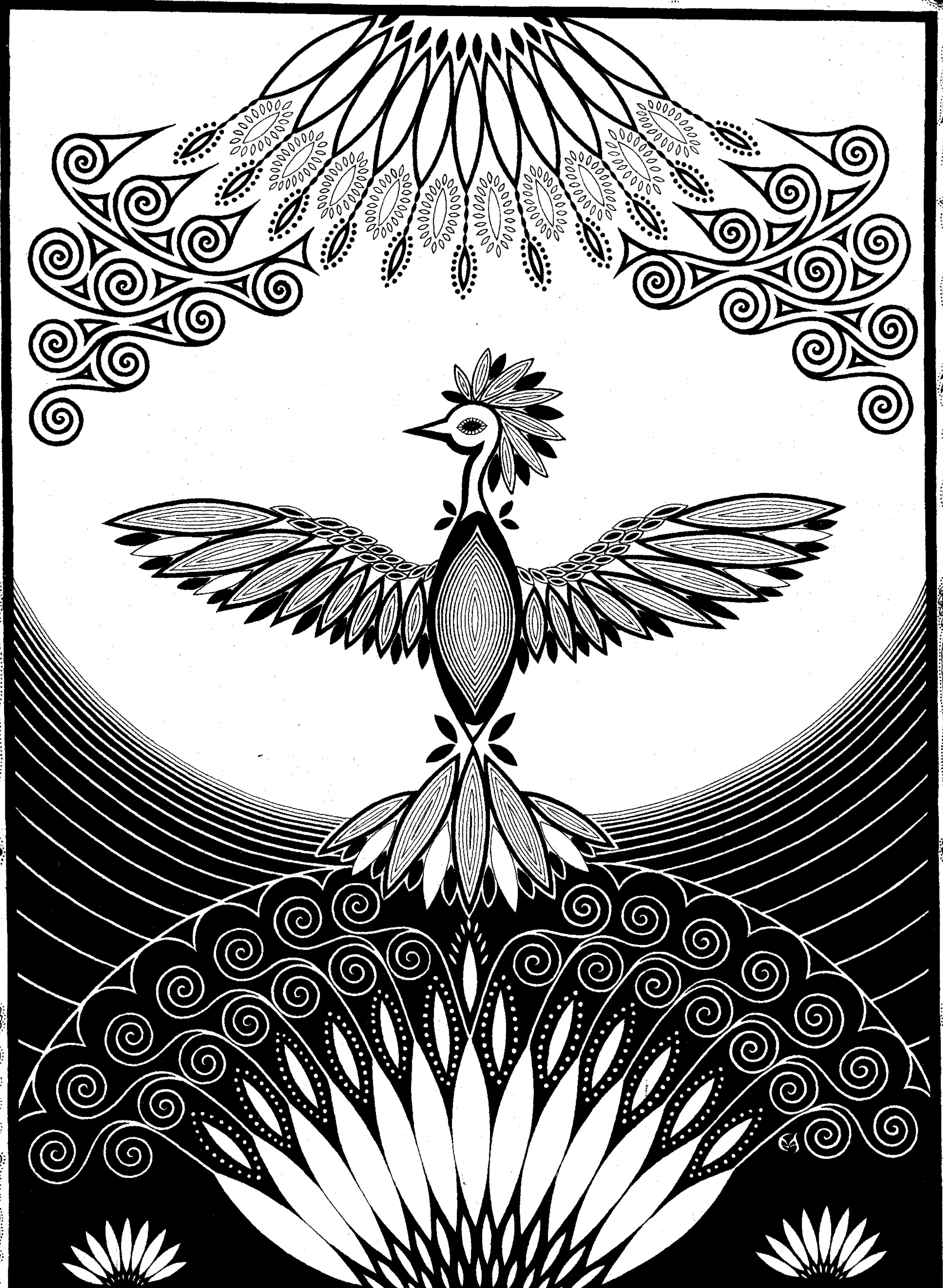
The Journal of The New Alchemists



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We dedicate this Journal to the memory of

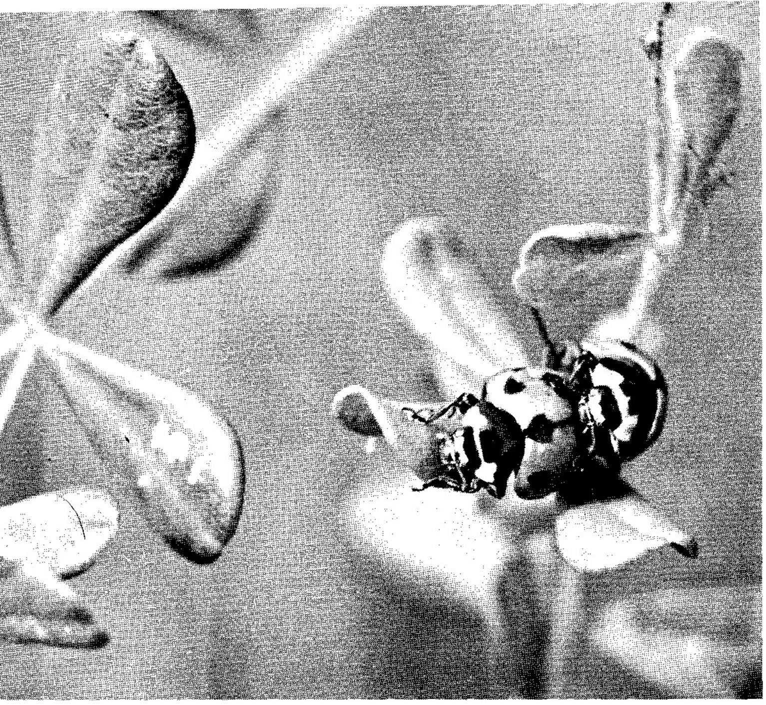
MARSTON BATES

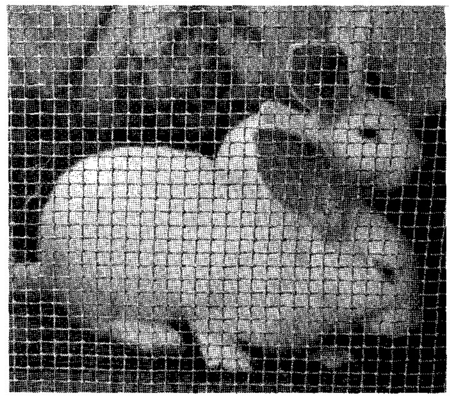
Born, July 23, 1906 Died, April 4, 1974

Marston, a brilliant ecologist, was a friend and teacher. The miniature tropical "rainforest" in his Ann Arbor house inspired New Alchemy's Backyard Fish Farms and Arks.

HIS BOOKS:

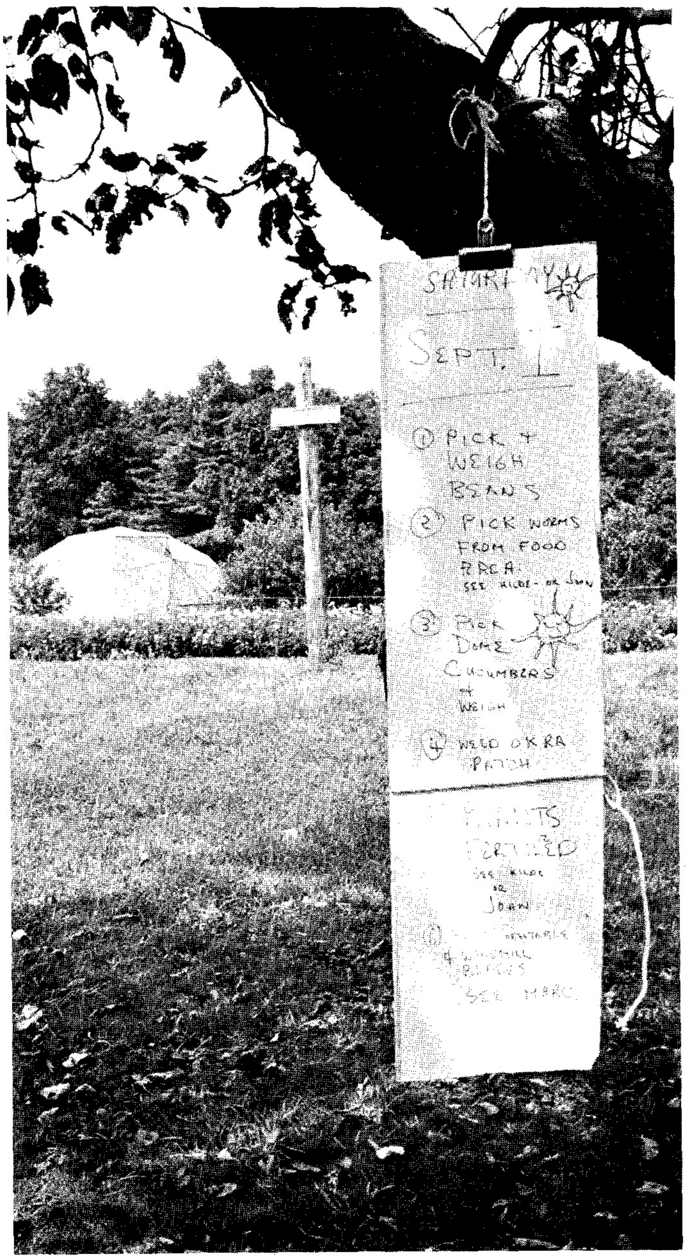
The Natural History of Mosquitoes...1949
The Nature of Natural History...1950
Where Winter Never Comes...1952
The Prevalence of People...1955
The Darwin Reader...1957
Coral Island...1958
The Forest and the Sea...1960
Animal Worlds...1963
The Land and Wildlife of South America...1964
Gluttons and Libertines...1968
A Jungle in the House...1970





This second issue of the Journal was planned, outlined, even partially written, as a description of the work of last summer. It was to have been a glowing account of fruitful gardens, fast-growing fish, August sun, brown tousled children, and a happy sense of slowly building the kind of alternative that eventually could be shared in a very broad sense, both ecologically and socially. Of course, we were aware of the Watergate issue being played like second-rate cloak-and-dagger across the nation's television screens, but, to most of us, long disenchanted with power politics, it was far more black humour than tragedy. So we went on cultivating our gardens and left Mr. Nixon to his plumbers and his tapes.

Then, in the fall, as we harvested our last vegetables, came the news of the resumption of the Arab-Israeli war, and Russia and the U. S. again picked up their nuclear toys. With the signing of the cease-fire and a temporary lull in the nuclear nightmare, another of the shadows hovering over this hulking technocracy took shape in the form of the energy crisis, staged for our benefit by Big Oil and resulting, so they chose to have us believe, from the Arabs' oil embargo. While all this activity was taking place on the national and international fronts, John Todd met with friends at an Ecology Conference organized by Murray Bookchin



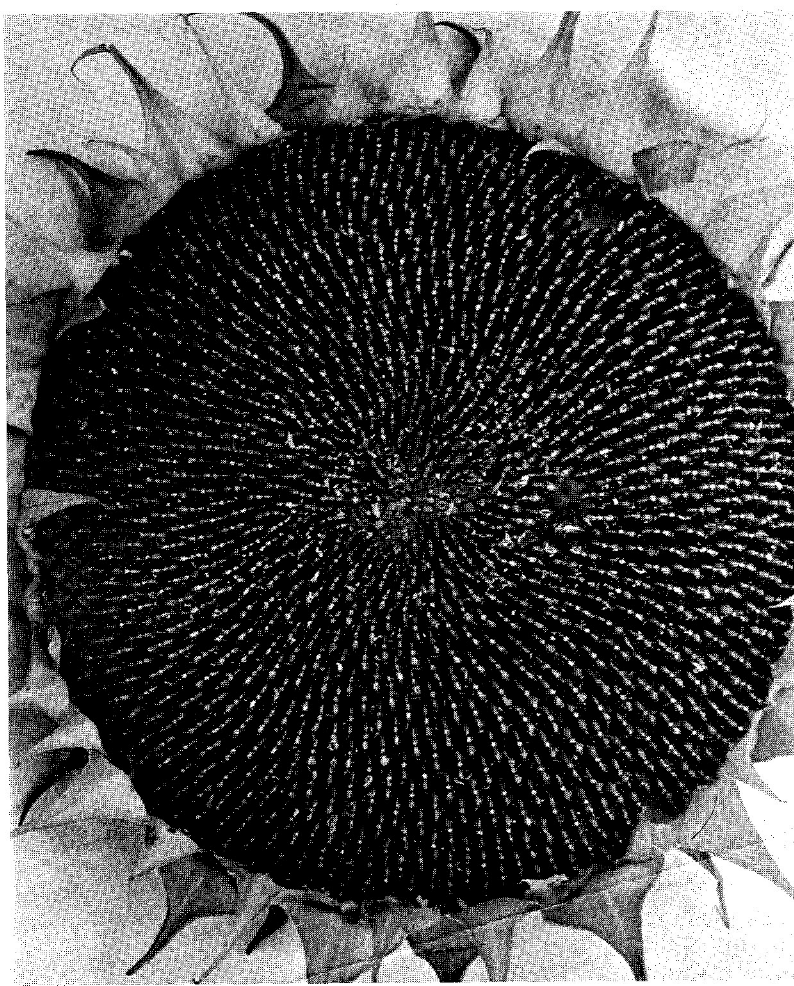
at Goddard College in Vermont and came away with new insights, based on the work of ecologist Howard Odum, that shook us and strengthened our sense of urgency. It was not that we had been unaware of the dangers inherent in our present economic system, but we had hoped that there would be more time for working out solutions to basic problems of, in Gary Snyder's phrase, "living lightly on the earth" and to developing a technology that would be, as Robin Clarke said, "valid for all men for all time."

In Explorations, in the article entitled "The Dilemma Beyond Tomorrow", John Todd discusses the Odum report, leaving one in little doubt as to the magnitude of the real energy crisis and, at the same time, making quite clear the factors that led to our decision to slant this issue of the Journal towards a more crisis-oriented approach. To this end, we have collected such articles as "Towards a Self Sustaining Agriculture" by Richard Merrill, and the one mentioned above by John Todd, while post-poning others we liked equally but seemed less im-mediately applicable.

From last summer's work on the farm comes Hilde Atema's description of her experiment researching insect resistance in cabbages, Bill McLarney's papers on irrigating with fish metabolites and midge culture, and the collective aquaculture manual entitled "Walton Two, A Compleat Guide to Backyard Fish Farming." Complete instructions and diagrams of the water-pumping windmill that Marcus Sherman built last summer are followed by a thorough discussion of windmill electronics by Frederick Archibald.

The summer's work, some of the rest of which is touched on in the New Alchemy section, seems, with the economic and political oscillations of the intervening months, if anything, more relevant than it did at the time.

— Nancy Todd



Photos by Alan L. Pearlman

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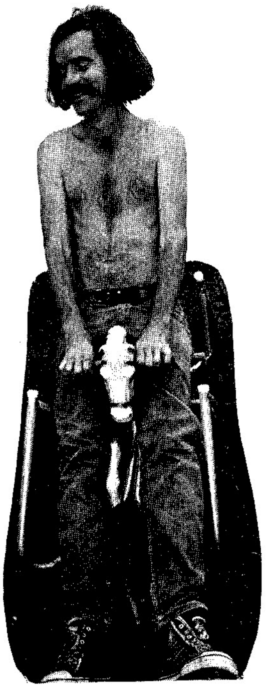
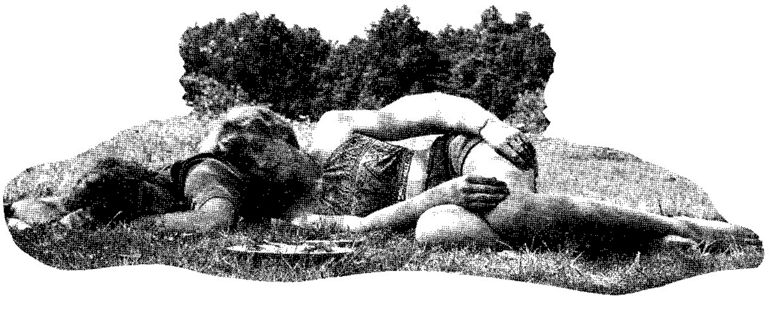




Photos by Alan L. Pearlman and John Cressey

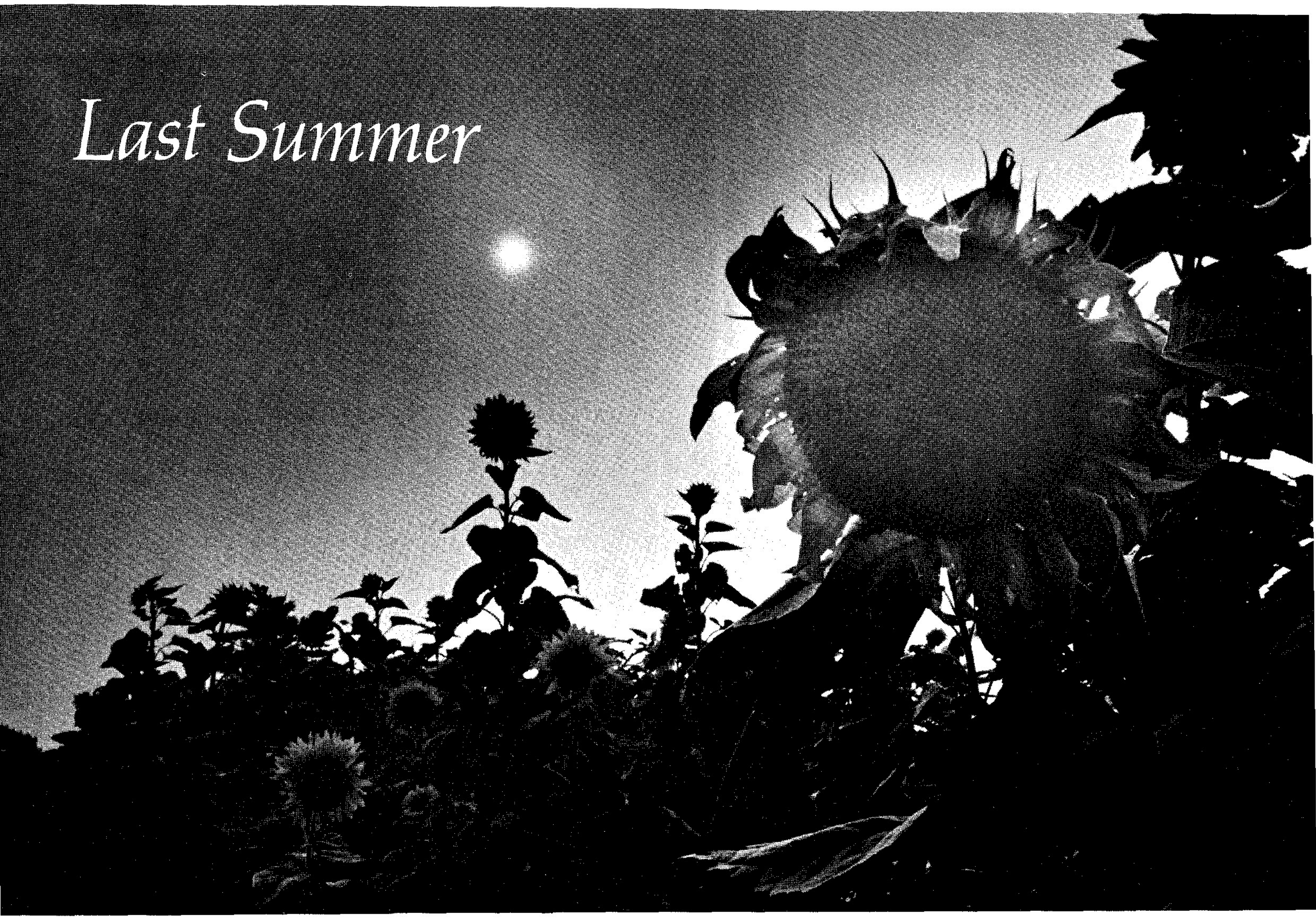


Photo by John Cressey

It was a summer of sunflowers, marigolds and cabbages, tilapia and midges, weeding and picking, video, film and the press, intense women's caucuses in the kitchen, and swimming, feasting and music by sun or firelight.

Clear spring days of planting were followed by a warm June. Then, came an overcast, wet July with wheat unripened on the stalk and sullen green tomatoes on the vine. August was hot and sunny and people, plants and fish bloomed. Then, as perfection never lasts, the summer people drifted away, the children were herded back into schools, it became a little cool to swim and summer slowly became fall, gently, as it does on the Cape, with a gradual transition from green to rust and copper, and a quiet folding away of the summer's brightness.

