These tiny shrimp-like crustaceans are found often in great numbers in the decomposing eel grass which forms windrows on most Cape Cod beaches. Though native to the edge of the sea and closely related to many marine forms, they apparently do not require a marine environment to survive, as those of us who mulch our gardens with "seaweed" find amphipods hopping about all summer. We thus used amphipods in the fish culture system by surrounding the pond with a ring of eel grass about one foot deep.

Periodically, the eel grass is turned over and some of the amphipods leap into the water and are eaten by the fish. In 1973 amphipods were provided daily from May 27 to July 9. It was not possible to determine the weight of amphipods consumed, but, as with the flying insects, the quantity is not as important as their availability at a time when animal protein is needed.

Midge larvae: For the past two years we have cultured larvae of the midge *Chironomus tentans*. (See midge culture article for details.) Most of the larvae produced have been required for experimental purposes, but we were able to provide an unknown number to the fish. It is doubtful that this was a significant contribution to their diet in 1973. This year we are installing a chironomid culture production system so that midge larvae will become an important fish food item.

Soybean meal: Of all vegetable proteins, soy protein has been found to be the most digestible by fish, and we have made it a staple in our fishes' diet. Soy meal was roasted in an oven at 350° for about forty-five minutes. While for the previous two years we had been forced to purchase soy meal or soy beans, in 1973 we harvested our first crop of soy beans and will now be able to provide our own. Soybeans can be grown in small, out-of-the-way places, and are not very space consuming.

Leafy greens: A number of leafy green plants were fed to the fish, by far the greatest in quantity being purslane. This common garden weed, which becomes abundant in late summer, was added in bunches and removed when the leaves had been stripped from the stems. Early in the season, before purslane was abundant, hairy vetch, which we plant as a cover crop, was substituted. We have been searching for another green to be fed after cool fall weather has decimated purslane and before vetch has begun its fall growth. Feeding trials this past fall indicated that sour grass, or sheep sorrel, should prove suitable. (Among the greens rejected in the feeding trials were radish tops, celery tops, mustard greens, clover, cherry leaves and mulberry leaves.) The acceptability of sheep sorrel to tilapia was discovered too late in the season to use it in significant amounts in 1973, but we plan to use much more of it in 1974. Another source of greens was carrot tops, which were fed whenever carrots were harvested.

Marigold blossoms: It was discovered late in the season that tilapia will eat marigold blossoms, the color of which suggests that they may be a good source of Vitamin A.

Filamentous algae: It was occasionally necessary to remove filamentous algae manually from the filter system. This algae was a minor constituent of the tilapia diet.

The quantity of food fed daily was determined according to a crude sliding scale designed to allow for an increasing food demand as the fish grew. Feeding was somewhat reduced when water temperatures became cooler in the fall.

Flat Top Pond Supplemental Feeding

The principal supplementary food given the fish in the Flat Top pond was a commercial feed, Purina Trout Chow, which contains a variety of ingredients such as fish meal, soy meal and other grain products, and a special synthetic vitamin mix. Total weight of trout chow given was 11.29 kg, or approximately twenty-five pounds, at an expense of \$4.00. A few of the supplementary foods given the fish in the Dome-Pond were placed in the Flat Top pond at one time or another, but weights were not kept as the quantity of these foods was insignificant in comparison to the trout chow and algae consumed.

The quantities of supplemental feeds used in both systems are presented in Section 4.

How to Estimate Quantities of Supplemental Foods

Animal feeds: A crude rule of thumb may be used to approximate the amount of animal protein required by the fish. Suppose for example your goal for your backyard fish farm is to produce one hundred pounds of fish every ten to twelve weeks. To arrive at an estimate, assume that approximately 10% of their diet should be made up of animal feeds. However, adding ten pounds of animal feeds would not suffice as it takes more than one pound of feed for conversion into one pound of fish. The conversion ratio of animal feeds for fishes may be closer to three pounds of feed to produce one pound of fish. You would then arrive at a figure 10 (10% of one hundred pounds which is target production) x 3 (amount of feed to produce one pound of fish) = 30 lbs. of animal feeds to supplement their primarily vegetarian diets.

This figure may be too high for a well-balanced culture system, but we doubt it. Approximately fifteen pounds of animal protein (or about one-half of the above figure) went into the Dome-Pond in 1973 and its final production was about one-half the goal of one hundred pounds mentioned above. With so little in the literature on the animal feed needs of tilapia, we are not able to present any more precise criteria for determining animal feed requirements

ing the pool by siphon will take several hours, so it should be begun very early in the morning to allow for removal of the fish during the daylight hours. Harvesting after dark, in addition to being inconvenient, is inadvisable if it is desired to keep any of the fish alive, as it may result in chilling of the reduced quantity of water by the cold fall air.

When about one foot of water remains in the pool, the siphon should be shut off and the actual harvest begun. Dip nets may be used, but a seine will be more efficient and may, if desired, be used to make a partial harvest before drainage is complete. If any very small fish are present, the seine should be of the finest size mesh available (sometimes sold as "Common Sense" mesh). Otherwise, larger mesh may be used more conveniently as it is less likely to become clogged with debris. The seine should be somewhat longer than the greatest width of the pool. The bottom of most commercial available seines, known as the "lead line" will be found to be underweighted, but additional weights may easily be added between the ones provided. "Minnow seines" may be purchased at some sporting goods stores, or you can order from net and twine manufacturers, including the following: NICHOLS NET AND TWINE, Commercial Fishing Supplies, Rural Route 3, Bend Road, East St. Louis, Illinois 62201.

Before seining, all obstacles should be removed from the pool. Operation of a seine normally requires two persons, one on each side of the pool. The seine may be pulled from the outside by means of ropes, or the operators may prefer to attach a pole to each end of the seine, and wade in the pool. In either case the ends of the seine should be kept next to the sides of the pool and the ropes or poles angled so as to keep the lead line on the bottom. The operators start at one end of the pool and proceed slowly toward the other where the seine is lifted and the fish removed. If you have never seined before, the first passes will be awkward, but with a little practice you will become very efficient. When seines or dipnets fail to produce any more fish, draining of the pool should be completed. A few fish will surely have escaped and may then be picked up.

If any of the fish are to be kept alive, a supply of water at the proper temperature should be provided beforehand. Otherwise the fish should be killed and processed immediately. (One firm blow between the eyes with a hard object should suffice.) Fish weighing $\frac{3}{4}$ lb. or less may be frozen whole, for cleaning as needed. With larger fish, it is best to gut, scale and, if desired, skin them first. Ideas differ concerning edible sizes of fish (we would appreciate your comments on this matter), but fish which are judged too small for human consumption should not be wasted. They may be fed to livestock, composted, or kept alive for future broodstock or simply as pets.

DO NOT RELEASE TILAPIA INTO NATURAL BODIES OF WATER. We can think of no faster way

of giving backyard fish farming a bad reputation than to have tilapia in natural bodies of water for even a brief period before they succumb to winter cold.

SUPPLEMENTAL FEEDING

Part 1 - PAST EXPERIENCE

Backyard fish farms are designed to make use of the algae produced within the pond as the primary food. Examination of the gut contents of tilapia at harvest indicated that they did indeed make extensive use of this food source. All the fish examined were packed with planktonic algae. Other foods are provided, not because of any further need for a maintenance food, but as growth promoters. It has repeatedly been shown, for instance that a small amount of high-protein food in the diet of such predominantly herbivorous fish as ours is very effective in increasing growth, particularly in young fish. However, we have not tested a "nothing-but-algae" system. Two types of supplemental food regimes were employed. The Dome-Pond received only foods produced on the farm. The Flat Top pond received commercial fish food. A brief description of the supplementary foods follows.

Dome-Pond Supplemental Feeding

Earthworms constitute a near-ideal diet for some species of fish and are probably a useful protein supplement for almost any fish. Some of the earthworms fed were separated from manure used on the gardens. Others were cultured in pits constructed under rabbit cages and supplemented with garbage.

Earthworms were the only food which required a special feeding method. If a handful of worms is thrown into a fish pond, a few dominant fish will often take the lion's share, so we employed a special worm feeder in the form of a small styrofoam "boat" with a number of holes in the bottom. When floated in the pond, worms tend to pass downward through the holes into the water, where they are eaten by the fish with an audible slurp.

Flying insects: Assorted nocturnal flying insects were harvested by means of an ultraviolet "bug light" donated by the manufacturer, Gilbert Electronics of Jonesboro, Arkansas. This light, mounted on a pole at a height of about 8' and provided with a tray below the grid, was operated nightly (except for very rainy or windy nights) during June and early July. During this period, moths are extremely abundant on Cape Cod and large numbers were taken along with lesser amounts of midges, mosquitoes, and other insects. The total weight of flying insects constituted only 1.2% of the total supplemental food. However, their importance is considerably greater than this figure might lead one to believe, since they are concentrated at a time of year when the fish are small, their need for animal protein

culturing algae and for further purification of the water. The upper and intermediate pools are 16.5' x 7.25' and 21" deep and are constructed of concrete.

The flow of water through the system is as follows: It is pumped from the bottom of the tilapia pond up through the filter at one end of the upper pool. From the bottom of the filter it flows to an outflow pipe at the opposite end of the upper pool. From the outfall the water enters the intermediate pool flowing to an exit pipe at the opposite end. From there it returns to the lower culture pond. The upper pool is higher than the intermediate pool which is situated above the culture pond, hence the flow after entering the filter at the top is by gravity. (Figure 8)

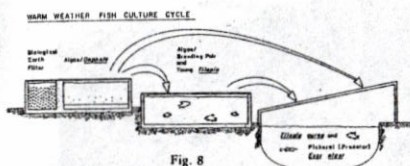


Fig. 8

During the first year of use, we recirculated the water within the system only sporadically. When the solar heater was needed the flow bypassed the upper two ponds and pond water entered the heater directly before returning to the pond. A better arrangement would have been to have a solar heater adjacent to the upper pond so that the warmed water would flow through the whole system as it now does in the Mini-Ark.

The forms for the cement pools were constructed like bottomless boxes, one inside the other. They were held together with wires to ensure a uniform thickness when pouring concrete. Principles for construction of cement pools may be found in "Garden Pools, Fountains and Waterfalls", a Sunset publication by Lane Books, Menlo Park, California. Drain pipes were

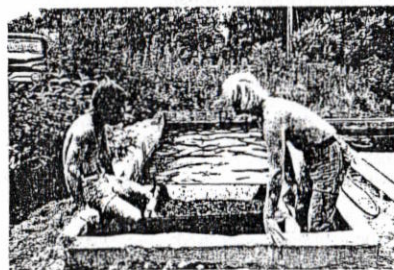


Photo 4 Photo by John Cressley

installed before pouring concrete. At least 2" inside diameter pipes are required to handle maximum flows easily. Smaller bottom drains were also installed to empty pools completely. The forms were placed upon bricks leaving a space between the walls and the bottom of the pond. This permitted us to pour the walls and bottom in one continuous operation. The concrete was poured between the forms and allowed to flow outward until the pond bottom reached the depth of the bricks. Further concrete poured at the same locations subsequently filled up the walls and the bricks holding up the form were imbedded in the pond bottom at the point where the bottom intersected with the walls.

The pools were insulated by placing 1" styrofoam on the bottom of the pool and inside the forms along the sides before pouring concrete. The styrofoam which comprised the outermost section of the pool sides was painted with wet, pure cement to protect the exposed styrofoam above ground level.

We wished we had paid more attention and made the tops of the pools sides perfectly flat and regular which would have simplified the cover design considerably. Photo 4 shows the pools before their covers were added.

Covers for Upper and Intermediate Pools

Figure 9 illustrates the night blind-reflective system devised for the upper and intermediate pools. They worked quite well, but we did not like them because access was a major hassle involving lifting the night blind-reflectors and storm window sections off. The problems of easy entry were solved in the Mini-Ark.