— *NJT*

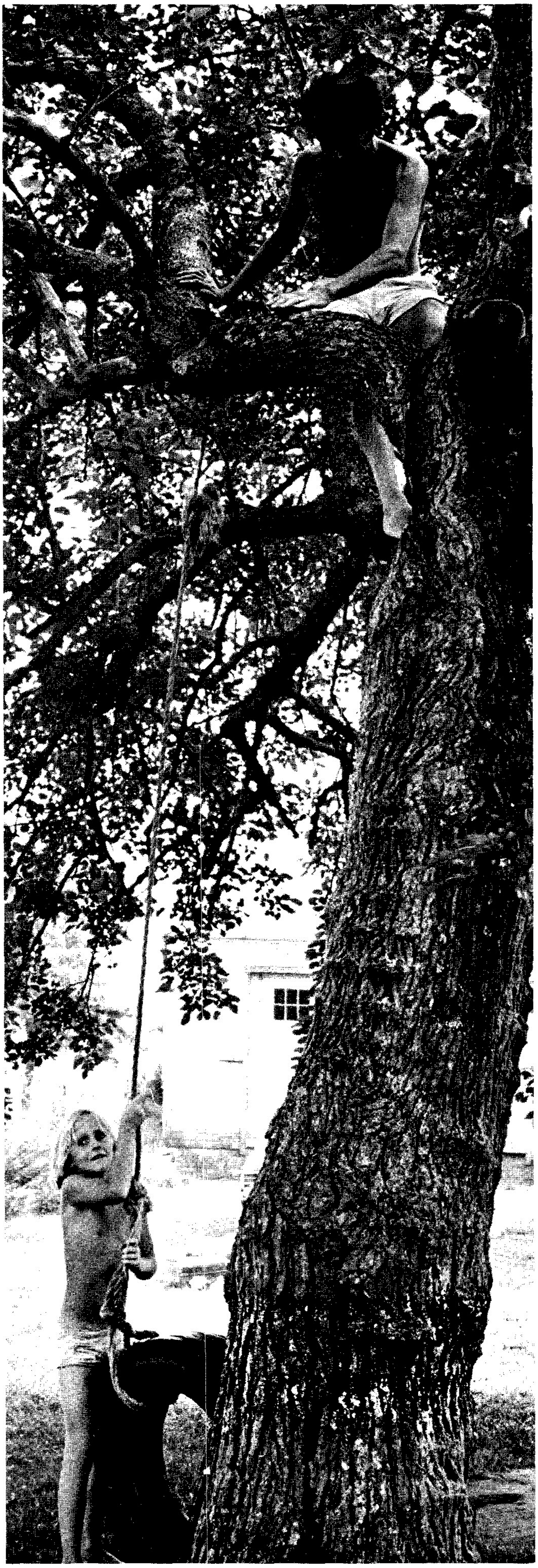
The Gardens

The work on last summer's garden really began in February when Hilde, armed with a variety of gardening manuals and innumerable seed catalogues, sat down to do the planning. To have some basic goal or guideline, we had agreed to plan a garden that would provide vegetables for twenty people for a year, preserving as much as possible. In addition there would be Saturday lunches and other less predictable feasts. Plotting all this was incredibly complicated. The previous year we had had Yedida and Rich Merrill from New Alchemy-West to guide us. Last spring Hilde and Earle had to find a way to estimate how to stagger planting times to avoid total inundation by all the green beans, for example, maturing at once. They had to learn what each crop required in terms of sun, shade and moisture, and which plants would be best near each other. We did experiment with planting several lines of pole beans and corn side by side with the idea that the beans could climb the corn stalks for support. This was definitely not successful. The corn was slow in germinating, and the beans uncooperatively took off without it.

The immediate outcome of all the reading and research was a giant chart that ran the length of one kitchen wall. With accompanying maps of the garden, it was designed so that anyone who wanted to help with the planting could check the chart under the appropriate date, find the list of seeds to be planted and locate on the map in which line, in which garden plot to plant them. The chart was a monument to clear thinking in two ways. Dealing as we do with large numbers of people who stop by and want to help, the chart made it possible for people to understand very quickly what they could do; even more gratifying were the beautiful gardens and the full harvest.

All the gardens were surrounded by what grew to be young hedges of marigolds. Judging by this summer's experience, the marigold, alleged to be a repellent, is at best a decoy or trap plant, attracting pests away from other crops. At times during July there seemed to be a Japanese beetle for every marigold blossom. We were almost completely free of aphids which had been a great nuisance the previous summer; still our motive in planting them in such abundance had been as much for their aesthetic as their utilitarian virtues, and there is no question as to the beauty and colour they brought to the garden.

In a productive, healthy garden where diversity is considered fundamental, there is the beginning of an agricultural ecosystem which can harbor, on some crops at least, a fair insect population. The garden was bountiful yet the insects got their fair share..... for example, it seemed the beans would be overwhelmed, first by the Japanese beetle and later by the bean bug, but they kept producing and we had



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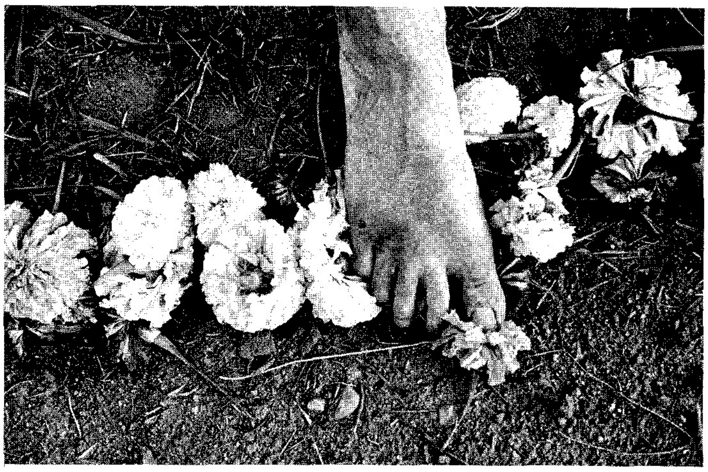


Photo by John Cressey

more than our wildest expectations. This was true of a number of crops. In our diversified garden no single crop was significantly reduced by pests, not even by the Japanese beetle. We did routinely pick the beetles from the grapes and young trees where damage seemed greatest. Perhaps it's a kind of tithing. Or perhaps to quote Gary Snyder again with this kind of sharing, "how can the Harvest fail?"

We tried one method of insect control which should perhaps be mentioned, although it would only be of use to groups with large populations of children. We tried paying the kids a 'penny a pest' for every creature they destroyed. The kids killed hoards of insects and were making fortunes until Bob Angevine ventured that he felt that the project was based on faulty economics, and that we couldn't afford it.

The other major garden experiment last summer in a season of happy experiments was in the use of fish pond water as a fertilizer. It worked. This is discussed by Bill McLarney in *Land and Its Use.*

In addition to the basic food garden which included a good many vegetables and herbs I have not mentioned, we undertook growing, in a largely experimental way, several other crops. Along the perimeters of the vegetable garden, we planted strawberries, blueberries and grapes. The grapes were planted to see whether there would be

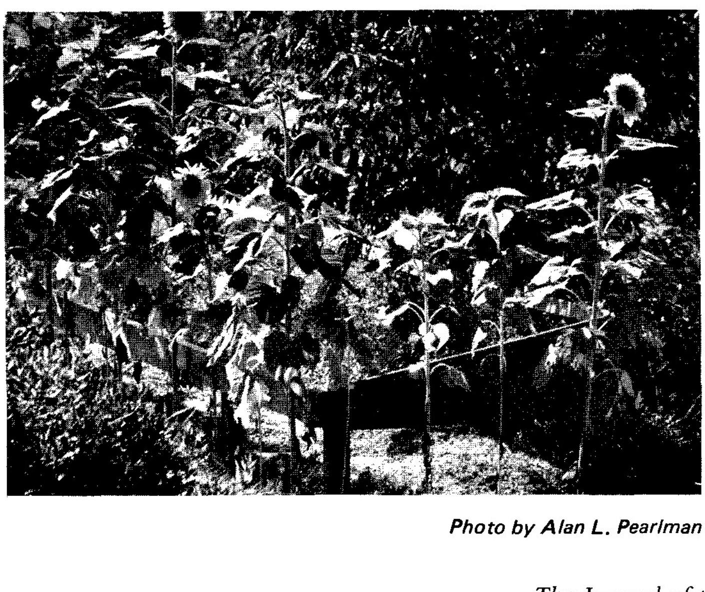


Photo by Alan L. Pearlman

varieties of wine grapes particularly suited to the Cape. Next to the fence between the garden and the woods we planted rosa rugosa, but many of them did not survive Similarly, the sweet peas we had hoped would swarm over the fences failed to do much, and we have decided it was a good lesson in listening to your land and letting it guide you. It seems that marigolds belong with us here whereas sweet peas do not, at least until our land is more fertile.

We grew a magnificent field of sunflowers that stretched to 14 feet in height. From the windy spring day when the Shanti school helped us plant them, they puttered along slowly. One June Saturday, it was difficult, when weeding, to distinguish sunflowers from weeds. Then suddenly, in beanstalk fashion, they shot up. By August there was a jungle where one could lose oneself, green and shaded, on the sunniest day. Then Earle with his machete decapitated them one by one and our forest was gone. The seeds will feed rabbits, chickens and people. We also had a very successful soy bean crop. They will be used as a supplementary protein for the tilapia, as well as food for ourselves.

Again, largely as an experiment, we decided to try growing wheat, although the day when one can think of merely experimenting with a crop may be drawing to an end. The wheat was nothing if not an adventure. It is said that wheat had not been grown on the Cape for a hundred years. Nothing daunted, we decided to try. Getting the seed was the first obstacle, costing Bob Angevine endless phone calls, letters and arguments, and thoroughly trying his equable disposition. We did eventually acquire the seed and it was planted in late May. During succeeding weeks the wheat grew well, although the weeds offered some competition, and held its own until a flood, due to heavy rains, just as it was heading stalled it and there it sat, water logged, so that in late July, we had a fine field of a little waving wheat, somewhat dominated by the waving weeds. We chose to be pleased and consider it not a bad effort for the first time. But then, having grown it, we were faced with a problem we had not until then considered. What were we to do with it? Obviously it had to be harvested. We certainly couldn't waste it. We settled after much pondering on the plan of waiting for Saturday when there would be lots of people and --- picking it.

The first hour was great fun, sitting or standing in the field, gathering tottering armloads and staggering to the edge with the enormous sheaves. There was considerable theorizing as to whether it was more efficient to pick one or several stalks at a time, avoiding taking weeds or to pluck great handfuls and then separate wheat and weed. Rival schools sprang up, each determinedly advocating its own method. By the second hour, one was beginning to wonder why the picked area had grown so little in relation to the vast amount that surrounded it. By the third, conversations began to lag and the crowd had thinned perceptibly as we began to remember other equally urgent jobs. By the end of the day, we had picked a ragged little pocket handkerchief in the great expanse and were definitely discouraged.

The next day, being Sunday, we devoted to other things and by Monday morning Bob had somehow unearthed an ancient cutter that moved through the field chopping weeds and wheat indisciminately, but doing so quickly and easily. Once cut, the field was raked, and then the task of separating the wheat and weeds was finally accomplished by putting everything through a shredder/grinder which had had its bottom plates replaced by bars.

Having come so far there yet remained the winnowing of the wheat from the chaff. Earle, who rarely fails to rise to a challenge, pondered various means. One method involved a vacuum cleaner connected to a large tube. The vacuum forced air upward through the tube where Earle at the other end was dropping in the wheat. The chaff was at once blown off while the wheat hovered in the upsurge of air until the vacuum was turned off and it could be collected. It was not an unpleasant job and it was certainly an interesting-looking apparatus, but as the wheat could be processed only a cup at a time, Earle rejected the method as too slow and technology and ingenuity notwithstanding, settled on traditional winnowing, tossing the wheat in the air and relying on wind power for the rest.

If the project did cost a great deal of time, it was valuable in that it gave us the confidence that wheat could be grown, if necessary, in what would generally be considered an inhospitable area and that the problems of harvesting and processing could be solved without recourse to either expensive equipment or herculean physical labour. Bob, who is in charge of the field crops, is going to try wheat again as he feels our problems may be eliminated by planting a couple of weeks earlier, giving the wheat a better jump on the weeds.

Photo by Alan L. Pearlman

Squash Flowers

Each forest
is proud of its trees but places its trust
in underbrush. The sleek, striped animals
run for cover.

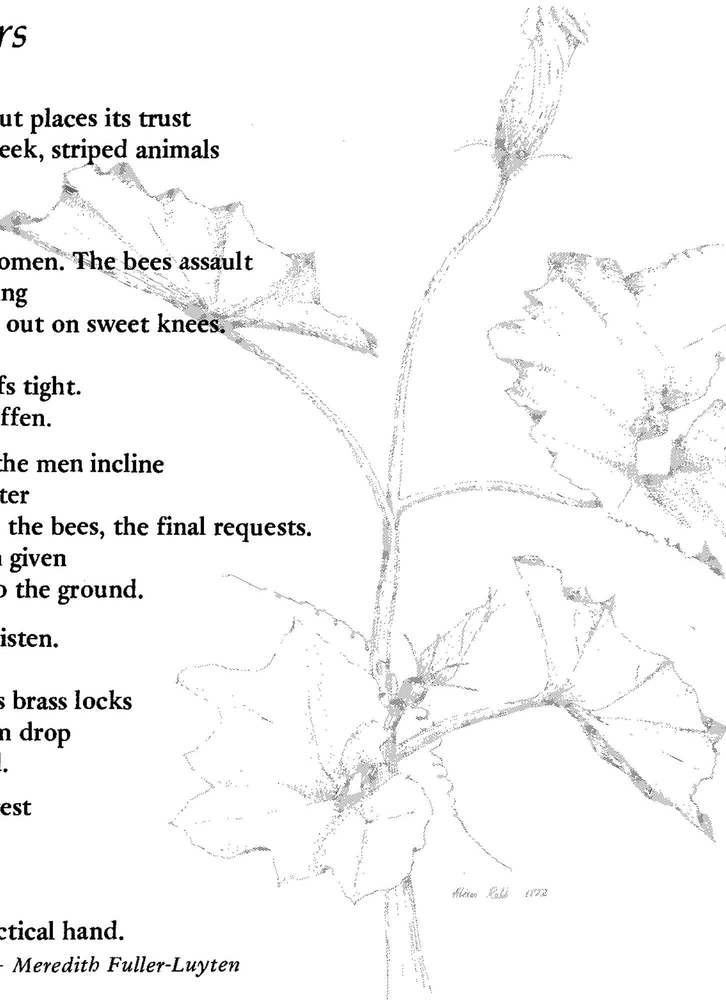
Here are the tall men
and here the heavy women. The bees assault
the men, hum-humming
then back awkwardly out on sweet knees.
The women wait
twisting their kerchiefs tight.
Their short necks stiffen.

But the gold cups of the men incline
their gold thrones teeter
generous to the wind, the bees, the final requests.
By dawn they've even given
their weight in gold to the ground.

The covered animals listen.
Down among trunks
the kerchiefs bright as brass locks
slide open and in them drop
the favors of the dead.

Each cradle in the forest
rocks with gold.
Each hidden animal
receives a coin
from its mother's practical hand.

— Meredith Fuller-Luyten



October Squash

1.
The vines that shot off
like startled snakes
that curved down
like snakes from trees
that tightened
like hunting snakes
that grew as green
as garden snakes
and made fruit
pale as the snake's belly
lie as stiff and thin
as snakes on a spring day.

2.
The Epeira climbs
the wasting plants.
Her web breathes.
Her flies are tucked away
as softly as her eggs.
Her black body
her jointed legs
her gold-leafed back
center themselves in cold air.

— Meredith Fuller-Luyten

PRESERVATION OF FOOD; PRESERVATION OF SELF

Another major aspect of the summer's work was the preserving of food, an activity that one appreciates all the more with rising food prices and hard frozen ground. We did try either to freeze or to can as much of the summer's vegetables as we possibly could. There was some spoilage when we lacked either the time or the courage to tackle the vegetables soon enough, but between feeding the rabbits and composting anything that had gotten past its prime, very little was actually wasted. Mary Lou Macilvane, who spent the summer with us, was vital throughout this process. Not only was she ready to tackle any pickling, canning or jam-making that had to be done, but she was cheerful about it.

The food-processing, and predictably the housekeeping, are the areas where the difficulties of sex roles are most readily apparent, and equally predictably, it is the women who are least pleased with their lot. More than one visitor to the farm has commented that our roles with some exceptions are, in the main, still structured along traditional lines. The reasons for this are obvious. If, as a group, we have agreed on certain goals and projects we feel to be important, then it seems efficient for all of us to do what we do best. For example, I don't know how to make a windmill. It would take me some time to learn, as mechanics is not a field in which I shine. Granted, I could probably eventually master it, but while I am off apprenticing to Earle or Marc, my share of the garden work would not be done, vegetables would be stock-piling in the kitchen and correspondence lying unanswered in my box. Although all of us, as women, do not wish to emerge from our domestic cocoons and stretch our wings only to turn to housekeeping and cooking for a larger crowd than before, there are not many jobs that we could hold "out there" in the system as it exists in which we would not feel in some way compromised. Our idealistic and political selves are happy with the group. Obviously we are in a fine double bind.

There is no simple answer. The solution so far in our case and in many others I think must be to work with men whose consciousness has been sufficiently raised to understand how thoroughly sexist has been all of our backgrounds. If we are to work in groups with both sexes, I do see a transition, perhaps on the slow side for our taste, coming about in which the jobs, particularly those that we as women find most psychically oppressive, are being shared on an equal basis. It is certainly starting to happen with us. Several of the men cook. A gratifying number crowd the kitchen after Saturday lunch to do the dishes; yet I still have a memory of a hot afternoon, a sticky kitchen, stacks of vegetables threatening to molder and an all-female and very resentful crew. Dave Engstrom said once that transitions are always hard, and so they are...... as long as they keep happening, I guess.

The Media

Well, no man is an island, of course, and we have always wanted to share our ideas as broadly as possible. At the same time we are well aware that one of the fastest ways to be co-opted in this culture is to become, in any way, a darling of the media. So our attitude, when approached, is always distinctly schizophrenic. Bill McLarney can be relied upon to growl at almost any overtures. With the rest of us, our response tends to vary depending on how closely the views of the person or publication interested in us tally with our own.

Early press coverage posed no problem. Only like-minded magazines contacted us and we were glad to cooperate with ORGANIC GARDENING AND FARMING, MOTHER EARTH and LIFESTYLE and with a number of small underground or independent publications which shared many of our ideas and ways of viewing the world. The same applied to Stephanie Mills when she came to interview us for CLEAR CREEK. We wrote an article for THE CAPE COD NATURALIST because we felt it might explain our ideas to people in our own region and indicate a common bond in the area we both loved.

When Peter Jones from the B. B. C. arrived a year ago, we were somewhat surprised to be approached by the major leagues, but felt so supportive of his ideas that we agreed to work with him. The resulting film, *Science is Dead, Long Live Science,* caused a great stir in England we were told. Although a visiting English friend assured us that 'the movement liked it', most of the scientific establishment emphatically did not and while we were aware of the hornets' nest it had stirred up, it happened so far away, none of us have seen the film and so it has had little reality for us.

The past spring and summer the scenario (you see how even the vocabulary infiltrates) shifted when we faced the Great NEW YORK TIMES Tilapia Challenge and The National Film Board of Canada.

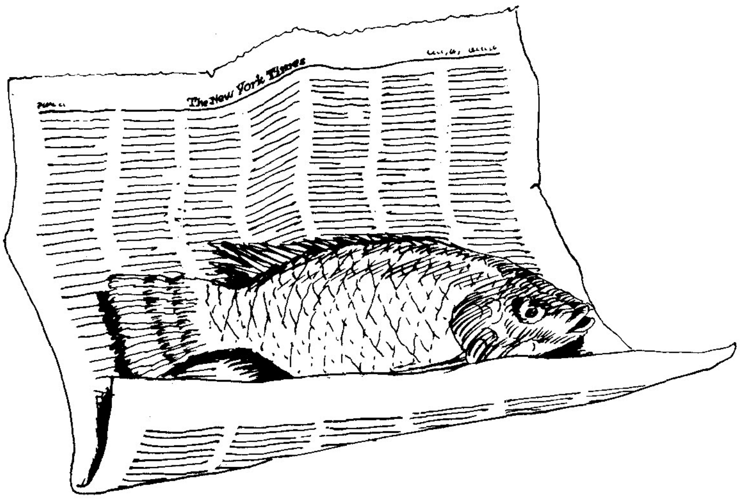
* * * * *

John Hess, who is the Food Editor of THE NEW YORK TIMES, had advised us of his arrival one August Saturday. We knew from his writing that he was sympathetic with ideas of ecology and soft technology. What we didn't know and were delighted to discover was the depth and range of the knowledge that he and Karen, his wife, had of food. Not only were they familiar with the most cultivated French cooking, both Hesses had a profound interest in poor peoples' food. Mrs. Hess, who knew more about food than anyone I have ever known, knew innumerable ways of using every scrap and bone of meat or fish, how to make palatable tough, over-age vegetables and an amazing variety of ways of coping with beans. She said memorably "we have forgotten how to be poor." The Hesses are working together on a collection of recipes, traditional to a variety of peoples, that make use of inexpensive, nutritious foods. This type of contribution would rank, I think, with a book like *Diet for a Small Planet* as enormously useful to all those who for ecological, economic or political reasons have rejected the refined, prepared and packaged foods that are regrettably still the norm.

The Hesses talked to a variety of people, toured the farm, worked with us in the garden and in the kitchen and altogether were part of a very pleasant farm Saturday. Then, just before he rose to go, John Hess flung down his gauntlet. "Granted, growing inexpensive, high-quality protein is useful, even necessary. But how do your tilapia taste?" We were taken aback. People don't very often ask that. Bill McLarney, who has eaten tilapia frequently, wasn't there for the moment, so after a slight hesitation I leapt into the pause and declared with forced heartiness that they were delicious, definitely delicious. I remembered that various people had had them in Costa Rica and pronounced them excellent, but I had sampled them rather uncritically which had left me with an unclear memory. And growing conditions on Cape Cod are not, after all, identical to those in Costa Rica.

John Hess went on to say that he would very much like to try one for himself, and if Karen would consent to do the cooking, could they come back and taste the tilapia? We had planned a feast for the following week, and although we should have preferred to check out the tilapia in a less exposed way, we rose to the challenge. The next Tuesday, nets and fishing lines in hand, Bill, Earle and most of the kids went fishing for tilapia. To our enormous delight, a largely neglected pond netted fourteen fish, some of which had grown to over half a pound in ten weeks. So far so good. The taste was still an unknown, but we certainly could grow 'em. Mrs. Hess instructed Bill, who with an enthusiastic, if unskilled staff of small boys, was in charge of the cleaning, that the heads were to be left on. Then, the cleaning done, Mrs. Hess took over. We had decided, after much debate, not to use any of the more exotic recipes that people had sent us, but to cook them simply to evaluate, critically, the taste of the tilapia *per se.* Mrs. Hess chose to fry some, dipping them first in flour, seasoning them only with salt and pepper. The others were baked in tin foil in the oven, again seasoned with salt and pepper, with parsley and lemon added just before serving. Mrs. Hess worked with breathtaking speed, chopping, oiling, frying, while I hovered about ostensibly being helpful.