Culture Pond

The lower culture pond was lined with clear polyethylene. It had the same dimensions as the Dome-Pond and the same problems associated with plastic liners; namely leaks that required patching.

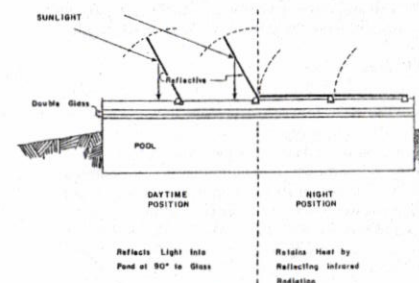


Fig. 9
Night Blind - Reflective
Pool Tops



Photo 5
Interior Flat Top

Photo by John Cressy

Structure over the Tilapia Pond

A frame of 2" x 6" 's was constructed just slightly larger than the pond and covered with a double layer of fiberglass panels which were separated by a 1" of air space. The whole unit was tilted upward facing south and held in place by cement blocks. See reflection in Photo 5 for construction details. The roof was wired to the blocks to increase stability of the structure in high winds.

The side and north face were built of plywood and black plastic. A door was placed on the north face for entry into the rear crawl space and another door was placed at the south end of the roof for feeding of the fish and top-side venting. A small bed for growing plants was built along the north wall on the inside.

The Solar Heater

A solar heater was situated adjacent to the flat top (see Fig. 6 for location). The solar heater was an 8' x 8' x 5" waterproofed box with aluminum roofing attached to the bottom. The heater was tilted and mounted as shown. The aluminum roofing, painted black to absorb heat, was situated so the grooves or channels were vertical. Water entered the system at the top through PVC piping that had holes drilled along the lower edge to let the water flow out and down the grooves to a trough at the bottom. The heated water then flowed through the trough and into

the tilapia pond. The holes drilled in the piping were slightly smaller at the point of entry and larger at the far end of the heater. By trial and error it is possible to obtain a uniform flow down the grooves by altering the hole size in the pipes slightly.

The front face of the solar heater was covered with a double layer of plastic with an air space between the layers. A glass front, possibly made from storm windows would have been better.

BACKYARD FISH FARM THREE: THE MINIATURE ARK: A WIND-POWERED, SOLAR-HEATED, COMBINED BACKYARD FISH FARM AND GREENHOUSE

The Miniature-Ark (Photos 6 & 7) is a small, experimental structure for growing a variety of foods. Should the ideas within it prove successful, agriculture in the future might be provided with a basis for becoming more autonomous and regional, capable of shifting into even urban settings. The Mini-Ark requires no outside sources of electricity or fossil fuel heating and it is constructed of long-lived materials so that once established, the costs of running the system are minimal.

The Miniature-Ark is for us a fusion of those things with which we most desire to work; namely the sun, wind, small aquatic ecosystems, food plant associations and cycles linking all of these.

the beginnings of what could evolve to a complex tilapia polyculture.

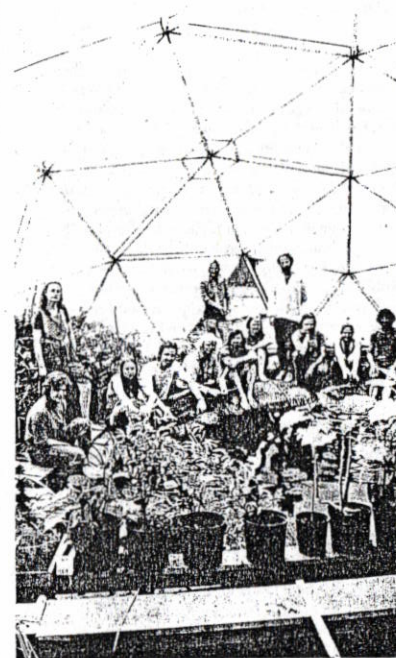


Photo by Peter Simon

Two Important Notices

1. Be sure you have facilities for holding fish before you order. We can't stress this point strongly enough.
2. Check your state laws before ordering fish. In some states a permit will be required, and in a few the importing of tilapia is illegal. We suggest that you talk to the state fisheries folk, as we have found them almost without exception to be interested in the idea of closed systems aquaculture, since it doesn't threaten wild lakes, ponds and rivers. Explain to them what you are doing and in most instances they will probably be happy to provide you with permits, if needed. Most of the laws you will run up against are designed to protect native fishes against the introduction of potentially harmful exotics. Be sure and point out to fisheries authorities that tilapia will not overwinter in the wild and are therefore not a threat

should someone allow them to escape into lakes or ponds.

PREDATORS AND POPULATION CONTROL

One of the principal limitations of our past attempts to culture tilapia has been over-population in the ponds, as the tilapia have reproduced before they reached harvestable size. For example in the Dome-Pond in 1973 we harvested six hundred and sixty-two small fish weighing 7.37 kg or 29.1% of the total harvest. The majority of these were young *Tilapia zillii*, which unlike most tilapia are not mouth breeders and thus produce larger broods. The young tilapia were certainly strong competitors with the adults for food. Over-population control is essential to the full development of the backyard fish farm idea.

At this stage we have not completed our search for, and evaluation of, potential predators. You will have to do your own experimentation. We recommend that after four weeks of culturing tilapia you add two or three native pickerel (*Esox niger*) to assist in cropping the young. The pickerel should be small. Last year we introduced a small pickerel into the tilapia pond and it survived. It was, however, after the tilapia had stopped breeding so we did not gain any information as to how the pickerel can control their numbers.

Yellow perch (*Perca flavescens*) were added to the Dome-Pond, but did not survive.

Four small brown bullheads (*Ictalurus nebulosus*) have been added to the Mini-Ark. They may hassle breeders who are trying to establish a breeding territory, thereby reducing the incidence of spawning. Bullheads may eat the young, but this has yet to be determined.

Three or four small pumpkinseed sunfish (*Lepomis gibbosus*) or blue gills (*Lepomis macrochirus*) might also crop young tilapia. They are well worth experimenting with, and are easy to obtain.

There are also tropical predators. A visit to a good aquarium shop should turn up several candidates. We are going to experiment with a few oscars, *Astro-natus ocellatus* and the strange-looking arowana, *Osteoglossum bicirrhosum*, as tilapia predators.

HARVESTING

The final step in operating the Backyard Fish Farm is, of course, harvesting the crop. This should be done in the fall when it is no longer possible to consistently maintain water temperatures in the mid-seventies or above. While the fish will survive and appear healthy at lower temperatures, growth will be virtually nil.

The first step in harvesting is to siphon or pump off most of the water in the pool. The hose should be screened to prevent loss of very small fish. Drain-

a matter of days.

A crude but useful quantitative evaluation of an algal bloom may be made by means of a simple instrument called a Secchi disc (Fig. 14), used by aquatic biologists for centuries, and which you can construct yourself. The disc, with its alternate bands of black and white, is slowly lowered into the water on a measured and marked string until it is no longer visible. The depth at which it becomes invisible is called the "Secchi disc visibility." Secchi disc visibility in a tilapia pond should approximate those in our ponds.

STOCKING

It is possible to begin with either breeders or young tilapia. In either case, the techniques for handling and stocking fish are the same. The primary concern is to acclimate the fish to the temperature in their new environment. Check the temperature of the water in which the fish arrived and of that of the pond where they are to be kept. If the temperatures are within one degree Fahrenheit of each other, the fish may be introduced immediately. Otherwise the fish, in their containers, should be floated in the pool. When temperatures inside and outside the containers are equalized, they may be released.

If breeders are placed in a heated, fertilized pond and well fed, spawning should commence without further intervention. However, some people, particularly those with tropical fish breeding experience may enjoy breeding their tilapia in an aquarium, where the fascinating parental behavior can be observed. The following instructions for breeding are based on our experience, chiefly with *Tilapia aurea*. We have no indication that breeding procedures for any of the other tilapia species should be substantially different. (A few species do not "mouthbreed", but they will respond to the same treatment.)

Optimal breeding conditions consist of water temperatures in the eighties and, if possible, an abundance of food for the adults until courtship is observed. (This will, in some cases, occur almost immediately.) Adult *T. aurea* will accept most of the foods described

SECCHI DISC READINGS

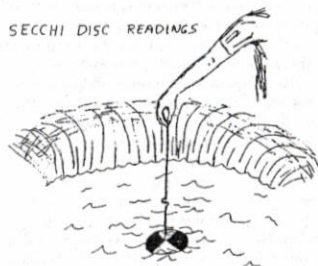


Fig. 14

under "Feeding"; local aquarists may be able to suggest foods which are especially good for inducing breeding.

Males of most species may be distinguished, with some difficulty, from the start by their longer fins, but once a male becomes interested in mating, his colors will become brighter and he will be seen spreading his fins and displaying them to the female. If she is not ready to breed, he may become aggressive and chase her. In a large enclosure the female will ordinarily be able to escape serious injury. However, in an aquarium you may wish to add some sort of submerged shelter, like a flower pot turned on its side.

If the female is receptive breeding will occur very soon. The actual spawning act will take place near the bottom, and unless you breed in an aquarium, you will probably not witness it. In spawning, the female releases the eggs in small batches, which are individually fertilized by the male. When spawning is completed, the female will pick up the fertilized eggs in her mouth. Soon thereafter, you may see her swimming about with distended mouth. Within a day or so, the eggs hatch. At first the young remain in the female's mouth. (During this time she does not eat.) Gradually, they begin to venture forth, to return to her mouth if frightened. This behavior may be rather alarming to you when you first observe it, but it is perfectly normal. NEITHER PARENT WILL EAT THE YOUNG, unless severely or repeatedly frightened.

When the young are independent of the parent (or even before) they may be transferred to the growing pond. Use the stocking technique described above.

HOW TO OBTAIN TILAPIA

As a start we recommend you get to know the most helpful and knowledgeable tropical fish dealer in your area. He or she may be able to provide you with helpful advice on the care and breeding of tilapia.

A number of people have informed us that they acquired their tilapia through aquarium dealers. In most cases these fish have been *Tilapia mossambica*, or Egyptian mouth breeder, which is the species of tilapia most commonly grown in the tropics. Other usable species may turn up in the aquarium stores. However, some species favored by hobbyists are not suitable for culture as food fishes. For example, *Tilapia mariae* is unlikely to reach a large enough size to be interesting on the table.

Your local dealer may be able to obtain *Tilapia aurea*, which is our favorite of the several species we have tried. They seem to make the best use of the green algal "soup" in our ponds. We also grow *Tilapia zillii*, a slightly smaller and more colorful species. *T. zillii* presents more of a population problem than most other tilapia, since it is not a mouthbreeder and thus can bring off larger broods. However, it is one of the best of tilapias in utilizing leafy vegetation. Stocking these two species, with their different feeding habits, together represents