Then, after a suitably suspenseful lull came the triumphal bearing of the platters of tilapia to the picnic table. Anxious moments..... cautious, tasting sounds, and then in tones ranging from surprise to relief and enthusiasm, "It's good, it really *is* good!" And McLarney was heard to mutter, "I told you so."



As for the Hesses, both of them said that the tilapia had far exceeded their expectations and were unquestionably superior to any hatchery-raised fish they had tried. But the best moment of all came one morning a week or so later when we opened THE NEW YORK TIMES and came upon the article describing the affair under a headline that read "Farm-Raised Fish: A Triumph for the Sensualist and the Ecologist."

* * * * *

Our other major media experience was with The National Film Board of Canada. Perhaps because the Canadian Government has lavished less of its resources in the recent past in making the world safe for democracy, while not, of course, denying some of its citizens the basic freedom to make a handsome profit in arms manufacture, it has had the money to provide for a number of useful organizations, among them, The National Film Board. The Film Board has released many beautiful, informative and useful films. When we were contacted by them, we were doubly susceptible, in the first place because of our respect for the Film Board's work, and secondly, because the producer of the proposed film was to be John Todd's sister, Dorothy Todd Hénaut. Her plan was to make a film that would be interesting to a number of specific audiences "ranging from small farmers to middeclass back-to-the-land freaks, to government people at federal, provincial and municipal levels, to schools both in terms of the old agricultural departments and the new departments of the environment, and to frustrated housewives and bankers looking for ways of reducing their alienation and getting some kind of concrete grip on their lives."

National Film Board films are distributed to public libraries across Canada, where they are available to any citizen or group. Outside Canada, the Film Board has offices in many foreign countries. The ready availability of the film and its complete dissociation from anything that smacked of commercialism convinced us that beyond our own publishing program, this might be another vehicle for the dissemination of our ideas, particularly as the main film, which had to be somewhat general and descriptive, was to be backed up by satellites on the windmills or fish ponds, giving considerable technical detail.

Dorothy arrived in early May to do a pilot video film. The video was a marvellous toy for us. We would work for the morning, and then at lunch play the morning back. It does extraordinary things to one's concept of time. It is also useful as a communications tool, forcing one to define and clarify ideas to oneself and others.

Dorothy left with her completed tape, acquired permission in Ottawa to do the film, and returned in late August with a crew of inspired clowns who were, at the same time, first-rate film-makers. Then, for the benefit of the cameras, as they say, we explained ourselves endlessly and tried to look spontaneous as we repeated a conversation for the third time or carried the same load of garbage to the compost heap, pretending that we hadn't just done it.

There are now coiled in boxes on the floor of a film editor's office in Montreal ten hours of film on The New Alchemy Farm. Most of it will eventually be cut and a film lasting from half an hour to an hour will emerge. We are discussing the possibilities of wider American distribution with Film Board people, feeling it may be a timely tool - Dorothy likes to think of it as a sort of celluloid earth gypsy – hopefully providing something of a catalyst in people's lives, by suggesting the possibility of alternatives in technology, food, and energy production open to them.

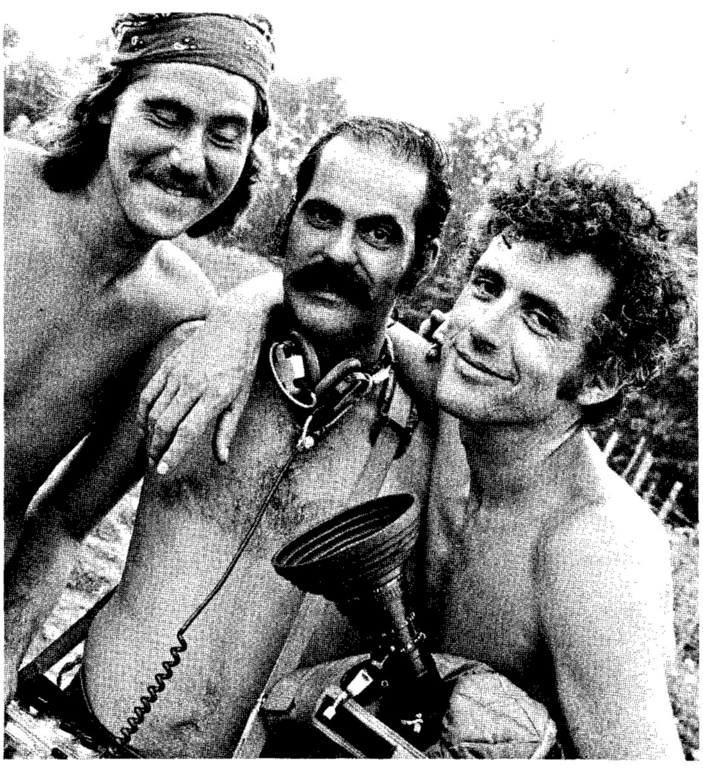


Photo by John Cressey

The Dump: *as Resource and Allegory*

High on our list as a supplier of resources is the Falmouth Dump. The announcement of a dump run is usually greeted with clamouring cheers from the children and general scrambling for position on the truck. Earle even has for such an occasion a dump hat in the style of latter day Sergeant Pepper. The dump, luckily for us, is "conveniently located" and a short drive takes one to an area which has been cleared of its scrub oak and pine to expose gravelly mounds and hills reminiscent of parts of Southern California. There one can scavenge among objects declared obsolete by society and emerge with clothes and toys in fine condition. Earle found one of Susannah's favorite dolls and her most princessly dress there. In a more prosaic line it has provided a major source of lumber, electrical cable, motors and other parts for machinery. We have found fish barrels, which make excellent containers or planters, and an ice cream freezer, vacuum cleaners, carpeting and innumerable containers of all kinds, not to mention discarded leaves that we brought back for composting.

Photos by John Cressey

Most of us probably have our own horror stories of the waste and extravagance that are our civilization's legacy to its children. Earle was a part of one this fall. In need of lumber for some new rabbit hutches, Earle drove to the dump to discover an unexpected windfall of newly abandoned wood. With lumber prices soaring and many other projects planned, he decided to load the truck as full as possible and then come back again for the rest of it. At the exit he was stopped. "NO", the man said, "it's illegal to take anything from the dump. I can't let you do it." Earle, having defied the law in this way countless times before, explained and argued. The man was quite nice about it, but firm, in a resigned way. He was, he explained, acting on a Higher Authority than his own. Even in his anger, Earle knew that this man could not be held accountable for such absurdity, that new trees would be cut and that people would be forced to pay higher prices for lumber that might well be no better than that that was being scrapped. Bound by a law that defies all common sense, yet somehow provides a neat metaphor of our present economic system, he put the truck in reverse, turned it around and replaced the lumber to see it buried under several tons of gravel.

What, I wonder, will future archeologists speculate happened.

The New Truck

or *howwekeptontrucking*

We have been, in the main, uncannily lucky, not only in having people help us, but frequently in having them do so in the most appropriate way at the most timely moment.

Our old truck had been doing a valiant job, but it was at the expense of an inordinate amount of time and attention from Bob, Earle and Marcus, all of whom were feeling that their energy could be more creatively used elsewhere. As it became increasingly obvious that the old truck was due for imminent retirement, Nancy Willis, who works with us in the summer, ventured that she had a friend who might be willing to donate a truck. The only trouble was that the would-be donor and his truck were in Colorado. The distance between Colorado and Cape Cod might normally loom as prohibitive, but again providence was with us. Bob Angevine was about to fly to California to visit New Alchemy-West and was perfectly willing, on his return, to fly as far as Colorado, meet Frank Bacon, Nancy's friend, pick up the truck and drive it back to the Cape. He did. Now, thanks to Frank and Nancy, to whom we are extremely grateful, not to mention Bob, we have the truck that is indispensible to us for compost and dump runs, construction work and the innumerable errands that we do.

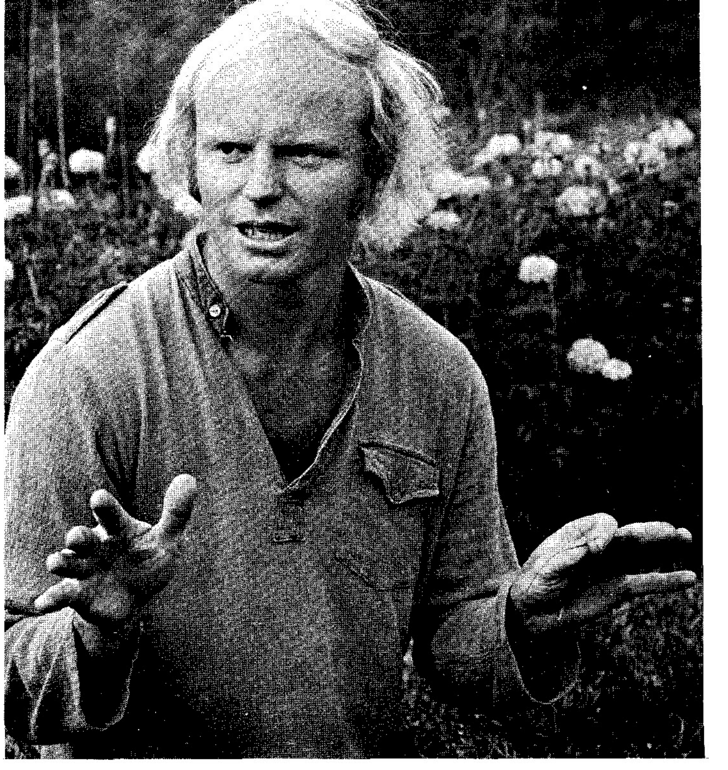


Photo by John Cressey

Foundation Support

It is extremely difficult for a small research and education institute not affiliated with universities or government to survive economically. We live on a fiscal razor's edge. The Stern Family Fund and the Point Foundation have provided us with the support to pay salaries, maintain the center and carry out the research. In short, our survival has depended upon their assistance and we thank them for it.

A Further Note to Associates

Perhaps many Associates don't realize just how instrumental are their contributions to the running of the institute. I have been reading recently of the Findhorn Community in Northern Scotland and how their needs (which are carefully distinguished from desires) are almost always provided for in some unforeseen way.

For us, it is frequently our Associates who are fairy godmothers, sending in a flurry of memberships just as a project seems to be in danger of faltering. We are as grateful for their good faith and optimism as for their generosity.

We mentioned in Journal 1 that we planned to publish a list of the names and addresses of our Associates. We have since reconsidered because we are afraid that, with our wider circulation, the mailing list could be picked up by advertisers, and our Associates would be subjected to the same annoying paper pollution via the mail by which we are plagued.

We would offer instead to Associates interested in the possibility of locating fellow travelers in their area that you write to us and we shall gladly check our files and let you know of others within a useful communicating distance.

Mail - and the Journal

As it has become fashionable, if not downright satisfying, to blame one's problems on the energy crisis, perhaps we could say that, due to the energy crisis, we have had a quantum jump in our mail: Incoming, that is. The reason we can choose to trace this leap back to the energy crisis is that it is probably the reason that a variety of magazines, most of which we've never seen, have dropped our name, usually in connection with alternative energy programs. As a result, we are subject to a flood of letters referring to articles we hadn't known existed. Marc Sherman responded on one such occasion, on the eve of his departure for India, with his windmill bibliography which guides people to most of the available sources on wind power. Using a printed bibliography rather than writing the hundreds of letters that would have been required otherwise did save considerable time, but still took a fair effort. Even this did little better than make a dint in the mail. So, in order to make our information available as widely as possible, we have decided to make the Journal our major organ of communication. Though less personal than answering letters, we shall try to be as sensitive as possible to the bulk of questions directed at us and to plan issues around them. We hope, in this way, to be more useful in that we will make more information available to more people and to do so in greater detail than would be possible through individual letters.

— Nancy Todd

Photo by John Cressey

Last *But Not Least*

Please note the change of address for New Alchemy West:

New Alchemy Institute West
Box 376
Pescadero, California 94060

Photo by Alan L. Pearlman

Book Reviews

Rudolf P. Hommel, *China at Work,* MIT Press, 1969 – $3.95 (first edition, 1937).

Hans E. Wulff, *The Traditional Crafts of Persia,* MIT Press, 1969 – $7.95.

Peter van Dresser, *A Landscape for Humans,* 1972, Biotechnic Press, P. O. Box 26081, Albuquerque, New Mexico 87125 - $3.00)

These are valuable books for people wanting to get back to the land and live simply and self-sufficiently. Modern Americans having been brought up, as they have, with everything treated as commodities and pre-packaged for them, lack knowledge and skills for producing basic necessities of shelter, clothing and food. These two books help fill this awesome gap with necessary information describing techniques that have been used by the Chinese and the Persians for thousands of years.

Rudolf Hommel spent eight years in China in the 1920's doing research for *China at Work*; the result is a careful recording, illustrated with hundreds of fine photographs, of the hand tools and simple machinery used for centuries by Chinese peasants in their daily tasks. The text explains the methods for using these tools and gives clear directions for such techniques and crafts as pise de terre (rammed earth) walls; house heating with limited fuel supply; cart, sled, and boat building; hand spinning, weaving, potting, and metalwork; carpentry, brick and tile making and much more.

Of special interest is the chapter on farming. For people who want to produce their own rice and other grains on a small scale by hand, this chapter provides basic information on plowing, planting, irrigation techniques, fertilization, harrowing, tilling, threshing, winnowing, hulling and grinding. Also there are detailed descriptions and pictures of tools and processes for making soybean curd (to-fu); vegetable oil pressing; brewing and distilling, salt mining, fishing and more.

China at Work is part of a growing literature on the traditional ingenuity of the Chinese. Such books as F. H. King, *Farmers of Forty Centuries,* J. Needham, *Science and Civilization in China,* and Li Chi'iao Ping, *The Chemical Arts of Old China* have amply demonstrated the ingenuity of the Chinese in producing, for thousands of years, the necessities of a good life from the simplest of tools and materials.

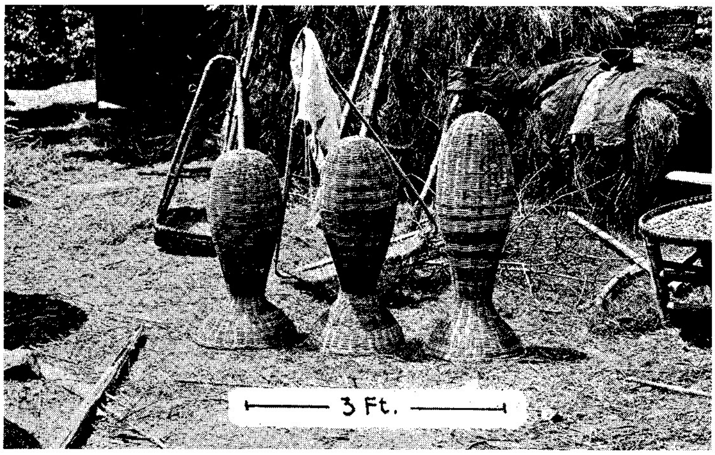
Hans Wulff began research for *The Traditional Crafts of Persia* in 1937 when as principal of The Technical College at Shiraz he was asked by the then Shah of Iran to incorporate "the great tradition of Persian craftsmanship" into the curriculum of the College. The result of his work is a comprehensive source book on traditional crafts which have survived in Persia since ancient times. The book is divided into sections on metalworking, woodworking, building and ceramics, textile and leather, agriculture and food treatment. It is amply illustrated with photographs and diagrams. The text never loses sight of the historical antecedents of present-day Persian crafts. In one volume Wulff combines the excellent qualities of both Hommel's and Needham's books on China. For instance, after discussing contemporary blacksmithing, he lists the ancient classifications of steel made by the philosopher-scientist Al-Kindi in the 12th Century. He introduces the woodworking section by listing about 200 species of trees with their Persian, Latin and English names and most important properties.

Like *China at Work,* this book is extremely useful for us today: there are pictures, diagrams and descriptions, for example of simple spinning wheels and recipes for natural dyes, a portable wood-turning lathe used by wandering gypsy craftsmen (to turn out, among other things, the parts of spinning wheels); Persian house domes and roof-vaulting systems; metal-working techniques, glassmaking, and many more.

The hand working farm methods of the Persians, strikingly similar to those of the Chinese, are clearly described. Especially important for people living in dry climates such as the American Southwest is the information on dry land farming and ancient Persian methods for conserving and distributing water.

China at Work and *The Traditional Crafts of Persia* are two inspiring books, invaluable sources of information, that one may turn to again and again in the effort to learn survival without "benefit" of modern technology. We are fortunate to have them available.

The current "energy crisis" with resulting shortages of basic commodities is making clearer to growing



Eel Cages or Baskets to Keep Alive Captured Eels.

– from *China at Work*

numbers of people the deep-rooted weaknesses of our highly-centralized, capital intensive, urban-industrial economic system. In the United States and other Western nations, this system is proving itself quite incapable of providing any assurance of the necessities of a good life, but seems rather to be leading us to economic and ecological break-down. The major existing alternative to the capitalistic system, state-controlled socialism, is experiencing, with industrialization, similar socio-ecological problems.

However, early in this century in India the failings of both economic systems were clearly foreseen, and a truly viable alternative proposed in the "social ecology" of Radhakamal Mukerjee (*The Foundation of Indian Economics*, 1916, and *Regional Sociology*, 1926) and in the "villagism" of Bharatan Kumarappa (*Capitalism, Socialism, or Villagism?*, 1946), among others. This alternative was put into practice to some extent by the Gandhi movement. In the West little has been done, the main exception in America being the Decentralist movement of the 1930's, which has been pretty well forgotten, in spite of the potential ecological crisis of the present day. Peter van Dresser took an active part in the Decentralist movement. In *A Landscape for Humans* (1972) he presents clear proposals for small-scale ecologically sound economic development founded upon a harmonious balance of local resource potential and human needs within the specific region.

Like Mukerjee, van Dresser realizes that essential to an economic development that is human-based yet ecological is the concept of regional self-sufficiency. Only when economics are based solely upon the natural resources and human needs of a particular region can a healthy, self-sufficient, and ecologically sound way of life develop. Our current system treats a region, its natural resources and inhabitants, as a one-way commodity, to be used until no longer profitable. The present ecology and energy crises result from the practice of mindlessly consuming the resources of region after region. Should a labor-intensive and resource-conserving economic system be allowed to develop, it would still be possible to live a fulfilling and harmonious life in this day of crises and shortages. Peter van Dresser shows the way in a region that he knows well.

A Landscape for Humans is an in-depth study of the northern New Mexico uplands. Van Dresser begins with a detailed description of the region: its geography; the history of Spanish, Indian and Anglo settlement; traditional practices; present means of livelihood; population figures; and natural resources. He then discusses the current trend toward resource depletion and rural depopulation. He shows clearly that this is in no way "inevitable", as its proponents maintain, but is rather based upon the dictates of our economic system. By the criteria of this system the northern New Mexico uplands are "uneconomic" because their resources are not conducive to profitable or large-scale exploitation. The only value of the region, from this point of view, is the potential human labor which can best be utilized as an urban labor pool, resulting in rural depopulation and the growth of increasingly parasitic urban groups. This need not happen. Van Dresser points to the history of the region. The Spanish settlers, mostly small farmers, were for hundreds of years virtually self-sufficient, producing almost all necessities of life locally. With careful resource management this region could again provide the basic needs of its inhabitants and, in fact, support a larger population.

Van Dresser discusses four areas or "potentials" for productive socio-ecological development: I) "A full complement of region-supplying primary industries" developed upon the basis of traditional skills and local resource availability. This would foster a truly regionally-centered industrial development providing employment and basic commodities for local use without destroying the environment; II) "Land- and skill-intensive agriculture and husbandry." The land in northern New Mexico is "uneconomic" in agri-business terms due to small holdings and limited water resources, but it is more than ample for providing food - vegetables, fruit, meat and dairy products - for the whole region; III) "Deep functional involvement of the community in soil and biotic conservation." This is the key to long-term regional self-sufficiency. The local people themselves must learn to conserve such natural resources as water, timber and soil, which are the true sources of a healthy productive life for generations to come; IV) "Enriched village-community economic, social and cultural life." The strengthening of local organizations is necessary for community control of resources and for guidance in planning and development within the region. Further, such organizations can provide, as they did traditionally, local social and cultural centers to counterbalance the lure of the "big city.".

These four "potentials" for socio-ecological development, and the possibilities and means of their implementation, are explored in great depth by van Dresser. The result is a study of immense value to northern New Mexico, and, with modification, provides guidelines for sensible small-scale development in any region. The problems of northern New Mexico are world-wide and the time has come for people to stay home and develop a new regionally centered and self-sufficient economy and way of life. We can no longer depend upon distant, potentially unstable, sources for our basic needs as most Americans do at present, leaving themselves extremely vulnerable to the effects of scarcity. *A Landscape for Humans* indicates a path from vulnerability to self-sufficiency, from weakness to strength. It is to be hoped that concerned people everywhere will read this book and put what they learn from it into action, in the task of developing strong and independent communities throughout the country.

— William Wroth, Box 3, Amalia, New Mexico 87512

Energy

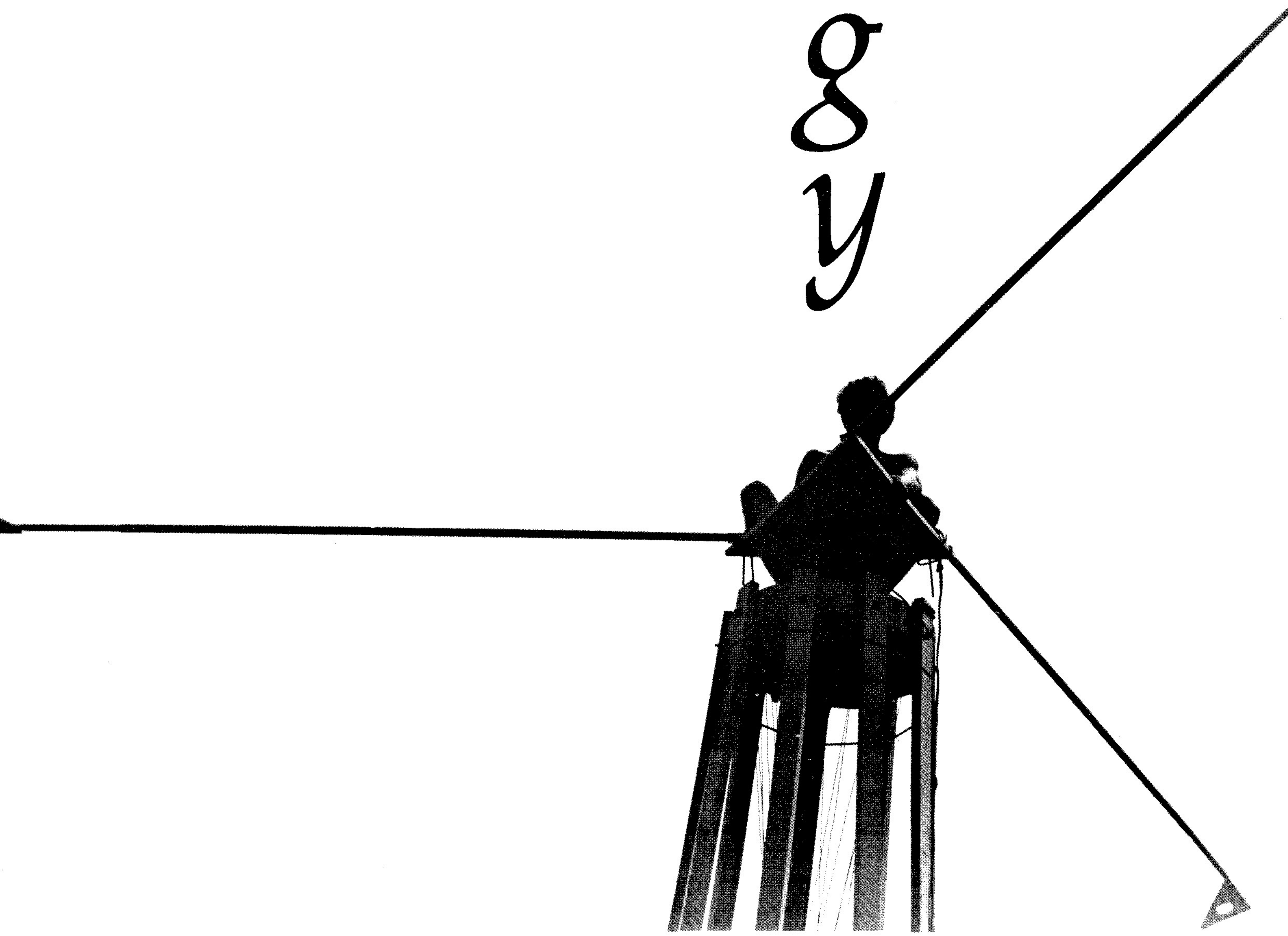


Photo by Alan L. Pearlman

We little thought, when we chose the title "Energy" for this section of the Journal, of how many shadings of meaning the word could be understood to have. I have seen it used to describe the positive force that believers in a New Age feel is growing swiftly now and will take us forward in an Aquarian Era of serenity and heightened awareness. Energy is spoken of to describe the impact of a personality or a group; of one's power to influence the people and events around one. It is still an apt term for what children have limitless amounts of.

We are still using it, in this section of the Journal, in a more traditional sense of the capacity to do work. At the same time, in doing so, we are deeply committed to working with as opposed to taking from nature, and, as this implies a contemplative approach of learning to listen to the wind and the sun and to growing things, then, perhaps when we chose "Energy" to describe our work, we half-intended some of the more subtle meanings to be understood as well.

— NJT

A Water Pumping Windmill that Works

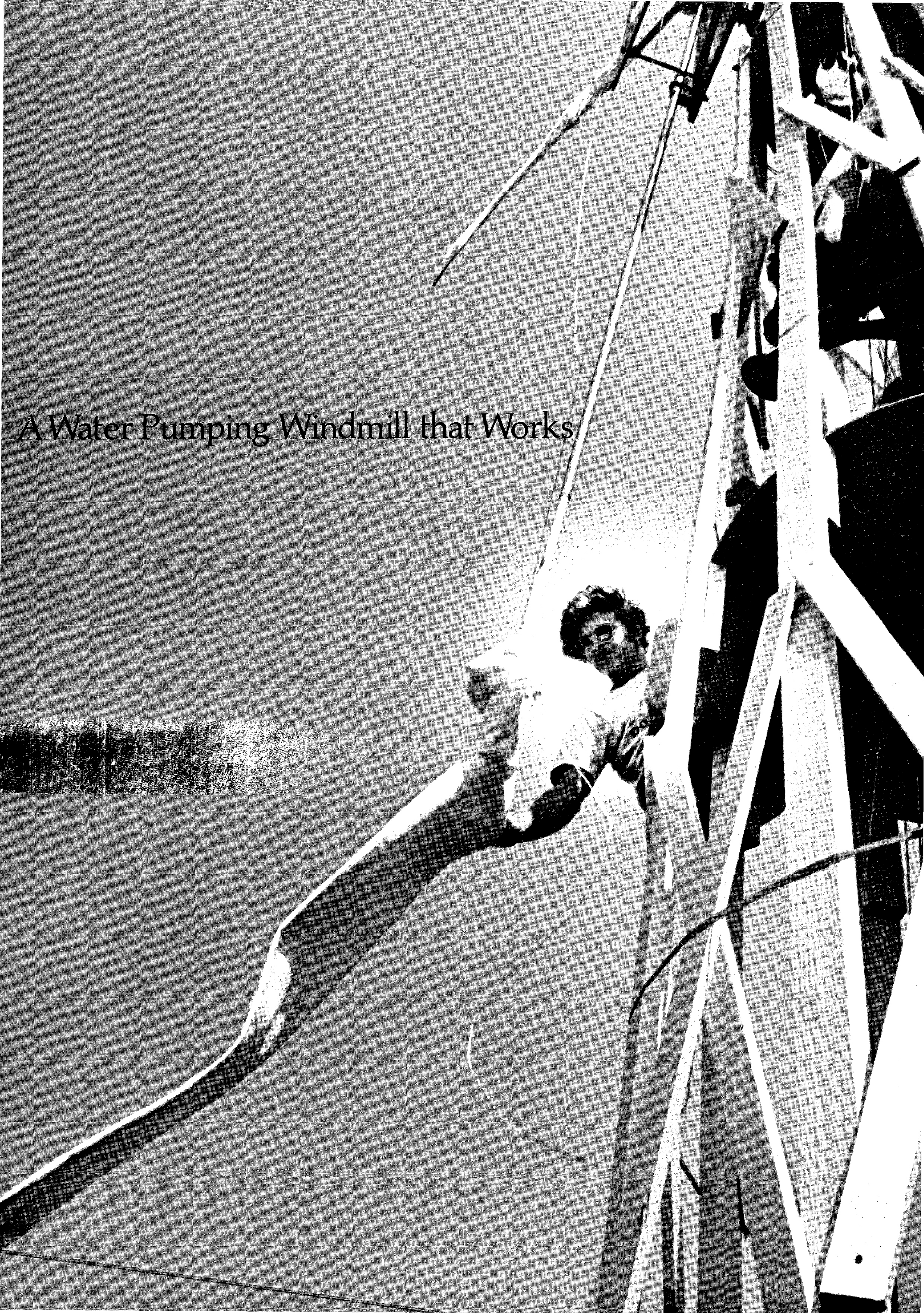


Photo by Alan L. Pearlman

This windmill consists of three cloth sails attached to three tubular steel masts which are fastened to a triangular plywood hub. The center of the hub is bolted to the end of an automobile crankshaft which spins in bearings mounted on top of a steel ball-bearing turntable. The bearing turntable unit, which allows the windmill to rotate so that the sails are always perpendicular to the wind, is mounted at the top of an eight-legged tower which is firmly guyed and braced. A piston rod connected to the crankshaft transfers power through a reciprocating vertical steel pipe which runs from the top to the bottom of the tower where it operates a high capacity piston-type water pump.

The tower legs are bolted at the base to eight telephone pole sections which are firmly buried in the ground to prevent the tower from blowing over in heavy winds. This windmill is designed to remain operational and to withstand storm conditions. Ideally the cloth sails should be removed if severe wind conditions are anticipated. Our windmill was built to supply circulating water to a series of twenty experimental aquaculture ponds. It was required that the water in each pool be replaced once each day. Water pumping trials showed a yield of 250 gallons per hour in a 6 mph wind with 18' diameter blades applying power to a 3" diameter pump through a 3½" stroke.

7.481 gallons/ft^3

$$\frac{250 \text{ gph}}{7.5 \text{ g/ft}^3} = 33.3 \text{ ft}^3\text{/hr}$$

$$33.3 \text{ ft}^3\text{/hr} \times 8 \text{ hr} = 266.4 \text{ ft}^3 \text{ in } 8 \text{ hr.}$$

This figure is lower than the calculated pumping capacity of the windmill.

Because of this we recommend that a crankshaft with a greater stroke or a pump of a larger diameter piston be used. A new mill that we have just completed uses 2 No. 350 cast iron pumps mounted in tandem (Mid-West Well Supply Co., Huntley, Illinois).

Parts

PARTS SHOWN ARE NOT DRAWN TO SCALE

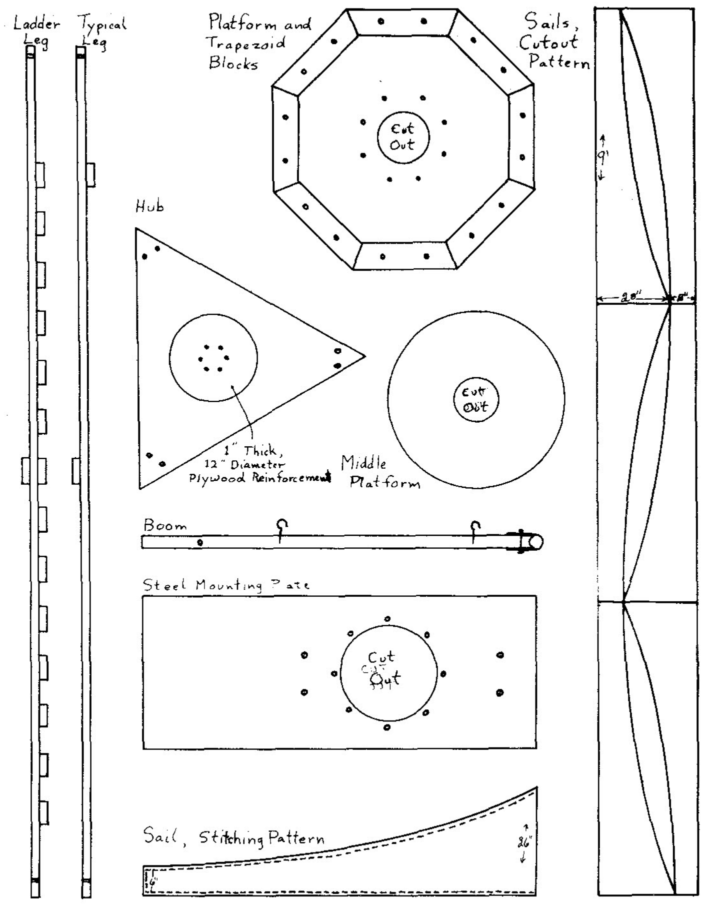
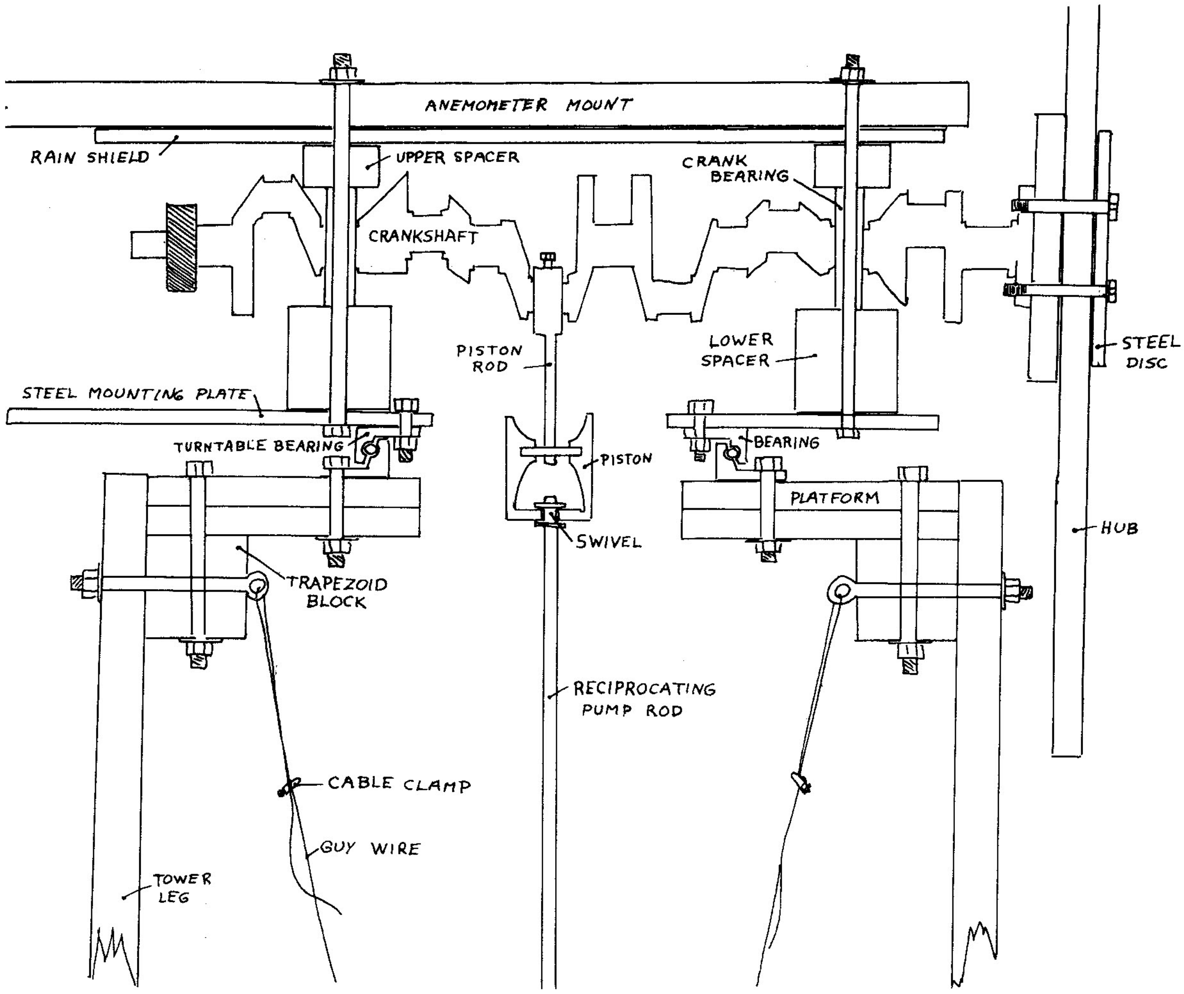
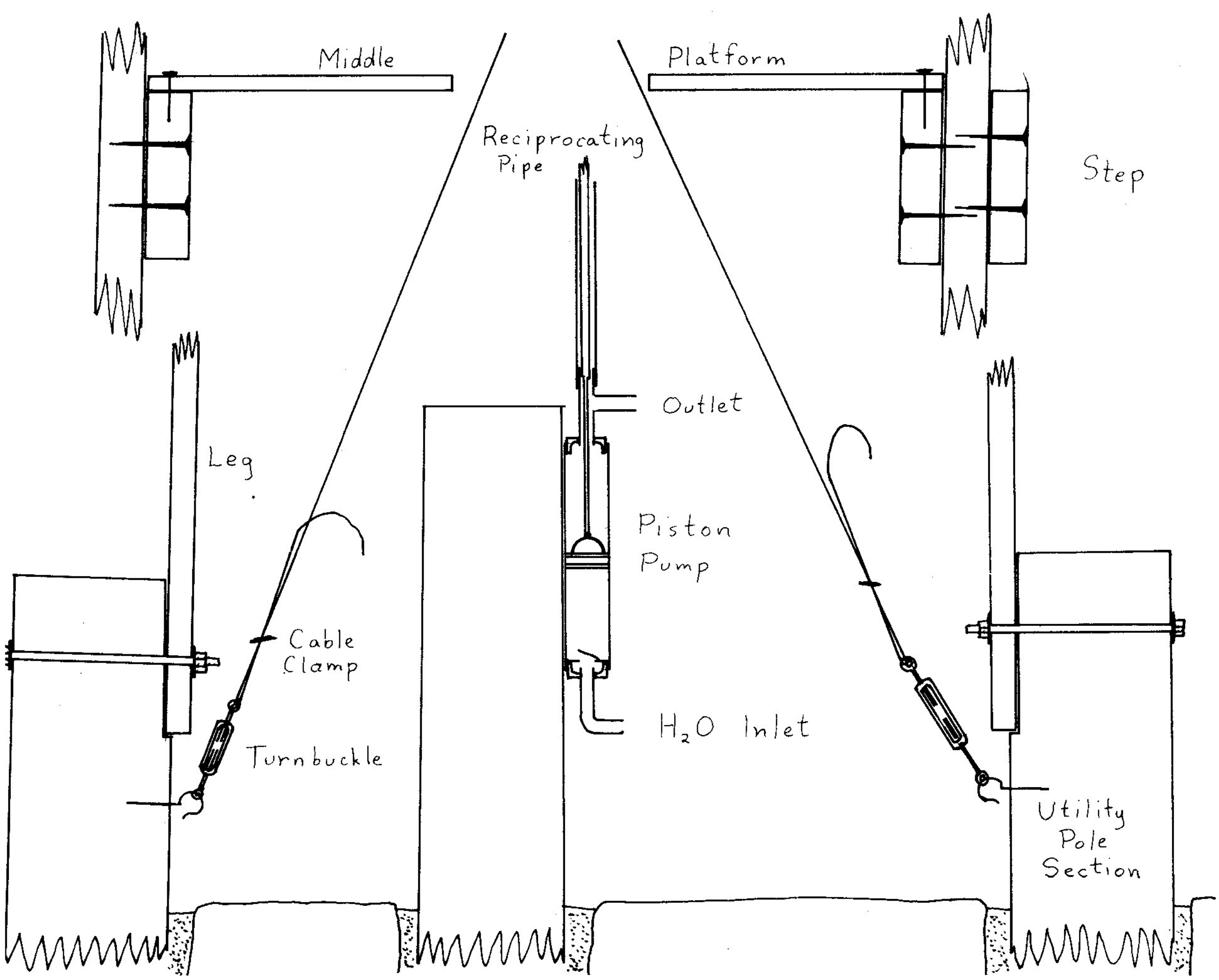


Photo by Alan L. Pearlman


ANEMOMETER MOUNT
RAIN SHIELD
UPPER SPACER
CRANK BEARING
CRANKSHAFT
PISTON ROD
LOWER SPACER
STEEL DISC
STEEL MOUNTING PLATE
TURNTABLE BEARING
BEARING
PISTON
PLATFORM
SWIVEL
HUB
TRAPEZOID BLOCK
RECIPROCATING PUMP ROD
CABLE CLAMP
GUY WIRE
TOWER LEG


Middle
Platform
Reciprocating Pipe
Step
Outlet
Leg
Piston Pump
Cable Clamp
H2O Inlet
Turnbuckle
Utility Pole Section

Materials in Order of Assembly:

BASE

8 - 6' sections utility pole (or railroad ties), concrete optional depending on hole depth

8 - 12"x ½" galvanized machine bolts, 8 nuts, 16 washers

8 heavy galvanized screw hooks to secure turnbuckles to base

TOWER AND TOP PLATFORM

8 - 26' x 2" x 4" spruce for tower legs

8 - 8" pieces 2" x 4" spruce to secure middle platform to inside of legs

16 - 8" pieces 2" x 4" spruce for ladder steps on outside of one leg

8 - 8" pieces 2" x 4" spruce for foot holds around top of tower

½ gross 2½" No. 10 galvanized wood screws

2 - 1" thick, 28" wide plywood octagons for top platform

1 - 10' x 3½" x 3½" spruce for making 8 wooden trapezoid blocks to secure platform to legs

16 - 7" x ½" galvanized machine bolts, 16 nuts, 32 washers, to secure trapezoid blocks to platform

8 - 6" x ½" galvanized eye bolts, 8 nuts, 16 washers, to secure top of tower legs to trapezoid blocks and to provide attachment for top of guy wires

16 - 27' lengths of t-v antennae guy wire for internal guying of tower

32 cable clamps to form loops at ends of guy wires

Several strong persons and 100' strong rope required to set tower in place, gin pole helpful

1 - 48" diameter ½" plywood disc for middle platform

16 guy wire turnbuckles

16 - 56" pieces 1" x 3" spruce for lower bracing of tower

1 - 8' piece ½" nylon rope with eye splices and safety clips (for safety line)

At least one capable person who is not afraid of heights

16 - 40" pieces 1" x 3" spruce for upper bracing of tower

1 gross 12 penny galvanized screw nails to fasten bracing to tower legs

TURNTABLE AND DRIVELINE UNIT

1 - Model No. M4-12P4 series 1000 Econotrak bearing (9" inside diameter) from Rotek Inc., 220 West Main Street, Ravenna, Ohio 44266 (about $129.00) with 6 holes (½" diameter) bored equidistantly in both top and bottom bearing ring segments

1 - 36" x 14" x ½" steel plate for mounting crankshaft on top of turntable bearing. A hole approximately 9" in diameter must be made in this plate through which the piston rod extends to connect with reciprocating rod

6 - 1¼" x ½" galvanized machine bolts, 6 nuts, 6 spring lock washers to secure steel mounting plate to top of turntable bearing

1 large stroke auto or truck crankshaft with 4 of its bearing retainers. An 8 cylinder crankshaft is preferable.