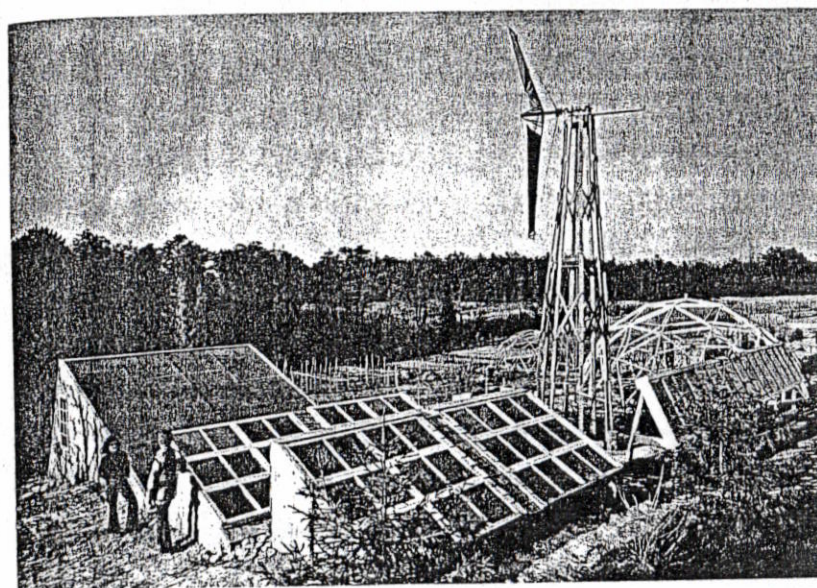


Photo 6

Photo by Ken Kabré

MINIATURE ARK

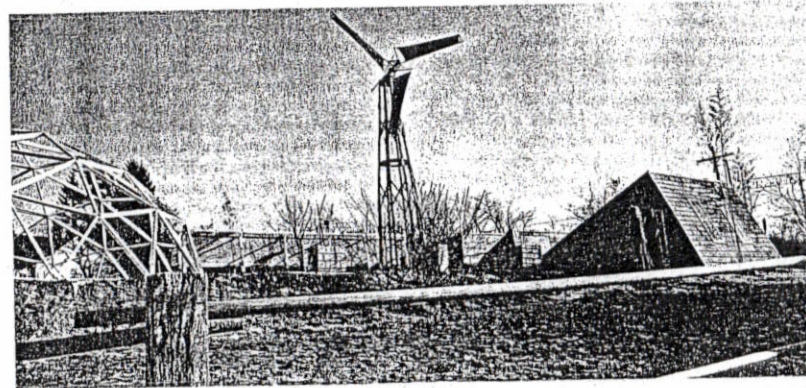


Photo 7

Photo by Ken Kabré

The sun provides the heat; the wind circulates the water through the solar heater, filters and ponds. The ponds, besides being the primary food base, or the backyard fish farm components, are also the heat storage and climate regulation element of the Mini-Ark, providing a long growing season within for food plants, including some tropical plants.

The Miniature-Ark was completed only recently. We do not yet know how well it will work, or how much food it can produce. It may be too small, even with further heat conservation devices, to provide year-round greenhouse capacity, but it should prove effective for growing several crops of tilapia annually and for culturing food plants for a large part of the year in our climate.

It was built as an advanced Backyard Fish Farm for experimenting with such problems as those associated with the variable flows generated by the windmill, biological self-regulation, association supplemental food chains for the fish, and terrestrial plant-aquaculture interphases.

Working and living with the small prototype is preparing us for the Ark which we will soon build. The Ark is described in the Land and Its Use section of the Journal.

A Brief Description of the Mini-Ark Windmill

A windmill provides the power for the miniature ark. It circulates the water through each of the components of the semi-closed system. The mill is new and experimental and after watching it work for almost two months we like it. However, it will take almost a year of trials under a full range of wind conditions before we will be ready to report on its performance.

In a number of respects it is a slightly larger, more powerful derivative of the water-pumping mill described by Marcus Sherman in this Journal. It was designed by Merrill Hall who collaborated with Earle Barnhart in its construction.

The sailing windmill puts out an equivalent of about 4-5 hp in 20-30 mph winds and provides enough starting power to begin operating two water pumps* (shallow well cast iron cylinders mounted in tandem) at approximately 8-9 mph. It will continue to operate at slightly lower wind speeds. The adjustable blade tip and base booms are set for a high starting torque and a maximum turning speed of approximately 60 rpm while pumping.

The tower was built as in the Sherman plans, with the addition of an extra buttress arrangement around the lower 8' of the tower. Eight foot long 2" x 4"s were mounted outside the base poles and fastened to the tower legs where the two come together. The buttresses provide extra tower strength for the larger sails and heavier mountings at the top of the tower.

*Midwest Well Supply Co., Huntley, Illinois 60142

SOLAR WATER HEATER

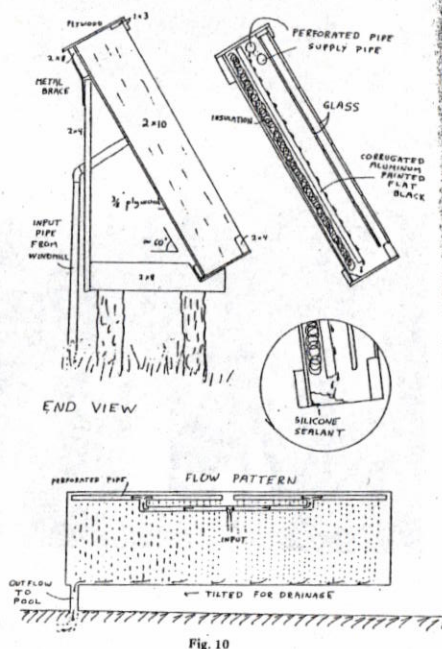


Fig. 10

Solar Heater

The aquaculture components of the Mini-Ark are arranged as in the Flat Top backyard fish farm; in fact the two small cement pools formerly used for the Flat Top comprise the upper portion of the new complex. The windmill's two pumps draw water from the bottom of the fish culture pond within the greenhouse, and during sunny periods it is pumped into a 32' x 4' solar heater. The solar heater (Fig. 10) has two panels of glass mounted in front of a blackened aluminum surface, over which the water streams. Upon leaving the solar heater the water passes to the upper or water purification pond. The solar heater is presently operated manually by turning on a valve directing the water to the heater. A temperature-sensitive valve is being constructed for the system.

When the sun is not shining the water bypasses the solar heater and proceeds directly to the upper pool. The system is set up to permit the windmill also to be used for irrigating and fertilizing crops with enriched water from the tilapia pool.

Section 3 Culture

PREPARATION OF THE POOL

Care of any fish begins before the fish are in your possession. You should plan construction of the pool and dome so they will be completed two weeks or more before you expect shipment of your fish. As soon as possible, fill the pool to capacity. (Ordinary tap water, even if chlorinated, will suffice for this and all other operations involving addition of water.) After a day or two, drain the pool completely and refill. Repeat this operation as many times as possible up to a week before you expect your fish. By repeatedly filling and draining the pool, you are leaching out any contaminants which may be in the pool liner. This precaution is intended primarily for those whose pools have plastic liners, but all types of pools should be filled, drained, and refilled once or twice.