2 - 6" x 3½" x 3½" spruce blocks for lower bearing spacers

2 - 8" x 1½" x 3½" spruce blocks for upper spacers

1 - 36" x 14" x ½" plywood for rain shield

1 - 8' x 1½" x 3½" spruce for anemometer mount

4 - 12" x ½" galvanized machine bolts to secure anemometer mount, rain shield, upper spacer crankshaft, bearings and lower spacer to the steel mounting plate, 4 nuts, 4 washers and 4 lock washers

6 - 3" x ½" galvanized machine bolts to secure bottom of bearing to platform, 6 nuts, 6 washers, 6 spring lock washers

1 piston and piston rod unit to connect crankshaft to vertically-reciprocating pipe

1 - 20' length ½" galvanized pipe to connect piston at top to pump at bottom

4 - ½" pipe thread screw collars and 2 - ½" inside diameter heavy polyethylene washers to secure top of pipe in hole in head of piston for swivel mount

1 adaptor to connect ½" pipe threads to 3/8" machine threads on pump rod

PUMP UNIT

1 - 8' section utility pole (or railroad tie) set in ground off center of line of travel of vertically-reciprocating pipe (pump cylinder is mounted on this)

1 Model No. 81 brass-lined pump cylinder No. 380-1-3021 from Demster Industries Inc., P. O. Box 848, Beatrice, Nebraska 68310 (about $45.00), or any large diameter piston pump or Model No. 350 Shallow Well Cast Iron Cylinder from Mid-West Well Supply Co., Huntley, Illinois (about $18.50).

1 "T" joint for outlet of pump

1 - 1¼" check valve for bottom of intake pipe

Adequate 1¼" plastic piping for inlet and outlet of water

HUB-BLADE UNIT

1 - 1" thick plywood equilateral triangle 30" on each edge for hub

1 - 12" diameter 1" thick plywood circle to reinforce center of hub

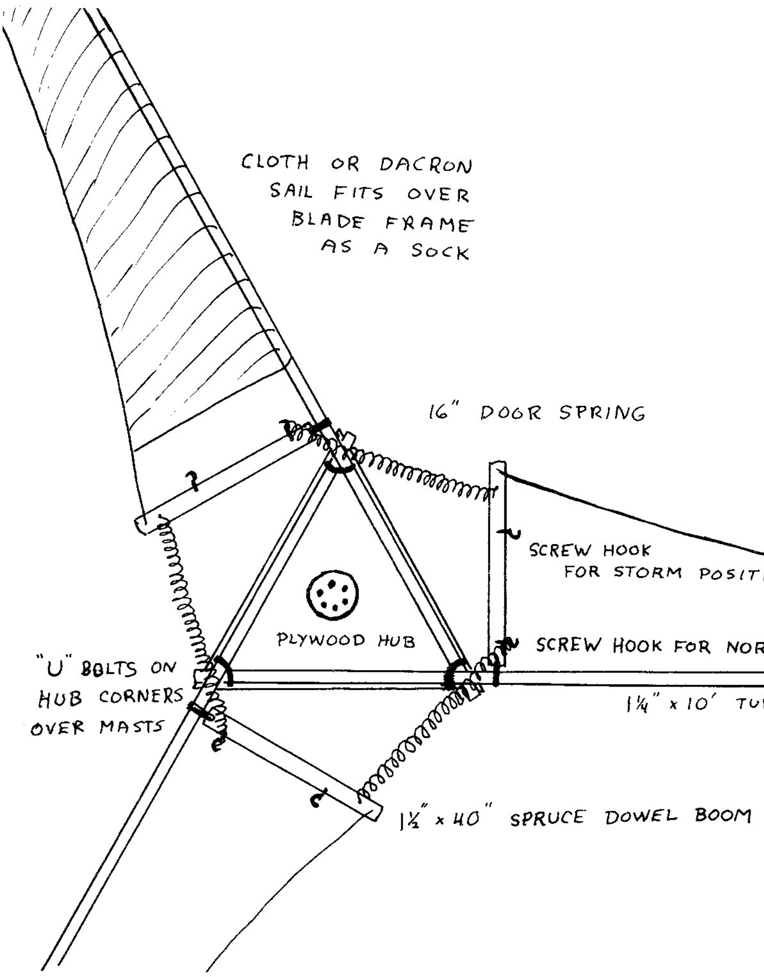
1 - 9" diameter ½" thick steel disc to reinforce center of hub (from hole in steel mounting plate)

3 - 10' long 1¼" tubular steel t-v antennae masts for windmill masts (arms)

3 - 1½" spread "U" bolts made from 3/8" threaded rod to secure masts at hub corners

3 - 1½" inside diameter galvanized steel pipe sections 6" long to prevent "U" bolts from crushing masts

6 wooden wedges 12" long, 1½" wide, 1" thick at fat end to adjust coning angle of masts to prevent collision with tower
3 - 2' x 1" steel tubing for mast extensions
3 - ¼" thick, 1" wide 21" steel straps for tip of mast extensions



12 - 1½" x 3/8" machine bolts to attach steel straps to tip of mast extensions, 12 nuts, 12 spring lock washers
3 - 2" cotter pins to secure mast extensions within masts
3 - 32" pieces 1" spruce dowel for booms at base of masts
3 - 1" x 8" medium gauge galvanized sheet metal strips to secure booms to masts
3 - 16" door springs for automatic pitch control
9 medium screw hooks to secure door springs to booms
3 - 12' long pieces nylon cord to form trailing edges of sail blade frames
9 yards muslin, cotton or dacron sail material

OPTIONAL ITEMS
1 anemometer (recording)
1 water meter
Water storage tank(s)

TOOLS NEEDED
Bit brace, chisel, cross-cut wood saw, hammer, level, open-end wrench set, paint brushes, post-hole digger, screwdrivers, sewing machine, shovel, socket wrench set, 9/16" wood bit, and wood clamps; *Optional:* electric drill (heavy duty), high speed drill set, jig saw, skill saw, and ½" steel strapping and tensioning tool from Signode Corp.

OTHER SUPPLIES NEEDED
1 gallon white exterior primer paint, 1 gallon exterior paint, 1 quart black Rust Oleum paint, Weldwood or Borden's 2-part plastic resin wood cement, all-weather farm grease, and silicone sealing compound

Most parts are available at any lumberyard, hardware store, auto junk yard and t-v supply store. Only the water pump and turntable bearing are "send away for" items. Total cost (less tools and labor) is less than $300.00 in U. S.

Note on scrounging: It is usually cheaper and more expedient to ask persons directly responsible for the article desired; i. e., the yard foreman, truckdriver, stockboy, job foreman, etc., not the purchasing agent or factory superintendent.

— *Marcus M. Sherman*

POSTSCRIPT

Testing of the mill: Since the article was prepared we have had an opportunity to test the sailwing windmill for ruggedness and pumping ability.

The windmill, with the cotton sail blades of 18' diameter, did indeed pump 250 gallons per hour in 6 mph winds. The water was pumped up 14' from a lake below the windmill. Our calculations and direct observations indicated that our pump was considerably undersized for the windmill. A larger stroke or a larger diameter piston pump would have been desirable. Our latest sailwing windmill, with sails designed by Merrill Hall, has two pumps mounted side by side (see drawing of advanced backyard fish farm mill) and we may yet add additional pumps.

Cotton versus dacron sails: During the winter trials the cotton sails did not stand up to continuous operation through storms and high winds. We decided to try dacron sails as dacron is a much longer-lived material, holds its shape better, does not absorb water during rains and is much stronger and lighter than cotton.

Photo by Alan L. Pearlman

Photo by Alan L. Pearlman

These are important factors when it comes to the design of large sailwings.

Merrill Hall made us a set of 3.8 oz. dacron sails to Marcus Sherman's design. From visual observations they seem to perform better than the cotton sails did. They are steadier and have a better configuration while driving in heavy winds.

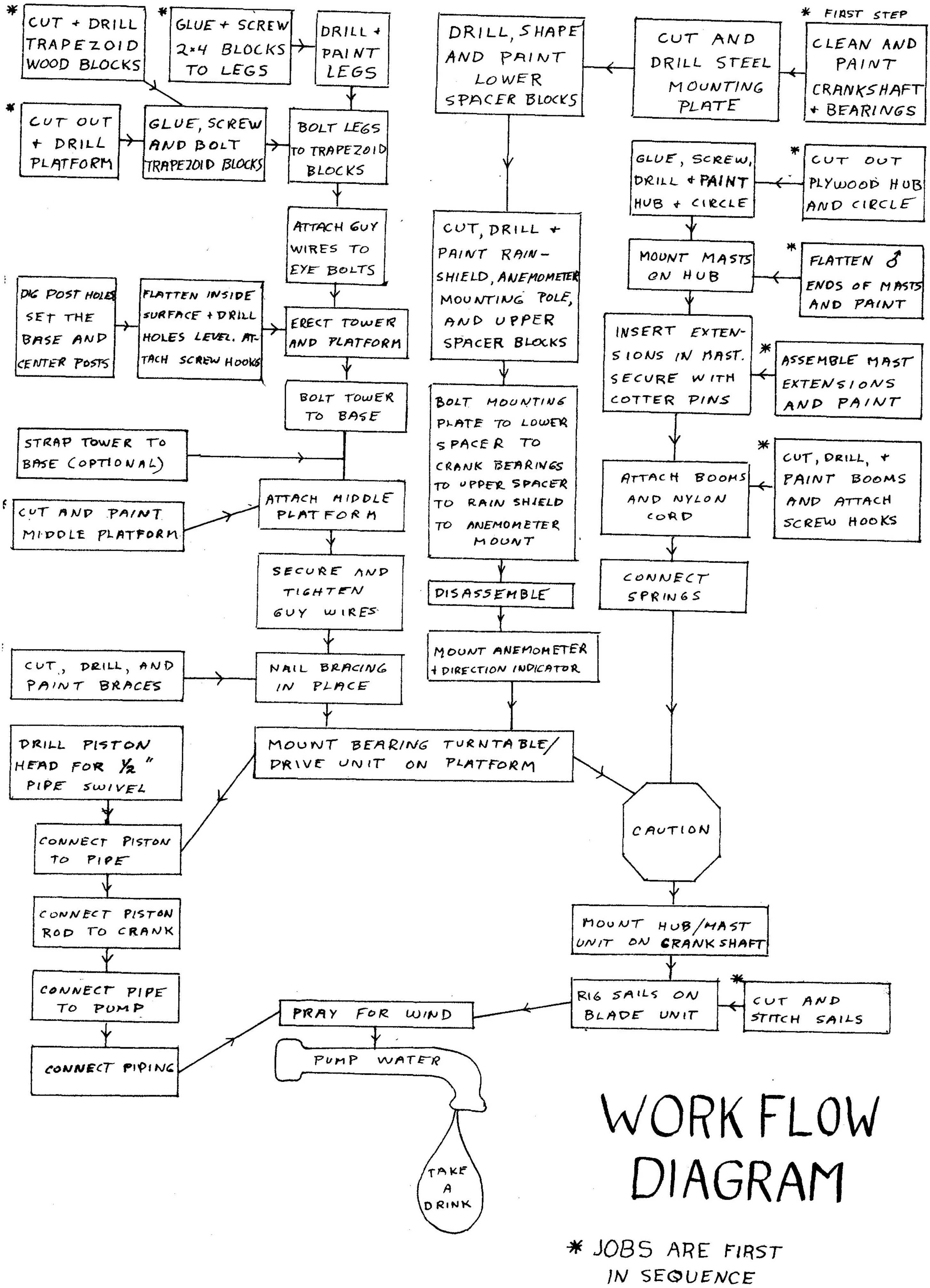
It was not long before we had a chance to test the dacron sails. With the feathering springs set in their storm position (see sailwing diagram) the mill came through a force nine gale (40 knots-plus winds) and continued to pump throughout the storm. The next gale arrived a few days later accompanied by freezing rain. This time we decided to leave the feathering springs in their full working position. The mill, to our great pleasure, was still pumping when the storm abated. The strong sails and Marc's spring feathering system have vindicated themselves, and since the last gale, a number of severe storms have been weathered.

Post Postscript

We have recently learned that dacron is not superior to cotton for use in tropical areas, although coloured dacron has proved more durable than white.

Problems: During high winds, bolts and screws, including those on the end of the crankshaft, shake themselves loose. We replaced the hub bolts with longer ones so that lock washers and nuts could be placed on the crankshaft side of the hub. If you plan to have your windmill operate during high winds, we advise that you do not skimp; get quality materials and build it to last a long time, perhaps even a lifetime.

The windmill as accomplice and ally: Our sailwing windmill with its bright red sails has brought us an immense amount of satisfaction. Having it around makes us feel better, and there is something almost magic about working with the wind. At the bottom of the tower with the wind passing through the rigging, one is carried off to the plains of Crete and to distant shores where men first used the wind to drive their vessels and embark upon the unknown.



* CUT + DRILL TRAPEZOID WOOD BLOCKS
* GLUE + SCREW 2×4 BLOCKS TO LEGS
DRILL + PAINT LEGS
DRILL, SHAPE AND PAINT LOWER SPACER BLOCKS
CUT AND DRILL STEEL MOUNTING PLATE
* FIRST STEP
CLEAN AND PAINT CRANKSHAFT + BEARINGS
* CUT OUT + DRILL PLATFORM
GLUE, SCREW AND BOLT TRAPEZOID BLOCKS
BOLT LEGS TO TRAPEZOID BLOCKS
GLUE, SCREW, DRILL + PAINT HUB + CIRCLE
* CUT OUT PLYWOOD HUB AND CIRCLE
ATTACH GUY WIRES TO EYE BOLTS
CUT, DRILL + PAINT RAIN-SHIELD, ANEMOMETER MOUNTING POLE, AND UPPER SPACER BLOCKS
MOUNT MASTS ON HUB
* FLATTEN ♂ ENDS OF MASTS AND PAINT
DIG POST HOLES SET THE BASE AND CENTER POSTS
FLATTEN INSIDE SURFACE + DRILL HOLES LEVEL. ATTACH SCREW HOOKS
ERECT TOWER AND PLATFORM
INSERT EXTENSIONS IN MAST. SECURE WITH COTTER PINS
* ASSEMBLE MAST EXTENSIONS AND PAINT
BOLT TOWER TO BASE
BOLT MOUNTING PLATE TO LOWER SPACER TO CRANK BEARINGS TO UPPER SPACER TO RAIN SHIELD TO ANEMOMETER MOUNT
STRAP TOWER TO BASE (OPTIONAL)
ATTACH BOOMS AND NYLON CORD
* CUT, DRILL, + PAINT BOOMS AND ATTACH SCREW HOOKS
CUT AND PAINT MIDDLE PLATFORM
ATTACH MIDDLE PLATFORM
SECURE AND TIGHTEN GUY WIRES
DISASSEMBLE
CONNECT SPRINGS
MOUNT ANEMOMETER + DIRECTION INDICATOR
CUT, DRILL, AND PAINT BRACES
NAIL BRACING IN PLACE
DRILL PISTON HEAD FOR ½" PIPE SWIVEL
MOUNT BEARING TURNTABLE/DRIVE UNIT ON PLATFORM
CAUTION
CONNECT PISTON TO PIPE
CONNECT PISTON ROD TO CRANK
MOUNT HUB/MAST UNIT ON CRANKSHAFT
CONNECT PIPE TO PUMP
RIG SAILS ON BLADE UNIT
* CUT AND STITCH SAILS
PRAY FOR WIND
PUMP WATER
CONNECT PIPING
TAKE A DRINK
WORK FLOW DIAGRAM
* JOBS ARE FIRST IN SEQUENCE

Wind Power — Windmill Electronics

Photo by Alan L. Pearlman

In Journal 1, we introduced the design of a home-built windgenerator made of recycled automobile parts, with details of the tower, swivel, transmission, and other mechanical parts. In the following article by Fred Archibald, we continue the development of the windmill by discussing the electrical system. The following diagrams and excellent technical advice allow the basic mechanical windmill to be adapted to several power ranges to suit the needs and situations of the builder. Equally valuable information is given concerning batteries and storage.

January 6, 1974

Dear New Alchemists:

I have been following your work with interest, and a little sense of participation, as I came up with the idea for the automotive differential-wheel spindle basis for a wind generator. Marc Sherman and I spent a long time discussing the system, both in the fall of '72 when the thing was started and this last Christmas. I have investigated the problem a bit further and hope that the following information, mainly on the electrics of the thing, will be of some use to you or your readers.

There are a number of problems associated with producing useful amounts of electric power from the wind for any length of time, if money is a consideration.

1. A constant voltage must be produced from a mechanical energy source (the propeller) varying from a few RPM to several hundred RPM.

2. A constant AC frequency of 60 CPS must also be produced from this variable speed source if standard appliances are to be used, and AC power frequency depends on AC generator speed.

3. The system must be able to withstand extremes of vibration, temperature, water and ice, corrosive salt spray and hundreds of thousands of revolutions with little maintenance.

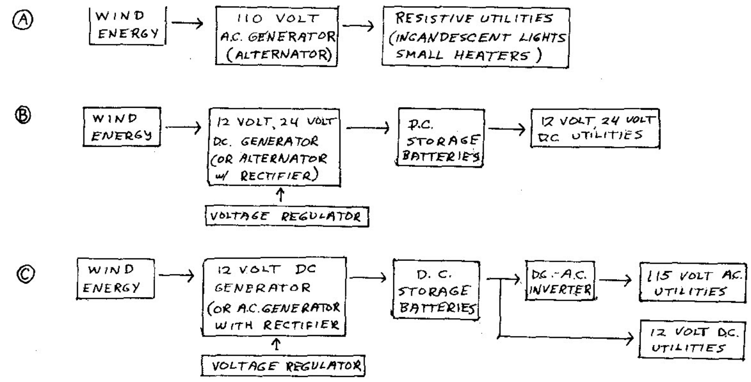
4. It must be designed to extract as much energy from the wind as possible and transfer it efficiently to the utilities to be run.

5. As wind conditions, terrain, facilities, and power requirements will be different with nearly every installation, blade size and design, tower height, and the generator:propeller mechanical ratio will be more or less specific for the site.

6. The components must be fairly cheap, very rugged, and widely available.

Cutting corners on Nos. 3, 4 and 5 will make the whole project a great waste of effort. Really, if you don't have the time or facilities to do this thing right, it will only be a toy.

There are many possible generation systems, but the three thought most practical for a small home-type system are:



System (A) is the simplest, but an AC generator run off the wind will have widely varying frequency and voltage which would damage most appliances. Only resistive heaters and incandescent bulbs would be usable, and these would flicker on and off with the wind.

System (B) is the simplest system with storage capacity. A number of commercial wind systems use this. DC power is available at a regulated level, usually 12 or 24 V, even when the wind isn't blowing, and can be used for a wide variety of lights, motors, small heaters, and radios. Many of these things can be bought or scrounged from old cars (12 V) or ordered from automotive or marine supply houses. A small 12V DC refrigerator is even made for marine use. However, the low voltage means high currents and therefore very heavy wire is needed. For instance, Edison calculated that it would take several *tons* of copper to light the houses in a city block using 10-volt bulbs in a 10-volt system. Therefore unless a great deal of heavy cable (like auto starter or 200 AMP arc-welder cable) is available, only small devices (< 50 watts) or ones very near the generator are feasible.

System (C), while the most complex, is the only one providing reliable power compatible with all the utilities in use commonly. The DC storage provides constant power whether the wind is blowing or not, and in turn allows the capture of wind energy when the electrical devices are not being used, which in a system without storage ability would go to waste. Both 12V DC and 115V AC utilities can be run directly and even European 230V AC ones with the simple addition of a transformer. The only limitations on this system are the *amount* of power produced daily, and the current or wattage rating of the inverter. Such a 115V AC system could be plugged directly into a house by pulling out the main circuit breaker or block of cartridge fuses and connecting the inverter directly to the house side of the circuit.

There are infinite variations on these three, depending on what's available, like 28V DC surplus aircraft generators, arc-welding generators, etc., but these are the basic alternatives open.

I won't discuss System (A), because it is the simplest to construct (electrically anyway) and is fairly useless except for heat production, and as even small heat-producing appliances like an iron or toaster use 750-1500 watts each, a very large generator and propeller would be needed to heat even a small building or fish pool.

The 115V AC system is just the 12V DC system with the inverters added, so it might be feasible to start with the 12 V system and later add the inverters. The solid state ones are around 70% efficient, i. e., 1000 watts of 12-volt DC power (83 AMPS) will produce 700 watts of 115V AC (about 6 AMPS).

The reliability needed in a fairly complex system like this is only possible with a really rugged well-designed generating system, and unless you have considerable engineering and technical facilities available to you, the best thing to do is adopt an entire system from another application. The only such system available and meeting the ruggedness, cheapness, and availability requirements is the modern automotive one. Only the automotive one is temperature-compensated to work from -40° to 260°F, go thousands of hours maintenance-free, and resist water, dirt, grease and exposure. If this doesn't sound like the generating system in your old car, it's because there have been some very significant improvements in the system since 1969, mainly the integrated circuit (IC) regulator.

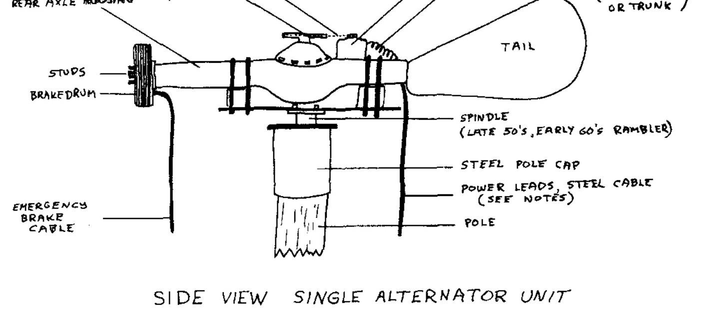
These new systems employ an alternator (AC generator) with an internal rectifier bridge to produce DC and an IC regulator, often also within the alternator unit itself (on '72–'74 units). These alternators come in a number of power (wattage or amperage) ratings, and for the wind generator, the higher the better. Sixty AMPS is the largest common size on big American cars and the best for this application. Sixty AMPS at a nominal 12 volts is 720 watts (generators actually put out 13-14 volts). This is the peak continuous output of 1 unit. As can be seen in the accompanying diagrams, 1, 2, 3 or 4 of these can be accommodated by the design, giving peak outputs of <u>720</u>, <u>1440</u>, <u>2160</u> and <u>2880</u> watts. In assessing the amount of power you need, it is very important *not* to compare directly the wattage ratings of the utilities to be used to these peak output values. The important figure is the *average* power output of the wind generator through 24 hours of the day. If optimal propeller and generator design will only produce 400 watts average (actually quite a good figure), then whether the peak potential power is 2160 or 2880 watts is not very significant, unless your area alternates between calm and very strong winds to get this average. To obtain a good average output, proper blade design, gear ratio, tower, and generator cut-in speed are all-important. The power capability of the system depends on the *length of time* used, at least as much as amperes consumed by utilities, and the storage capacity of the batteries. Even the average power produced is wasted if there is not sufficient storage capacity to hold it and few utilities are being used. In other words, a system producing only 100 watts average output would have stored 2.4 kilowatt-hours a day, if the battery system is adequate, easily enough to run a stove once or twice a day. Actually this would take a large DC-AC inverter, and so such large heating jobs should better be left to DC or other energy sources. The principle, though, is important; a small, continuous power input to a good set of batteries will provide adequate power for high consumption occasionally, say for morning pumping, coffee percolating and evening lights, radio, etc. Perhaps it would make us more aware of electricity's value to us also.

The accompanying diagrams will explain the outline of a feasible electrical system for a wind generator. It doesn't include blade design (which I know very little about) or the over-all ratio between the blade speed and the alternator rotor speed. A high-speed 2-bladed propeller might have an over-all ratio of 8-10 revolutions of the rotor to one of the propeller, and a slower sail type or 3 or 4-bladed type perhaps 20-25:1 ratio. The ratio is determined by selecting an auto rear end with a proper ratio. They vary from about 2.7:1 in big cars with automatics to 4.6:1 for trucks and many small standard shift cars (Datsun, Toyota, British cars, etc.) On top of this, the ratio of the diameters of the pulleys on the pinion shaft and alternators is added; i. e., 2" alternator pulley to 10" pinion pulley. A wide selection of these aluminum pulleys can be found at any hardware store.

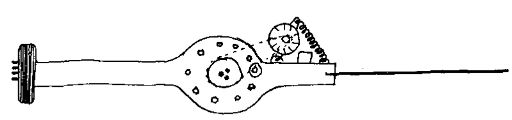
You'll probably read in the other papers about wind systems that pulleys, belts and gears all waste some of the wind's power. It's quite true, but the only way around it is to get a very slow-speed generator directly driven. It must have a very heavy shaft, heavy case and super bearings to take the propeller directly; and the only ones I know of are the ones custom-made for wind generators; and if you're willing to get into such expense, you might as well get an entire Quirk or Wincharger system. The auto rear end, of course, is a very long-lived and maintenance-free unit carrying a ton and with several-hundred horsepower flowing through it. So in a few-horsepower wind generator, it should last a tremendous length of time and consume relatively little power, if it is broken in and lighter oil is used.

Notes on Mechanical Aspects

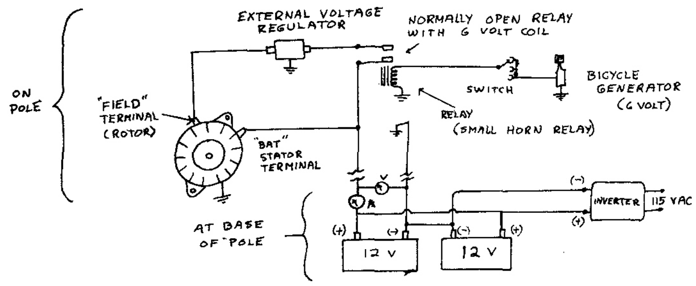
- for best efficiency, remove original oil and put in 20 W motor oil and *new oil seals*
- spider gears in differential may have to be welded together ("spiked")
- tail axle tube must be welded shut
- assembly should be balanced on pivot (spindle)
- a wheel center can be conveniently bolted to the original studs and the steel or fiberglass of the blades affixed to it by welding, bonding or clamping
- a fiberglass or sheet-metal shroud should at least partially protect the alternators and pulleys (not shown)
- ideally a commutator would transfer power from the generator to the ground (to permit free turning of the generator with the wind). This would be very difficult to build as 12 volts would be impeded by even a slight resistance and the generator rendered ineffective. The cables are allowed to hang free with enough length for 2 or 3 revolutions. A steel cable slightly shorter than the power cables, firmly fastened to the base of the pole and the differential housing, would provide a "stop" and prevent the power cables from being ripped off.
- a heavy marine or military type plug in the power cables at the base of the pole will allow their being unwound if they become twisted around the pole.
- stays from the pole cap to the ground will give the whole unit more stability
- the bicycle generator can be of the common type that is spring-loaded against the tire, and in the same way pushes against the alternator belt. In case this is too fast, a suitable surface of rubber on the rim of the brake drum would provide a surface for the generator to run against. A section of an inner tube could be stretched around the outside of the drum like a large rubber band
- all welding should be arc, if possible
- bolts you expect to get loose again should be at least galvanized, preferably brass or stainless steel
- if the belts are kept tight and the pulley ratio not too tight, belt drive will work quite well with 1-2 generators. If 3 or 4 are to be used, a second pinion pulley and belt must be used. Also auto belt drive isn't good with larger generators (greater than 1 KW).



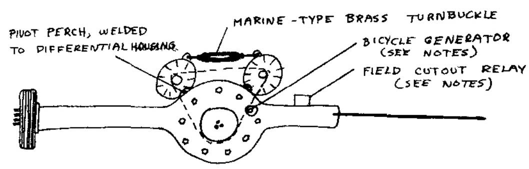
SIDE VIEW SINGLE ALTERNATOR UNIT



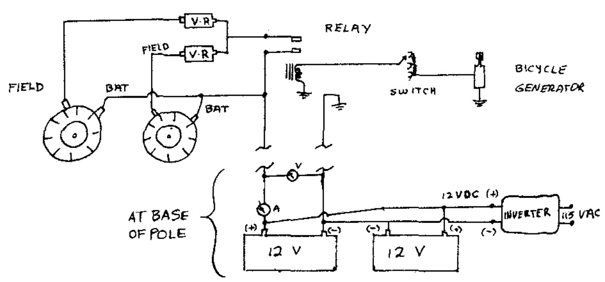
TOP VIEW SINGLE ALTERNATOR UNIT



SINGLE ALTERNATOR SYSTEM



TOP VIEW 2 ALTERNATOR UNIT



2 ALTERNATOR SYSTEM

Electrical Notes

- the bicycle generator-relay system cuts off the rotor current flowing from the (+) side of the battery when the speed of the wind is too low to produce power. In addition when the relay opens, the rotors free wheel, greatly reducing the drag on the propeller, allowing it to get up speed more easily. This is especially important in low-starting torque, high efficiency 2-bladed types.

- a 3-position switch is shown in the generator line. This will control the cut-in speed of the alternators. It may be desirable to change this according to the seasons or wind conditions. This could be replaced by a rheostat, or left out completely if desired.

- a good anemometer is a nearly indispensable aid in setting up and monitoring the machine, as is a $15 "VOM" or electrical multitester.

- the number of batteries needed will vary with the size of the system and how steadily the wind blows in your area, but remember that the batteries represent the only way to capture the wind's energy when utilities are off or using less power than is being generated. Therefore the more AMP-HOURS of battery capacity you have, the more efficient the system will be in using wind energy.

- the batteries will be one of the major expenses of the system so all the standard precautions should be taken to insure efficiency and long life.

1. Add only distilled water.
2. Keep them clean and dry.
3. Check them with a hydrometer frequently (1.230-1.280 corrected for temperature)
4. Have heavy wires and good connectors (covered with grease to prevent corrosion).
5. Don't completely discharge them, especially in winter.

- an integral alternator-regulator unit is wired just as units with a separate regulator (see sketches and schematics) with the low speed cutout relay taking the place of the ignition switch.

- these wires grounded securely to differential housing

- the more batteries are paralleled, the more wind energy you can store and the more will be available for peak use periods.

- the 2 alternator is almost identical to the single. Three or four can be paralleled in the same way. Make sure the relay has adequate capacity (current handling ability) if several units are used.

- all wires should be *soldered*, not clipped, clamped or screwed on the wind generator unit and the joints protected with acrylic, silicone or some other protective material.

- field and bicycle generator leads can be 16 or 18 gauge copper insulated, but (+) and (-) power leads from the stators to the batteries and inverter *must* be very heavy copper like arc-welding or auto "jumper" cables or most of the power generated will be used up in heating the power leads, and the voltage regulator won't work properly.

- wires on the wind generator should be tied down to prevent flexing in the wind .

- the external voltage regulator (if present) and cutout relay should be sealed as well as possible against the weather.

- be sure all electrical units (alternators, bike generator, relay, voltage regulator) are well grounded to the differential housing. Small pieces of braided grounding strap brazed to the housing are good.

- once installed, the solid state rectifiers (in the alternator) and voltage regulator are rugged and reliable, but if their polarity or battery polarity is reversed (the battery is hooked up backwards), they can be permanently damaged in a few seconds.

- the 1969 and later alternators with "IC" regulators are by far the best ones to get, but in any case it's probably not worth using the older DC generators (pre-1960 approximately) as they have much less power output and more maintenance, wiring, and poorer regulation and reliability.

- a spark-gap (¼" or so, obtainable as a TV-antenna accessory, or home-made) should be put between the (+) cable at the base of the pole, and the (-) terminal grounded by a steel stake, to protect against lightning. Unless you really need the power, it's probably best to disconnect the batteries and inverter during thunder and lightning storms.

- at least a DC volt meter and ammeter to monitor generator output should be mounted in the battery box, and preferably an AC ammeter and volt meter in the house, barn, etc., to monitor inverter output.

- never completely discharge the batteries as this shortens their life.

- lock the blade with the emergency brake whenever disconnecting the power leads between the batteries and the alternators. To disconnect the alternator from the batteries while it is charging could damage it.

- the excellent regulation provided by the IC regulator should significantly increase battery life.

- an alternator has brushes, but the slip ring has no breaks like the generator's commutator, eliminating nearly all the wear and sparking. Also an alternator's brushes only carry the field (rotor) current (1-3 AMPS) while a generator's must carry the full output (20-40 AMPS). Therefore alternator brushes generally last many times the life of generator brushes.

- if you stick to 12 V DC power, remember that every auto has two very useful large motors, the starter and the generator (the DC type, not an alternator). The starter is a series-type motor, with tremendous starting torque, good for low speed, heavy jobs, but takes lots of power and the generator is a shunt-type motor. This is really a versatile unit that can produce up to about 1/3 horsepower at a variety of speeds and can be picked up in any junkyard from 1955-1963 American cars. These units can be rewired or rewound if you are really a do-it-yourself type, but can be used directly and the speed controlled by a rheostat between the fields and the armature (about 10-15 ohms at 25 watts).

- actually if you wanted only a small amount of AC, one of these units driving an alternator from a later car with the diodes bypassed for AC and the DC motor (generator) adjusted to the right speed with the field rheostat to the proper speed will produce 115V AC at 60 cycles at a fraction of the cost of an inverter.

- for a really cheap auxiliary power supply, in case the wind doesn't blow, a 2½-3 horsepower horizontal crankshaft lawnmower engine will run an auto alternator, which can produce 12 V to charge the batteries or 115V AC 60 CPS if the engine speed is adjusted properly, usually 1800 or 3600 RPM.

- actually, in obtaining old alternators and generators, I stopped at a number of service stations and asked to look through their trash and got more old units than I knew what to do with for nothing, and most of them, after cleaning, were either perfectly usable or needed only a bearing, diode, or set of brushes!

- Chrysler specifies regulation (charging) of their IC-alternator from 50-5000 RPM; Ford and GM, I couldn't find.

Costs

- it's impossible to give a figure, as this depends on scrounging, but quality parts in some areas are a must.

- look at the ampere-hour capacity of batteries. A $35 battery often has twice the capacity of a $25 one as well as better materials and construction.

- rebuilt alternators ($25-$60) are usually just as good as new ones, if they come from a reputable firm and much cheaper. J. C. Whitney Co. of Chicago, a mail-order auto-parts firm, has good prices on these items. If you're handy, junkyard ones can be renovated for even less.

- the inverter(s) are another major cost, and as the solid state "multivibrator" type are quite new, there isn't much chance of finding a used one. The older mechanical reed type is rarely found, and anyway is very inefficient. A 500 watt continuous, 550 watt intermittent unit costs about $110 from such places as Lafayette Radio or J. C. Whitney. If more power is needed, two or more units can be bought. It's possible to make one from parts, if you are handy, but considering the time and effort and the cost of the parts, it's not practical unless you can "scrounge" the parts.

I guess all this makes pretty dull reading, but for the person serious about such a project, I hope it is of some use. Good luck in your various ventures!

— *Frederick Archibald*
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POSTSCRIPT

The last major hurdle of a low-cost wind generator is the blade technology and construction. Currently the only dependable blade design is a high-speed airfoil blade made of wood or fiberglass. This type of blade can be handmade, but becomes more difficult in larger sizes. We are presently investigating nautical sail design to determine if the long tradition and recent advances in that art can be turned toward low-cost wind generators. Progress toward that end is the success of the self-regulating sail-blades of Marc Sherman's water-pumping windmill described in this Journal.

Land and Its Use

Several years ago, in San Diego, we lived on the edge of a little canyon that was truly lovely. Word reached us, one day, that there was talk of rezoning it for "development" and that the development in question was to be a motel. Panic-stricken, we rushed to the next city council meeting to try to stay the execution of our canyon. I listened earnestly as the meeting opened, not having had much experience with politics, other than those of protest, since high school student council. The councilors (all men) began with a round of remarks which had the general effect of telling each other what good fellows they indeed were. Thus warmed, they turned to the topic of a piece of land that had recently been "improved." Again, the tone was congratulatory. I listened harder. (One doesn't in these cases, by the way, refer to land. One refers to property.) This particular piece of property had, it seemed, been lying fallow — just growing weeds and giving kids a place to play. With discerning judgment, the councilors had changed the zoning regulations and, as a result, the "property" had been "improved" into a gas station.

We work with land too. This section in the last Journal was devoted to land use in Costa Rica. In this issue we should like to describe our usage of a few sandy acres of Cape Cod.

Bill McLarney writes of his thoroughly heartening work using fish pond water in fertilizing and irrigation. Hilde Atema reports her findings from her study of insect resistance in cabbages, and several of us describe our newest project, one we are very excited about, the (as in Noah) Ark.

Meanwhile, all has not been quiet at New Alchemy West. Since the publication of the useful and successful Newsletter No. 3 on Methane Systems, New Alchemy West has acquired a permanent home near Pescadero, California. We view their new-found permanence as well as their climate somewhat enviously, but are at heart enormously pleased for them. In addition to all his other activities, Rich Merrill has finished his book, RADICAL AGRICULTURE, to be published this year by Harper and Row. It hardly need be said that we view the work as both extremely important and timely, or that we are particularly — well, yes, proud — to include the introductory chapter in this section of Journal 2.

— NJT

Photo by Alan L. Pearlman

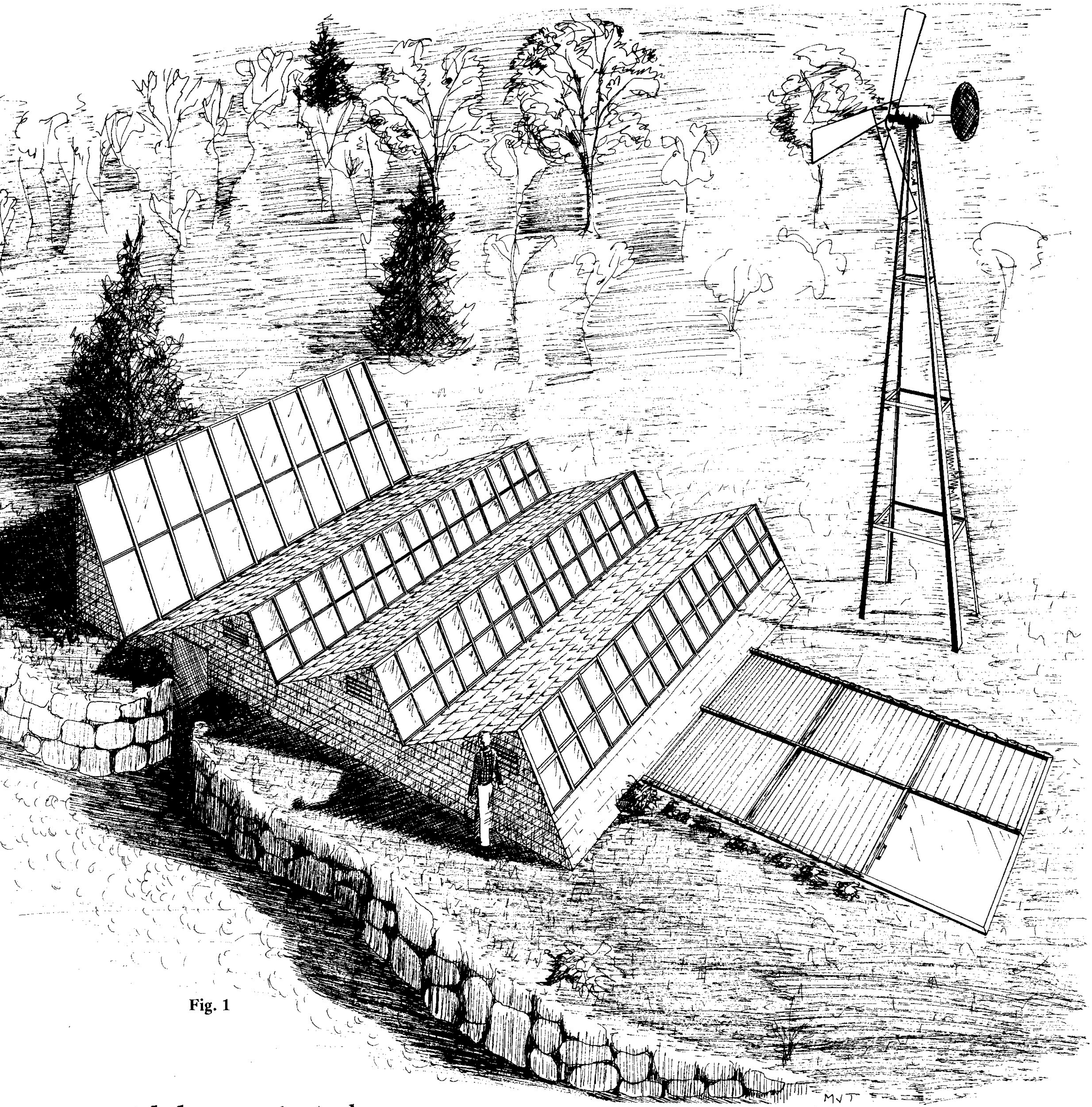


Fig. 1

New Alchemy's Ark:

*A Proposed Solar Heated and Wind Powered Greenhouse and Aquaculture Complex Adapted to Northern Climates**

*Support for developing and researching the Ark is being sought. Contributions to this research will be very much appreciated.

INTRODUCTION

The Ark is intended to provide an alternative to a significant energy consuming component of food production in America. Greenhouses, which provide substantial quantities of vegetable and flower crops, especially during the colder seasons, utilize large amounts of fossil fuels for heating and climate regulation. To help alleviate this situation we propose to develop and evaluate a low-energy, highly productive food growing complex heated by the sun and powered by the wind. The complex will be independent of fossil fuel heating or outside electricity sources.

If food demands are to be met in the coming years, indigenous, ecologically-derived and low energy strategies for raising food are going to have to be developed. Ecologist H. T. Odum has recently suggested that energy shortages in agriculture could result in severe food shortages in the not-too-distant future (1). He bases his argument on the fact that modern agriculture is extremely energy intensive, requiring up to 20 calories of energy to produce one calorie of food on an American table. Other food producing systems borrow less heavily on the planet's finite energy sources. For example, biologically-oriented Chinese farmers in Malaysia, with few outside energy inputs, can produce annually 66,000 pounds of pork and 7,000 pounds of fish as well as vegetable crops on small 4.4 hectare farms (2), and the Tsembaga peoples in New Guinea are able to support population densities equivalent to our own, with an ecologically sound agriculture which generates 20 calories of food for 1 calorie of energy input (3). The caloric disparity between our modern, high energy agriculture and the biologically-based ones just mentioned can be as great as 40:1 in favor of the latter. Our productivity is sustained by massive inputs of energy into each of the links in the agricultural sector, and it seems likely that as fuels become scarcer, biologically-derived systems powered by the sun and the wind will become increasingly important, if not essential (4).

Each facet of modern agriculture is highly dependent upon fossil fuels as its energy base. Nitrogen fertilizers require some 15,000 TKH/ton in their manufacture and the phosphate fertilizer industry consumes extremely large amounts of energy, only being surpassed on a per unit output basis by the manufacture of aluminum. Also most modern farms are dependent upon herbicides, fungicides, pesticides and machinery, all derived from energy-intensive industries (5).

The greenhouse culture of foods and flowers is in an especially precarious position. Besides the energy inputs noted previously, there are the additional inputs for the sterilization of soils and artificial heating for up to 6-7 months of the year. The heating of these structures is a major component of their operating costs and the scarcity of fuels is of great concern to farmers using greenhouses. The impending shortage of fuels was a catalyst in The New Alchemy Institute beginning its research into solar-heated growing structures in 1970.