A week before the fish arrive, fill the pool for the last time. This time fill it to within about a foot of the rim; this will prevent unnecessary sloshing about during management operations and keep the fish from jumping out. If your water supply is chlorinated, it will be safe for fish after simply standing for a day or two; the process may be accelerated by aeration or agitation. Once the chlorine has dissipated, the pool is ready to be fertilized and inoculated with algae. Standing for a week also allows the water to come to a suitable temperature.

Fertilization may be done with any sort of available animal manure, but be careful and add only small amounts; addition of green manures, e. g., plant wastes, such as tree trimmings, carrot tops, etc., may also help. Caution should be exercised, however, with chicken or other bird manures; if used in excess they may drastically alter the pH of the water, rendering it too acidic. Do not add any manures directly to the water; the particulate will interfere with management operations. A simple way to circumvent this problem is to place the manure in a burlap sack. Another method is to prepare a highly concentrated manure "tea" in some sort of basin outside the pool. This container should be provided with a partition which will permit the passage of water, but not solids. If manure is added only on one side of the partition, it will be possible to treat the pond with small amounts of concentrated fertilizer solution when necessary without introducing any particulate matter. It may also be helpful to sprinkle a small amount of rock minerals into the pool.

Inoculation involves the introduction of algae into the pond, and it should be done several times during the first week or so after the pool is filled. Some day it may be possible to provide selected stocks of algae of the types most beneficial to the fish; for now we must be content to add a mixture. To obtain algae for the pool

simply collect a gallon or so of water from each of a number of nearby ponds. The more different ponds you can obtain water from, the greater the likelihood of obtaining algae which will do well in the pool. In selecting ponds, look for the most fertile, which are ordinarily characterized by shallowness, soft bottoms, an abundance of plant and animal life, and perhaps a green tint to the water. If you know someone who raises tropical fish who can provide you with a supply of "green water", this should be added too.

ALGAE CULTURE

At New Alchemy-East we have had outstanding success in the production of planktonic algae. In 1973 we fertilized and inoculated the pool in early May. After the first week the bottom was never visible; the deepest Secchi disc visibility for the remainder of the season was 52 cm. The ranges of Secchi disc visibility for the six months during which fish were in the pool are as follows:

	Range of Visibility in cm
May	clear - 25 cm
June	52 - 20
July	30 - 11
August	data lost
September	18 - 9
October	20 - 15

Microscopic examination of the water showed the bloom to be made up almost entirely of a single type of single-celled green algae of the genus *Ankistrodesmus*. The nutritive value of this algae has not been determined, but the digestive tracts of all the tilapia we cleaned were packed with it.

No Secchi disc data were kept for the Flat Top pond, but its color and transparency usually appeared to be about the same as in the Dome-Pond. Algae from the Flat Top pond were the same as those taken from the Dome-Pond.

The algae you want to encourage are tiny, usually microscopic plants which are planktonic, that is, they remain suspended in the water. Do not under any circumstances add algae which form scums or filaments. Caution is also in order with rooted plants or plants which float on the surface, even though some of them may be good food for the tilapia. Any animals more than a few millimeters long accidentally collected with the algae should be removed; do not worry about smaller animals. If inoculation is successful, within a few days the water in the pool will turn a deep, rich green; you will not be able to see the bottom.

We have found that one dose of fertilizer at the beginning of the season is often adequate. Sometimes, though, an algae bloom may fade for no apparent reason. One way of getting it back is with a "booster" dosage of fertilizer, but there is another simple trick which is often effective. No one knows why it works, but many times simply siphoning off 10% of the water and replacing it with tap water will restore a bloom in

COST COMPARISON OF THE THREE NEW ALCHEMY BACKYARD FISH FARMS

Dome Backyard Fish Farm	Costs (Materials)	Flat-Top Backyard Fish Farm	Costs (Materials)	Upper Two Pools	Costs (Materials)
Pool The liners are black polyethylene 35' x 100' rolls. Cheap and quick to install, but very prone to leaks. Recommended only as temporary measure. Circular 16' diameter pool, 5' deep.		Upper Two Pools These were constructed with concrete, therefore permanent and suitable for working in and hard use. Made frames ourselves. Highly recommended approach for shallow pools.		Upper Two Pools Concrete, same as Flat-Top. Dimensions are 6' x 16' x 2'.	
Dome Frame For 35' or 30' dome, 25 footer can be used. Price Est. = \$50.00. For 30 footer, 2' x 4' frame - Price Est. = \$134.00. 2' x 4' more permanent solid frame which permits use of permanent wood panels and plywood panels and thence to more permanent structure.	\$ 35	Lower Pool 16' circular, 5' deep. Pool lined with black polyethylene. Lasted only one season.	\$ 100	Lower Pool 15' x 15' x 5' 1/2' deep, reinforced concrete and the dome for us - costly but worthwhile, as allows for lots of experimentation, permanence and the use of crayfish and spiny fishes like catfishes in the culture system. (includes prof. labor.)	\$ 100
Piping Piping for hubs was scrounged from dump and cut for us by a friend	50 to 134	Filter One refrigerator liner and the upper pool.	35	Greenhouse Top South face - two layers fiberglass. Sides and north face plywood, and shingles. Quality materials throughout. Built to last and includes benches for plants.	146
Filters Filters are patched metal refrigerator liners. Long-lived.	128	Pump and Motor A 1/2 hp motor and centrifugal pump such as exist in some washing machines.	167	Solar Heater A 4' x 32' solar heater, double glass front, aluminum-insulated backing. Water flows through pipes in aluminum sheets. Long-lived.	930
Pump and Motor A 1/2 hp motor and pump. These things can be scrounged.	Scrounged	Solar Heater Wood frame, aluminum roofing backing and double plastic covering.	Scrounged	Windmill Tower Crankshaft Bearing turntable Two pumps Decon blades and associated structure and rigging Piping for system Miscellaneous Costs	167 130 48 200 15 42
APPROXIMATE TOTAL COSTS	\$283 / \$370	APPROXIMATE TOTAL COSTS	\$455	APPROXIMATE TOTAL COSTS	\$2,286

Table 2

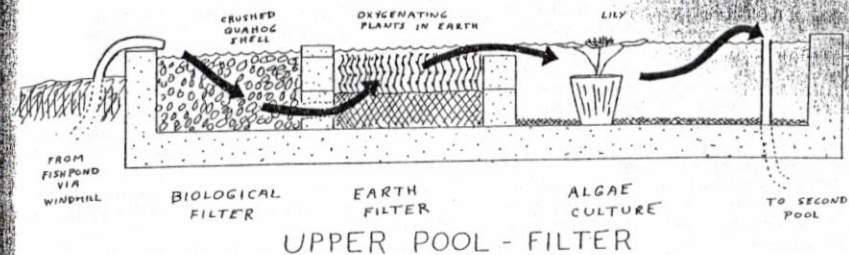


Fig. 11

Purification-Filtration Pool

The upper pool is covered by a double-glass fronted structure that is also used as a hot frame for plants. The warmed water provides suitable climate for starting plants in the spring, and during cool weather for growing lettuce, parsley, chard, spinach and onions. The flats of vegetables are placed along the pool edges and over the center support and with this arrangement enough light still reaches the pool.

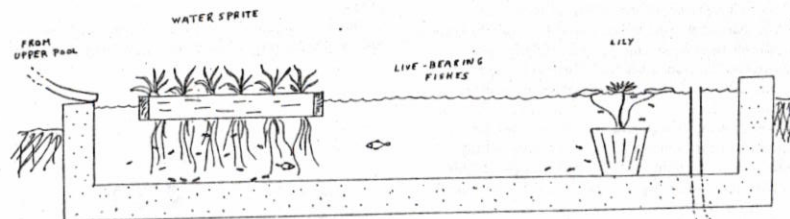
The primary function of the upper pool is to purify the water pumped up from the lower fish culture pond. When this water enters the pool it is laden with growth-inhibiting or arresting waste products given off by fishes. These substances must be detoxified and transformed if tilapia are to be grown to an edible size quickly.

The windmill with its highly variable pumping rate complicates the purification process. Hence we have sought a number of biological buffers for protecting the system, especially the bacteria which detoxify and restore water quality, during periods without wind. In the dome-pond with its continually

running electric pump the problem is more readily solved, but the "ecological" costs are higher.

The flow of water through the upper pool is shown in Fig. 11. The water splashes down onto a quahog and oyster shell bed passing downward through the bed before flowing into the next compartment. The bed of mollusc shells houses huge numbers of bacteria which, in the presence of oxygen, transform the toxic, growth-arresting fish excreta, including ammonia, into compounds including nitrites and nitrates which do not retard growth. Instead, after being transformed by the aerobic bacteria, these compounds are directly utilizable as food by the algae. With the aid of the bacteria a problem is turned into a solution; more algae can be cultured, which in turn leads to more fish growth. It is an elegant biological cycle. The whole system depends upon it for its health.

The filter is also the weak link in the whole process, as the windmill produces a variable water flow. The oxygen which the bacteria normally use to survive is derived primarily from the lower culture pond. Without this oxygenated water in constant flow the



- MIDDLE POOL - ALGAE
- AQUATIC PLANTS
- LIVE-BEARING FISHES
OR
- INVERTEBRATES INCLUDING DAPHNIA

Fig. 12

survival of the bacteria is jeopardized. Since there will be periods when the windmill cannot provide them with new water, we had to find ways of protecting the bacteria within and adjacent to the filter itself. Larger shells than would be optimal normally were used, so that algae could flourish in the uppermost layers of the filter and also so that the water mass within could be more stable. The algae on the top produce oxygen thereby aiding the bacteria throughout the filter bed. Further the second compartment of the purification pool was planted with a number of species of tropical and temperate plants considered by aquarists to be good oxygenators. They contribute to the maintenance of high oxygen levels throughout the purification pond. At the time of writing pond temperatures are inching up into the low eighties and the water within the filter has remained oxygenated even when the windmill was not pumping. We are hopeful that we have coped with the vagaries of the wind, and have done so by biological rather than expensive and energy-consuming technological means. The Mini-Ark's filter as a unit is less effective than a filter having an electrically-driven, continuous-flowing pump and more finely crushed shells, but the upper pool with its various compartments purifies the water in a variety of ways. The whole pool, a diversified, purification ecosystem, may function just as well as the Dome-Pond filter system. Purification processes are excellent points of departure for comparing technologically simple, inexpensive, easy to maintain, yet biologically complex, systems, with high energy, technologically-exotic modes of purification; biotechnics versus high techs.

The water passes from the filter bed into the next compartment through an earthen bed containing rock minerals, biodynamic compost, our own compost and the best soils on the farm. A number of beneficial changes may be taking place between the earth filter and the water, which might be increasing the stability, productivity and purifying ability of the whole system. Although we have no proof for this, the inspiration for earth as a possible contributor to a closed aquatic system came from limnological literature dealing with the role of bottom substrates in pond nutrient recycling.

After passing through and over the earthen bed, the water moves through the "forest" of oxygenating plants previously mentioned, and then into the third compartment where algae is grown and further purification takes place.

Purification-Supplemental Feeds Pool

The flowing water then flows downward from the upper into the intermediate pool (Fig. 12) where algae and algae-eating freshwater animals, including tiny crustacea called daphnia, are cultured. Within the confines of a small raft, tropical plants called water-sprite are grown. They are eaten by tilapia. The inter-

mediate pool serves two functions; in the first place the water is further detoxified and purified in the absence of fish, and secondly, the pool is used to culture supplemental foods for the tilapia.