The present world-wide acreage of greenhouses is quite extensive. United States (5,202 acres), Britain (4,267 acres), Holland (18,242 acres), Italy (12,700 acres) and Japan (26,000 acres) are significant greenhouse producers of foods. The energy required to sustain these structures is not known, but it is believed to be extensive (6). Expansion of greenhouse production of foods is held in check by fuel scarcities and by competition from southerly regions connected to northern markets by highly developed transportation systems. As transportation costs increase, glasshouse food culture systems will come into their own, if and only if, alternative heat sources can be found for them.

We propose to construct and research a greenhouse - pond complex for the growing of vegetables and for the intensive culturing of fishes which will be heated by the sun and powered by electricity from the wind (Figure 1). The prototype will require no outside sources of heat, or chemical fertilizers, fungicides, pesticides or soil sterilization. It will be a self-regulating food ecosystem requiring the sun, waste materials and labor to sustain its productivity. The heat storage-climate regulation component of the system will be a 13,500 gallon aquaculture pond. Solar heat will be trapped directly by the covered pond and by pumping the pond water through a 300 square foot solar heater. The adjacent greenhouse will be situated below the frost line and will derive its heat from direct sunlight and from the warmed pond water passing through pipes in the interior of the structure. Many of the components have already been

1. H. T. Odum, 1973. Energy Ecology and Economics. Paper invited by Royal Swedish Academy of Science, 26 pp.
2. K. F. Vass, 1963. Fish Culture in Freshwater and Brackish Ponds. Chapter In: J. D. Ovington, ed., *The Better Use of the World's Fauna for Food.* Symposium of the Institute of Biology, No. 11, 175 pp.
3. R. Rappaport, 1971. The Flow of Energy in an Agricultural Society. Scientific American, Vol. 224(3), 116-134.
4. H. T. Odum, 1971. Environment Power and Society. John Wiley, 336 pp.
   J. H. Todd, 1971. A Modest Proposal. Bulletin of the New Alchemy Institute No. 2, 26 pp.
   J. H. Todd, 1973. Restoration and Reconstruction in Costa Rica. The Journal of the New Alchemists (1), 32-47.
   J. H. Todd, 1974. The Dilemma Beyond Tomorrow. The Journal of the New Alchemists (2).
5. D. Pimentel, L. E. Hurd, A. C. Belloti, M. J. Forster, I. N. Oka, O. D. Sholes and R. J. Whitman, 1973. Food Production and the Energy Crisis. Science, Vol. 182(4111), 443-449.
6. Dana G. Dalrymple, 1973. Controlled Environment Agriculture: A Global Review of Greenhouse Food Production. Economic Research Service, U. S. Department of Agriculture, Foreign Agricultural Economic Report No. 89. 150 pp.

developed at New Alchemy (7). We intend to combine these various components into an integrated food production system for the year-round raising of a diversity of foods. Solar-heated greenhouse and aquaculture greenhouse complexes like the Ark, if proven successful and adapted widely, could help alleviate possible future meat and vegetable shortages in the more northerly parts of the country, particularly during the winter months or during crisis periods when transportation is disrupted.

ORIGINS OF THE ARK CONCEPT

Structures that enhance the growth of cultivated plants by extending the length of the growing season have been in use for several centuries, for practical purposes beginning with the availability of glass windows. At the beginning of the 18th century, cold frames and buildings with large south-facing windows were in general use in England. These were usually unheated due to lack of sub-zero temperatures and generally mild climate. The technology of growing structures was brought from Europe to the eastern U. S. around the mid-1800's, where substantially lower winter temperatures resulted in two lines of further development, the heated glass greenhouse and the unheated pit-greenhouse. With the discovery and availability of heating fuel, the former structure rapidly gained favor and is recognized as today's conventional greenhouse. The unheated pit-greenhouse, though evolved for northern climate winters, has been generally forgotten (8).

7. W. O. McLarney, ed. 1973. The Backyard Fish Farm Working Manual for 1973. Rodale Press, Emmaus, Pennsylvania 18049. 54 pp.
J. H. Todd and W. O. McLarney, 1972. The Backyard Fish Farm. Organic Gardening and Farming Magazine, Jan. 72.
W. O. McLarney and J. H. Todd, 1974. Walton Two: A Compleat Guide to Backyard Fish Farming. Journal of the New Alchemists (2).
8. K. S. Taylor and E. W. Gregg, 1969. Winter Flowers in Greenhouses and Sun-Heated Pit. Chapter 1, *Origin and Development of the Greenhouse*, 3-16. Charles Scribner's Sons, New York, 281 pp.

Pit-greenhouses are unheated structures having a glass face towards the south, an insulated face towards the north, and whose growing area is below the level of the soil. These conditions result in capture of the sun's heat to keep the growing area above freezing throughout the winter. The first pit-greenhouse in the U. S. was built about 1850 in Waltham, Massachusetts. Since then, pit-greenhouses have been used sporadically in the eastern U. S. as far north as Vermont, where it is possible to raise long-season vegetables in the summer and salad vegetables all winter with no supplemental heat (9).

Experience with pit-greenhouses indicates that small amounts of auxiliary heat, such as the heat loss through a basement wall into the pit, are sufficient to improve the operation and stability of the system (10). Several solar-heated house designs incorporate such technology that can be adapted to this purpose, specifically the Thomason and MIT solar house designs (11). In these systems, the sun's heat is captured during the sunny part of the day by water flowing through a collector and the heat is stored as hot water for later use. This technology is directly applicable to the greenhouse/aquaculture

9. K. Kern, 1972. The Owner-Built Homestead. Chapter 9, *The Pit Greenhouse.* Sierra Route, Oakhurst, California 93644, 90 pp.
10. Ibid. Taylor, 1969. Chapter 2, *The Insulated Pit*, 17-33.
11. B. Anderson, 1973. Solar Energy and Shelter Design. Senior Thesis, Department of Architecture, M. I. T.

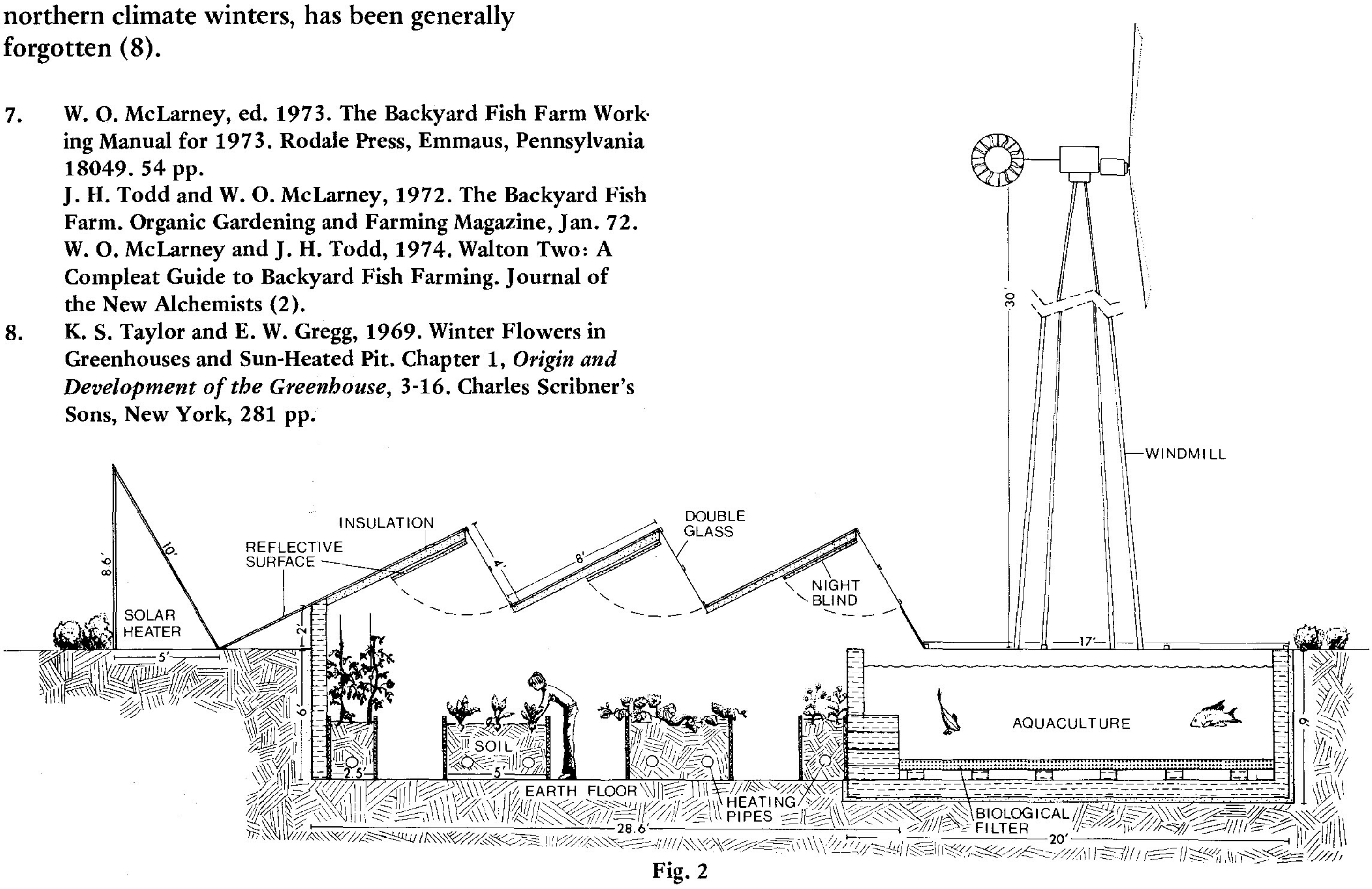


Fig. 2

complex, where a large body of water is available for heat storage. Water from the fish pond can be used to absorb direct solar energy and excess heat from the greenhouse. This heat can be released into the greenhouse at night to maintain growing temperatures.

New Alchemy Institute has investigated solar heating of growing structures and the moderating effects of large ponds of water in several experimental structures. In 1971 a transparent dome-greenhouse was built and used to grow salad vegetables during the winter using auxiliary heat from a wood stove. It was used again in the winter of 1972, this time heated only by daytime sunlight and heat radiating from the earth; hardy vegetables could be maintained throughout the winter. In 1972 two dome-greenhouses were built which contained aquaculture ponds; these ponds were maintained at approximately 80 degrees F. from May 15 to September 15 solely by passive solar heating and selective venting. The ability of the ponds to moderate the internal climate of the greenhouse was dramatically evident in late fall, when outside frosts and cold snaps had little effect on the air temperature inside the greenhouse. Thus combining aquaculture with growing plants is an ideal way for meeting the temperature stability required in a greenhouse structure.

DESIGN AND OPERATION OF THE ARK

Our experiences which led up to the Ark concept are chronicled in "Walton Two, A Compleat Guide to Backyard Fish Farming" in the aquaculture section of this Journal. Particularly pertinent is the description of the Miniature Ark, which incorporates into its design many of the concepts we wish to explore in the larger system.

PHYSICAL SYSTEMS

The proposed solar-heated greenhouse/aquaculture complex is designed to demonstrate a facility capable of producing meat and vegetables year round, employing solar and wind energy as its power base. Its major components are illustrated in Figures 1, 2, 3 and 4 and are described below; general dimensions of the structure are given in Figure 5.

i - A pit-greenhouse growing structure comparable in size to a conventional small commercial greenhouse. Partially sunken, it offers an attractive visual profile suitable for widespread aesthetic and landscaping acceptance; functionally, it utilizes the earth's heating and insulation qualities to aid in climate control.

ii - An insulated 13,500 gallon aquaculture pond with transparent cover, capable of providing fresh high-quality meat protein on a year-round basis with warm and cool season fish crops. The pond utilizes a sub-sand biological filter for continuous water purification and nutrient cycling.

iii - A solar heat collector to heat the aquaculture pond during sunny periods. The solar water heater will be of the Thomason design (12) and its pump will be powered by electricity from a wind generator. The solar collector will be controlled automatically and will act secondarily as a wind screen for the other structures.

12. J. D. Thomason and J. L. Thomason, 1972. Solar Home Plans. Edmund Scientific Company.

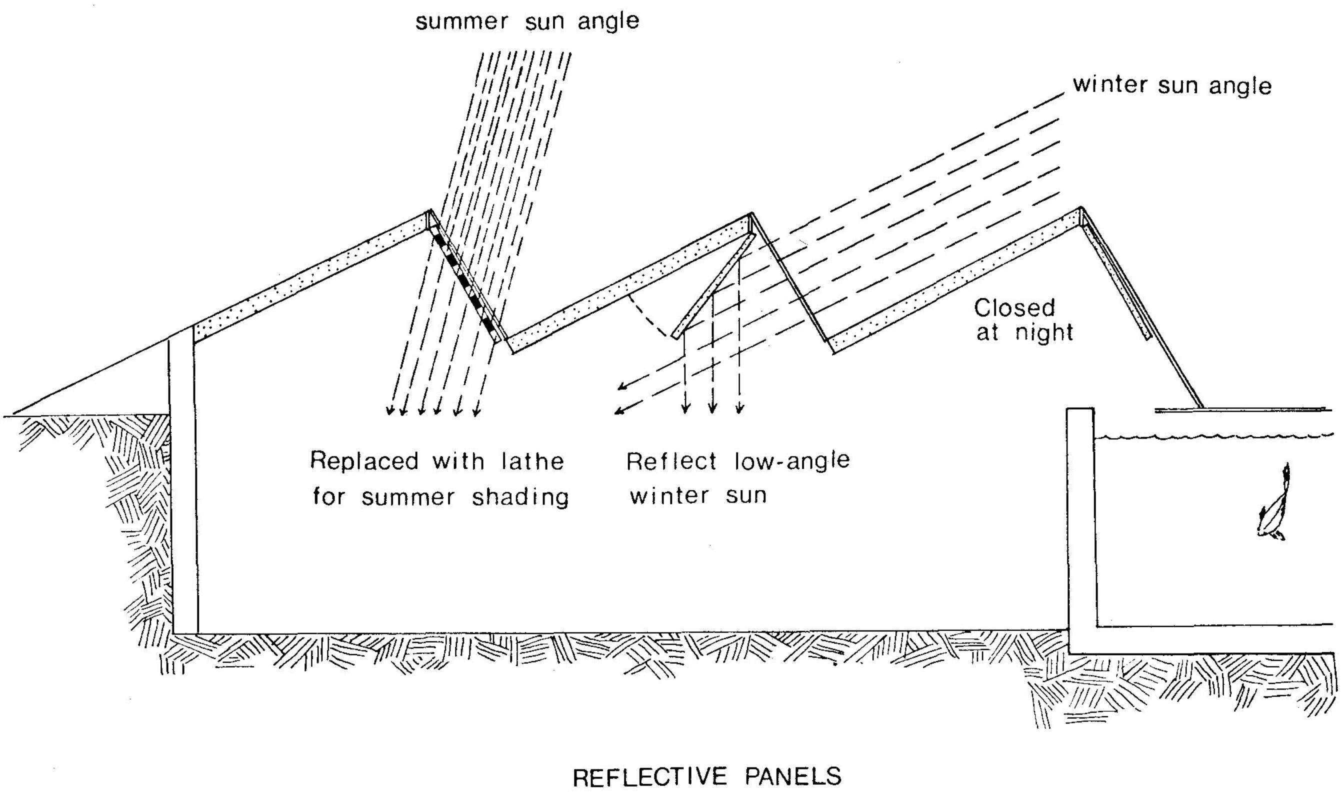


Fig. 3

iv. - A wind generator to produce electricity for water pumping circulation and lighting. At the present, commercial windmills do not produce enough electricity in average wind areas of the northeastern United States to meet our needs, and their costs are exorbitant, being far beyond the utilities on a kilowatt hour basis. Our plan, though, is to create an electricity system for the Ark which is independent of fossil fuels, nuclear power plants and public utilities. Towards this end, we have in the early developmental stages a 10 kw wind-driven power plant designed to produce substantial amounts of electricity at average wind speeds (13). If successful, our electricity costs within a few years may be competitive with the utilities.

It is possible that the Ark may require two windmills to function optimally. If so, an inexpensive water pumping mill, similar to the one used to power the Miniature Ark, will circulate water through the system during windy periods, and the new electricity producing mill with battery storage during spells without wind.

13. Merrill Hall, 1974. A Wind Driven Power Plant for Household Use. A Research Proposal from The New Alchemy Institute. 18 pp. Not for distribution.

v. - Design and operating features related to solar energy collection, conservation and distribution are detailed in Figures 1, 2, 3 and 4. Reflective surfaces (as well as the roof angles) of the greenhouse act to direct a maximum amount of light into the greenhouse and onto the solar collector. Reflective surfaces within the greenhouse and on the north wall result in a 25-35% increase of light on the plant canopy (14). Reflective night cover panels can be positioned to direct daytime light entering the greenhouse onto various plant areas, and the same panels act as nocturnal heat retainers at night, reducing heat radiation from the structure by 15-20% (15). The aquaculture pond is insulated from the ground and covered with a double membrane skin, and all glass surfaces of the greenhouse and solar collector are double glazed. Finally, all glass surfaces will be treated with a material to prevent droplet condensation and thus

14. J. Maghsood, R. Alward and T. A. Lawland, 1973. A Study of Solar Energy Parameters in Plastic-covered Greenhouses. Presented at the International Solar Energy Society, U. S. Section Annual Meeting, Cleveland, Ohio, October 3-4, 1973.

15. Ibid. Maghsood *et. al.*

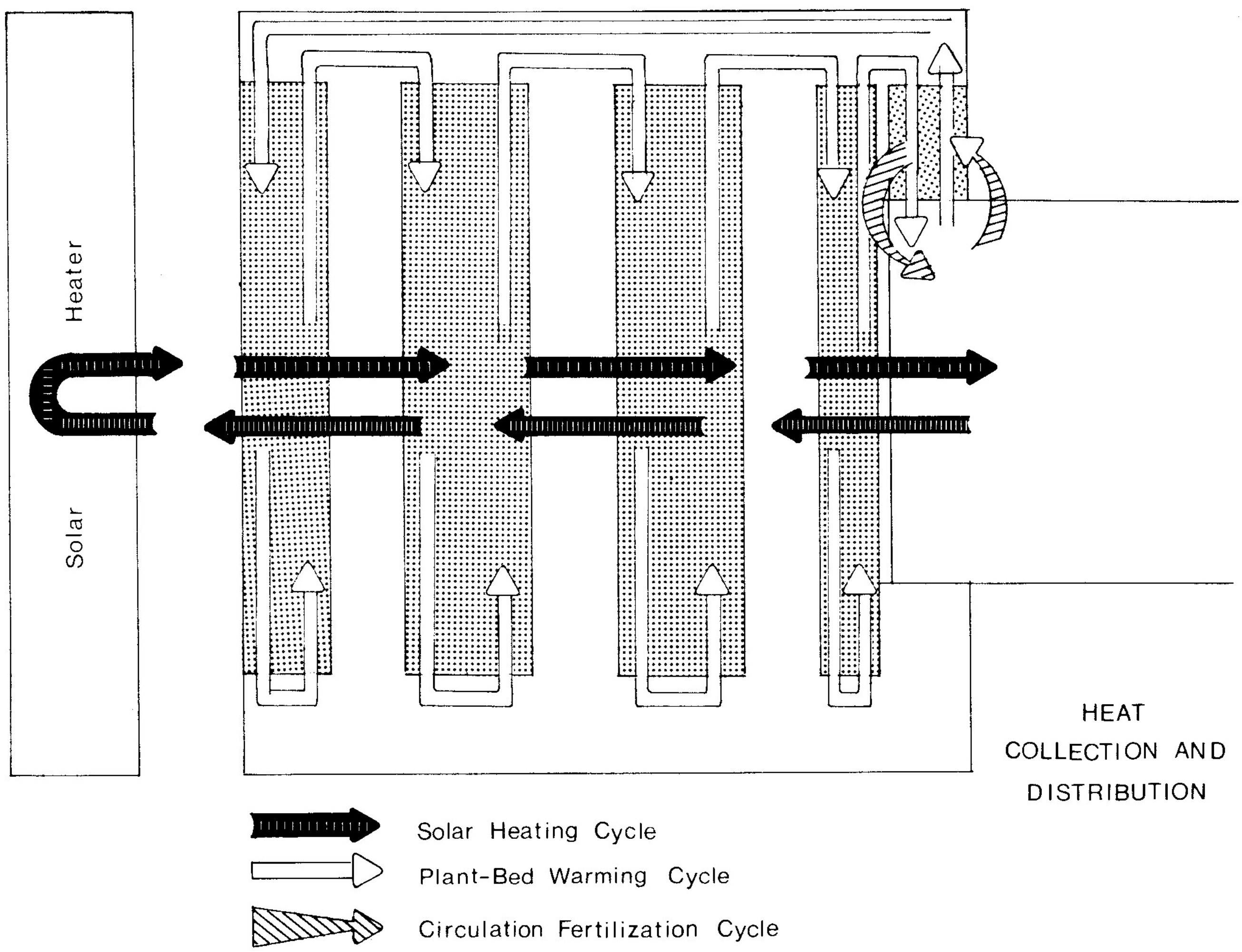


Fig. 4

allow up to 50% more light penetration than untreated glazing (16).

The greenhouse/aquaculture complex is operated in any of three modes depending on outside conditions. During daylight hours heat is stored in the aquaculture pond by circulation through the solar heater. During night hours and very cold, cloudy winter days, heat is transferred from the aquaculture pond to the soil beds in the greenhouse; warm pond water is passed through pipes in the greenhouse soil. Heat loss from the soil acts to heat the air around the growing plants. Finally, during periods when heating is not required, water can be circulated through the biological filter for aeration and purification.