Periodically the intermediate pool is drained entirely, and its contents, including the algae and small animals, are flushed into the lower pool where they are eaten by the fish. Young tilapia require small amounts of animal protein in order to grow rapidly and remain healthy. We are attempting to raise in the intermediate pool a goodly portion of these needs for the Mini-Ark.

The structure over the intermediate pool also doubles as a hot frame. This past spring tomatoes, peppers, lettuce and a wide range of herbs were grown in flats before being planted. The small glass-fronted structures were vented for brief periods on dry days and the plants did not become diseased, despite the warm, humid atmosphere enveloping the plants.

Greenhouse-Fish Culture Structure

The moving water flows from the intermediate pool into the greenhouse (Fig. 13) where it splashes into a reinforced concrete pond (15' x 15' and 5 1/2' deep). The pond was built by a man who normally builds foundations for houses and was not afraid to tackle our unorthodox request for a "foundation" that wouldn't leak and would be strong enough to hold water. This is the pond where the tilapia are cultured.

Before being filled in March, the bottom of the pool was covered with a thin layer of compost, earth and rock minerals. A variety of organisms were collected with fine nets from local ponds and introduced to the pond as soon as it was filled. The temperature of the pond water rose slowly and for a month algae and a variety of invertebrates including midges, mosquitos, *Chaoborus* fly larvae, daphnia, *Diaptomus* and Ostracods, were grown.

Our strategy for the first tilapia crop was to permit animal populations to build up so that they would be

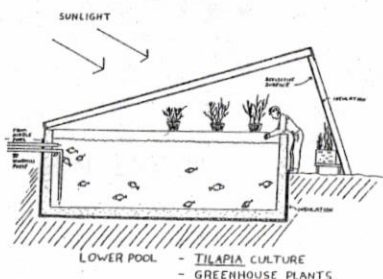


Fig. 13
Greenhouse - Fish Culture Structure

plentiful enough to provide the first animal food needs of the newly-introduced tilapia. When the temperature climbed up into the low eighties on the surface, the first crop of tilapia comprised of fifty *T. zillii* and one hundred fifty *T. aurea* were introduced. Amazingly, the young fish cropped the animal or zooplankton population almost entirely within a few days, testifying to the acceptability of these organisms to the tilapia palates. Their subsequent needs for animal protein will be provided from the intermediate pool when it is drained.

After ten weeks the culture pond will be drained and the edible-sized fish removed. We have incorporated native fishes in the Miniature-Ark to try to keep tilapia populations in check by either disrupting their spawning or by eating the young. With subsequent crops we will experiment with supplementing the diets of the cultured fishes with live-bearing fishes grown in the intermediate pool.

The greenhouse is a simple structure (Photos 6 & 7). The roof is made of a double layer of fiberglass and is supported by a frame identical to that of the Flat Top fish pond cover. The roof angle was adjusted so that sunlight enters the area at right angles during the short days of fall when reflection off the roof should be minimized. The angle for the roof can be calculated by determining one's latitude and adding fourteen degrees. At 44° latitude the roof angle should be approximately 58°. There is a door at the base of the roof to permit entry over the south end of the pond.

There is also a full-sized door at the back of the pond to the plant-growing area. The sides of the structure are

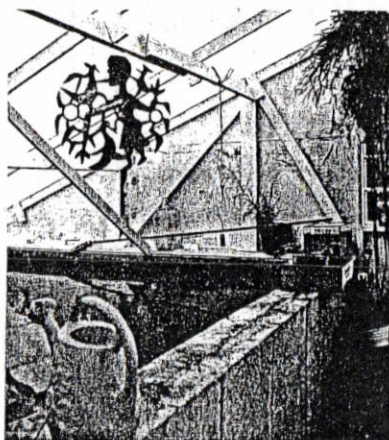


Photo by Peter Sherman

Interior - Mini-Ark

constructed of plywood covered with shingles. The north face was built the same way. Two long, narrow windows were placed on this wall so that one can look out over the gardens and woods while working with the plants in the growing benches that line the north wall. Plants are also grown in containers along the sides of the pond. Rice has been planted in one of the benches to give it a head start on the weather. In early summer the seedlings will be transferred to a small experimental rice paddy that will be fertilized and irrigated with pond water. We do have no idea how the short-grained rice will fare in our area. Within the greenhouse are also growing a number of tropical food and ornamental plants, the seeds of which were brought back from our Costa Rican, Belizean and Haitian travels.

With the approach of fall the Mini-Ark will be insulated along the sides and back and a reflective surface (possibly aluminum foil) will line the interior walls and back to reduce heat loss and, more importantly, to increase the amount of light reaching the plants during the time of year when light is decreasing. It will also be possible to cover the cement pond cheaply with a clear material, such as storm windows, if it is deemed wise to extend the growing season within.

The Miniature-Ark is our first long-lived structure. With it we are freed from constant maintenance and repair and are able to experiment without the nagging worry that the liner may spring a leak and drain the ponds, robbing us of a lot of precious information. In our area, with its sandy, permeable soils, this luxury is worth the price of cement.

Table 2 (on following page) is a cost, problem, life span and benefits comparison of the three backyard fish farms. This should provide a guide for deciding which system to build first. In designing and constructing your own system, you may want to incorporate a variety of ideas, such as combining a dome system with the purification-filtration "hot frame" pools, or using a dome and windmill together. Or, and this is something we plan to explore, it might be interesting to separate the "hot-moist" aquaculture component from the "cooler-dry" greenhouse area for growing plants. There are a number of ways this might be accomplished: In the proposed Ark, the pond will be at one end of the greenhouse and it will be possible to separate its climate from that of the plant-growing area for extended periods. Some of the heat transfer in this system will be through pond water circulation pipes located in the beds where the crops are grown and from the wall common to the pond and greenhouse. But there are other possibilities you might want to work with.

The design and direction of future backyard fish farms need be limited only by nature and by the imaginations of people who try and emulate and work through her. We should try to strive to make them beautiful as well as productive.