BIOLOGICAL SYSTEMS

Aquaculture Components

The New Alchemy Institute has pioneered the concept of algae-based, tropical aquatic food ecosystems for northern climates and developed "backyard" fish farms which produce high quality, nutritious fishes cultured on sun-waste-algae food chains (17) (See also Walton Two - this Journal). *Tilapea aurea,* also known as St. Peter's fish, are native to Africa and are ideally suited for intensive culture. Since they are primarily algae feeders, the cost of raising fish protein is mainly in the initial construction costs of the system and a small amount of labor to maintain the ponds and crop the fish. In order for tilapia culture to work, pond temperatures of approximately 30 degrees C. are necessary. At lower temperatures growth does not take place. It was our attempting to maintain tropical temperatures that prompted us to research solar-heated ponds.

During the first year the 13,500 gallon pond, which is also the heat storage component of the whole complex, will be set up as a fish culture system and will

16. C. Roseman, 1973. Coatings that Control Solar Light, Heat and Condensation in Solar Stills, Greenhouses and Other Structures. International Solar Energy Society. U. S. Section Annual Meeting, 1973. Figure based on personal communication with Roseman concerning experimental glass coating.

17. The quality and taste of the *Tilapia* in our culture systems is excellent. The food editor of the *New York Times* described our fish as the best-tasting farmed fish he had experienced. *See:* Farm-Raised Fish: A Triumph of the Ecologist and the Sensualist by John Hess, N. Y. Times, Thursday, September 6, 1973.

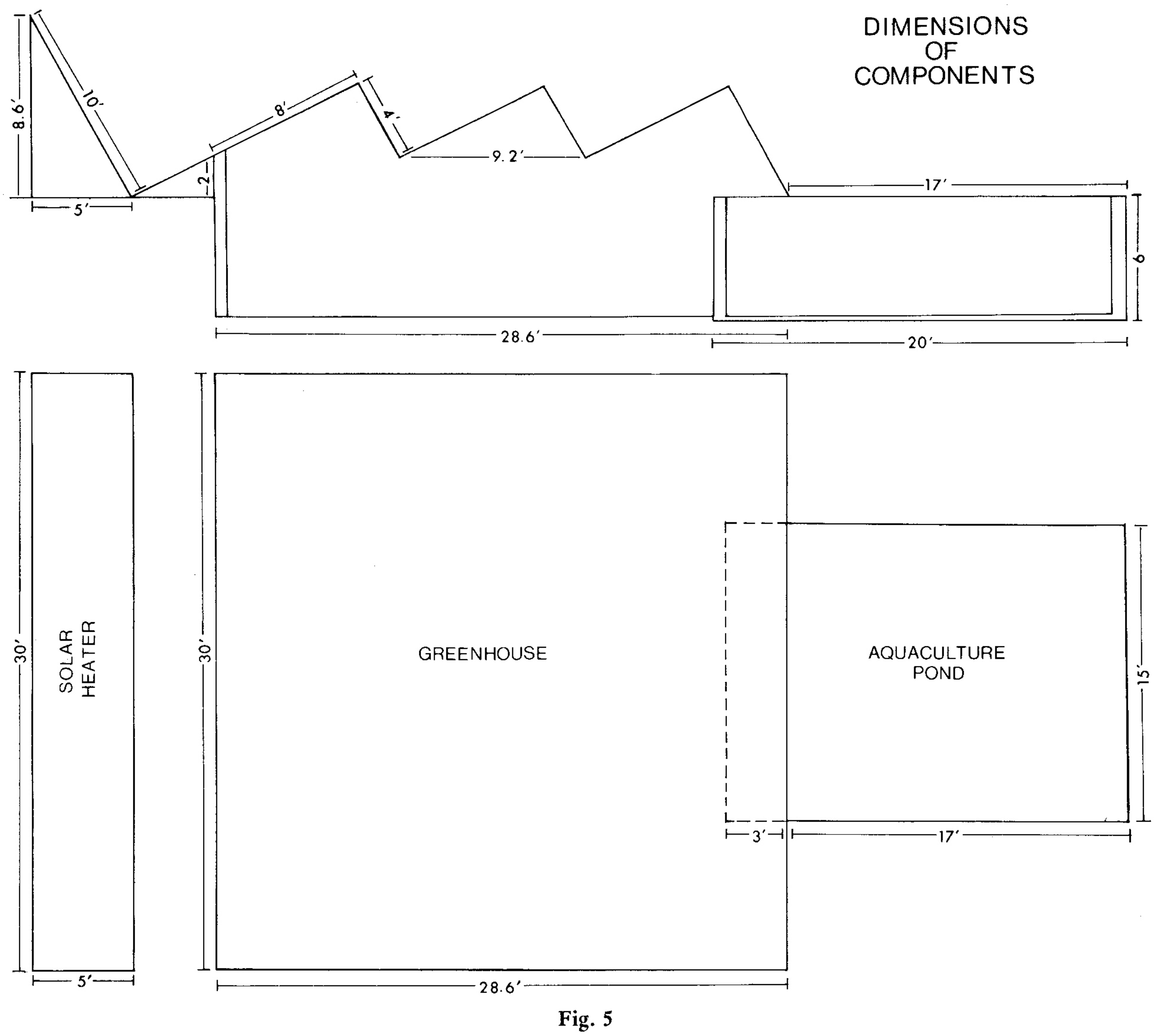


Fig. 5

incorporate the best of the ideas that have been developed out of our previous findings. They are:

1. *Biological Filtration*

A biological filter will encompass the whole bottom of the pond and will eliminate growth-retarding metabolites, especially ammonia. A perforated fiber glass false bottom will support a 6" layer of crushed clam, oyster and high magnesium dolomite. These materials will buffer the system and act as a substrate for the bacteria which break down the fish substances to compounds readily utilizable by the algae for their growth. The primary task of the bacteria will be to alter the ammonia to nitrates and nitrites which promote algae growth without inhibiting fish growth.

The water for the heat collection and distribution systems will be drawn out from under the filter, thereby ensuring a continuous flow of water through the filter and high filtration efficiency.

2. *Fertilization*

The pond will be fertilized with compost, rich soil, rock minerals and manures in order to sustain optimal algae production in the ponds for the fish to feed upon. This past season a breakthrough was accomplished; through the mixing of small amounts of the above compounds into the ponds, algae production was not the limiting factor in the small aquaculture systems. It would appear that we have overcome the two main stumbling blocks to intensive pond culture, namely the optimization of algae production and the breakdown of growth inhibiting waste products. The waste-algae cycle seems to have come into a productive and balanced relationship.

3. *Production of Tilapia - Summer Cycle*

Production figures are hard to estimate for the 13,500 gallon aquaculture pond. In our small 3,000 gallon solar-heated ponds we have produced 1 pound of fish per 60 gallons of water in 10 weeks *without* the critical population control, or optimal filtration. Projecting this production figure onto the proposed system would result in between 540 and 675 pounds of edible size fish being produced during the 6-7 month tilapia season. Initially 500 fish will be stocked into the system and they will be replaced with 500 young at 10-week intervals, as long as 28-30 degrees C. are maintained in the pond. There are a number of reasons to believe that these production estimates may be far too conservative. Firstly, our prior experience has been based upon culture systems in which the surface area of the filtration units was not maximized as in the present system. Secondly, the populations were too dense by a factor of five, as predators were not introduced. Thirdly, the above calculations do not take into account the fact that the production potential per unit volume increases with increasing pond size. Finally, larger ponds have more stable thermal and chemical environments which would improve fish growth.

Ultimately we believe the system will be able to produce several times the poundage of fish that have been indicated in this proposal. Intensive fish culture in Germany and Japan already has produced much higher yields, but these systems are dependent upon large amounts of additional food and energy inputs (2, 18).

4. *Cool Season Fish Culture*

During the time of year (November through April) when the water temperatures within the solar-heated aquaculture pond drop below 25 degrees C. the tilapia will be replaced with a polyculture pond including a number of native fishes and white amur or Chinese grass carp *(Ctenopharyngodon idellas)* and hybrid Israeli carp *(Carassius auratus)* in order to produce a winter crop.

The potential productivity of the cool season polyculture crop is unknown. After an optimal ecosystem has been carefully worked out, yields may come close to approximating the summer cycle.

It is hoped that when the aquaculture component of the solar-heated aquaculture/greenhouse structure is more completely worked out, the fishes in comparable systems will pay for initial costs and maintenance, particularly if costs are spread over a 10-year period. The greenhouse component would then be able to provide the income beyond expenses for its owners. This would make the concept appealing to large numbers of people throughout the country.

GREENHOUSE

The greenhouse will be established as an intensive food producing structure and vegetables and salad greens will be cultured on the growing beds as shown in Figure 2. The crops will vary from location to location within the greenhouse, depending on their light and spacial requirements and the time of year. During the fall and early winter months, a diversity of greens, peas and root crops will be grown, while during the late winter, spring and summer months heat-loving crops such as peppers, melons, eggplants and beans will predominate. Tomatoes will be grown year round. Accurate records of the yields and their market value will be kept.

GREENHOUSE MANAGEMENT

1. *Fertilization*

Initially the beds will be filled with compost and rich soils. Afterwards, the sole source of fertilization will come from the nutrient-laden pond water used

18. J. Bardach, W. O. McLarney and J. H. Ryther, 1972. Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. John Wiley, 868 pp. Note particularly discussion of intensive culture of carps, 29-74. This text, the definitive one on the subject in English, was primarily written by New Alchemy's W. O. McLarney.

to irrigate the plants. Our experiments linking aquaculture and the culture of terrestrial food crops have demonstrated the value of integrating the two. In experimental plots comparing aquaculture water with tap water we have obtained a large increase in yields of crops such as lettuce using aquaculture water (19). Interconnecting the aquaculture and plant crops in the solar-heated structure will reduce irrigation and eliminate fertilization costs.

2. *Pest Control*

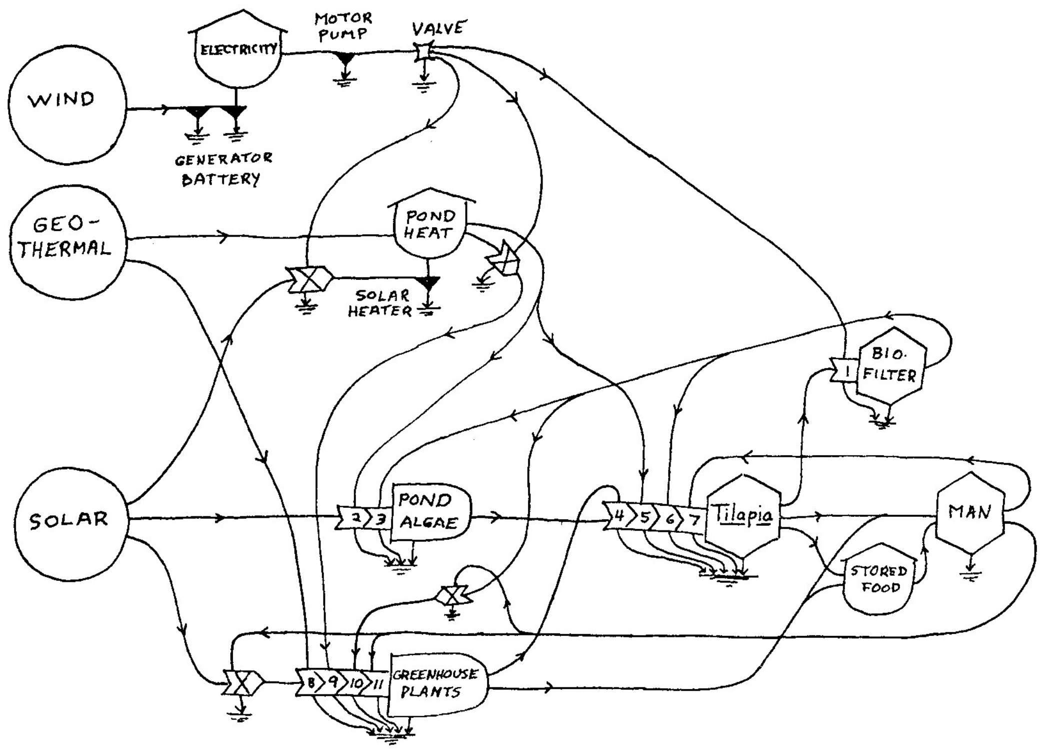
Pests, especially whiteflies, can become a major problem in greenhouses. They are usually controlled with toxic pesticides. We have had some experience with biological controls in greenhouses, utilizing toads, salamanders and tree frogs, which prevented serious outbreaks of insect pests in an 18-foot diameter dome growing structure. The warmer, more stable climate in the proposed structure will enable us to use small lizards, especially *Anolis carolinensis,* to control insect pests. Lizards have previously been used to combat pests in a miniature tropical rain forest housed within a greenhouse (20). Pest control animals were fed a supplementary diet of fruitflies grown on a small mound of rotting fruit to sustain them during periods when no plant pests were present.

3. *Disease and Humidity Control*

Routinely, greenhouses are sprayed with fungicides to keep down diseases which can be very damaging under conditions of intensive culture and high humidity. Our strategy will be to grow disease-resistant varieties of plants where possible and to limit disease by reducing the relative humidity within the greenhouse. This will be accomplished in several ways: First, the beds have been designed to be deeper than normal and this will permit less frequent watering of the crops. Secondly, the pond section inside the greenhouse will be covered part of

19. W. O. McLarney, 1974. Irrigation of Garden Vegetables with Fertile Fish Pond Water. The Journal of the New Alchemists (2).

20. One of us (Todd) was a doctoral student of the outstanding ecologist Marston Bates. He established in his house in Ann Arbor, Michigan, a "tropical rain forest" in order to try and understand the dynamics and interrelationships of plants, water, soils, animals including insects, birds and monkeys within a miniature ecosystem. He developed a number of sophisticated ideas on predator-prey relations in closed systems. Unfortunately, these were never published. His ideas have been an inspiration to us and we hope to extend them.



ENERGY FLOW DIAGRAM FOR SOLAR-HEATED GREENHOUSE AND AQUACULTURE COMPLEX

1) Circulation of fish pond water through biological filter. 2) Increased growing temperature for algae. 3) Nutrient cycling from fish wastes. 4) Terrestrial plants to Tilapia. 5) Increased temperature for Tilapia. 6) Removal of growth inhibitors. 7) Fish husbandry. 8) Earth heat warming the pit-greenhouse. 9) Night warming of greenhouse. 10) Irrigation by nutrient/rich water. 11) Vegetable gardening.

the time, especially during the day, to reduce humidity. Finally, when the sun is shining and the humidity outside is low, the vents will be opened fully, permitting the warm and moist air to rise out of the structure and be replaced with cool, dry air. Sporadic lowering of humidity levels should reduce the possibility of disease affecting crop production. Previously, this approach has worked for us and only two out of fourteen varieties of food crops, Black Simpson lettuce and Tiny Tim tomatoes, were damaged by disease. In these instances, the crop was only partially destroyed. In the management of the complex, we will attempt to replace chemical controls with biological ones. Biological controls will be mandatory in the greenhouse, as fishes are killed by fungicides and pesticides.

RESEARCH

After the Ark is completed, we plan an investigation of the whole system, so that our experience will be useable by others. Research will include studies of:

1. External and internal climates.
2. An energy budget for the total system.
3. Water chemistry and the chemical activity of the biological filter. This analysis will include routine measurements of oxygen, carbon dioxide cycles including free CO_2, and bound and half-bound CO_2, pH, nitrogen cycles including ammonia, nitrites and nitrates (methane if present) and phosphorous.
4. Productivity of each trophic level within the aquaculture system including the algae, algae-consuming invertebrates and fishes, and the fishes which feed primarily on animal protein. Trophic relations within the system will need to be accurately established in order to fill the available niches within the pond and optimize productivity.
5. Yields and value of all crops within the greenhouse.
6. Effectiveness of biological controls in regulating pests within the greenhouse.
7. Determination of labor required to operate the complex.
8. Economics of the solar-heated and wind-powered greenhouse and aquaculture structure in present and projected future terms.

With this information carefully collected and evaluated, it should be possible to determine if Arks will become useful tools for those trying to restore lands, protect the waters and inform the earth's stewards. We believe that the Ark will have the potential to help us restore and reconstruct during the stormy times ahead.

—Robert Angevine, Earle Barnhart and John Todd

Toward a Self-Sustaining Agriculture

Take not too much of a land,
wear not out all the fatness,
but leave in it some heart.

— Pliny the Elder
A. D. 23-79

Farming isn't a way of life,
it's a way to make a living.

— Earl Butz
U. S. Secretary of Agriculture

The fact that a culture can produce more food on less land with less human toil has been cited by people of many persuasions as a prime example of human "progress." Until recently there has been little reason to challenge this belief. As long as an agriculture produced food for its people and a surplus for foreign trade, the farm technologies used and the economic incentives encouraging them were justified.

The fallacy here lies in the assumption that the *only* purpose of agriculture is to produce food. Over the years many kinds of propaganda have locked us into this dangerous illusion, and we tend to forget that agriculture is dynamic and that its historic role has been to maintain productive land in order to sustain its people. In addition, a thriving rural culture has been vital in providing food and fibre and in absorbing dispossessed people during wars and economic depressions. [1] In a healthy society, agriculture provides not only food, but also a reliable buffer during social crises and a legacy of land stewardship for posterity.

Like most rapid revolutions, the green revolution has created more long-term problems than short-term "solutions." At first glance, the new farm technology is praised because it has allowed millions to leave their lands for a fantasized urban paradise free from rural toil. But, in the haste to free the majority of people from the need to work the land, an enormous dilemma has been created. The tools of liberation..... chemicals, machinery, monocultures, hybrid crop strains, etc., while they have alleviated scarcity and one kind of work, at the same time have precipitated mounting economic and ecological problems which not only compound themselves, but also threaten the sustaining potential of our farmlands. Since World War II, we have so altered our rural environment and have become so totally dependent upon a single chemical strategy for food production that we face a future in which a major human concern must be the increasing hazards of supplying the fuels and chemicals needed to keep the food coming. We brag of being a nation where food is relatively cheap and agriculture efficient, yet ignore the fact that most measures of food prices and farm efficiency fail to take into account the endangerment to such valuable resources as soil fertility, water, wildlife, public health and a viable rural economy. When we stop to consider the full impact of the agricultural tools that have replaced the people who have crowded into the cities, it is clear that "modern" agriculture is causing more problems than it is solving.[a]

There are other problems associated with the green revolution beyond those of environmental hazards and the destruction of a healthy rural base. Today's farms require massive inputs of fossil fuel energy to maintain them in a stable state. In fact, during the last few decades we have simply been exchanging finite reserves of fossil fuels for our supplies of food and fibre. Obviously, this trade-off cannot continue indefinitely; if agriculture is energy-intensive, then fuel shortages must inevitably lead to food shortages. In the very near future, we

a. The amount of U. S. farmland under cultivation has actually decreased over the last generation. Unfortunately the urbanization of prime farmlands is beyond control. Opening up marginal lands for farming requires high-energy technologies and increases the threat of pollution and exploitation of finite resources. It is a vicious problem with no obvious solution under present priorities of uncontrolled growth and development.

will have no choice but to adopt agricultural techniques that utilize renewable energy supplies. These include: the recycling of organic wastes to supplement synthetic fertilizers; the use of renewable forms of energy (solar, wind and organic fuels), to help supply rural power needs; the application of ecologically diverse cropping patterns and integrated pest control programs to reduce the use of pesticides. Without a broad approach to these alternatives, modern agriculture could well become self defeating rather than self sustaining.

The full consequences of the green revolution present a number of unresolved questions concerning the relationship between modern agriculture and the quality of life. In the past, many of these questions have been considered rhetorical or academic. Today they suggest forcefully that we have not been adjusting our priorities to the accelerated pace of current events. For example:

1. What is the total impact of modern agriculture on our indispensable natural resources?

2. What are the long-term effects of pesticides and synthetic fertilizers on public health and on the continuing ability of farmlands to produce quality food?

3. Is the displacement of rural culture by high-energy technology an inevitable or even desirable consequence of social "progress"? If not, how can economic policy and public sentiment be changed to encourage the success of independent farmers who are best able to safeguard the rural environment for future generations?

4. What are the consequences of an agricultural system totally dependent upon non-renewable supplies of fossil fuel energy? Is not such an agriculture itself non-renewable? Do further increases in food production justify additional uses of fossil fuel resources?

5. Will increasing costs of fossil fuels mean total monopoly of agriculture by corporations, industry and the petroleum technology? If so, what effects will this have on price, availability and quality of food?

6. Why does agricultural research continue to focus attention on developing farming methods that are geared to machines and fossil fuels rather than people and renewable energy inputs? Why do ecologically sophisticated techniques of agriculture continue to be considered "inefficient" and "backward" by the U. S. Department of Agriculture and much of the scientific establishment?

7. To what degree can the polluting, high-energy techniques of agriculture be replaced by the renewable and self-sustaining energy of natural resources and biological processes?

MODERN AGRICULTURE: A WASTELAND TECHNOLOGY

The new (farm) technology is an economic success because it is an ecological failure.

— Barry Commoner

By its very nature, agriculture makes a heavy impact on the environment. Ever since neolithic tribes began to cultivate endemic wild plants, agriculture has involved a tradition of people manipulating their surroundings in order to grow plants and to husband animals for food. The results have often been unfavorable. Throughout history, people have accelerated natural erosion by rapid deforestation and poor soil management. Frequently the cultivation of plants for export has also placed a strain on local economies.[2,3] In the United States, land destruction has been a matter of record since 17th century tobacco and cotton farming in the south. Wind erosion and the midwest dust bowls of the early 1900's are now infamous history. Current data from the national land-use inventory show that 64% of the U. S. croplands are in need of soil conservation.[4]

Today, however, the traditional hazards of agriculture are overshadowed by an arsenal of sophisticated technologies which cast the environmental impact of agriculture in new dimensions.

PESTICIDES: OVERKILL AND DIMINISHING RETURNS Pesticides are poisons which kill pests; insects (insecticides), weeds (herbicides) and plant diseases (fungicides). Prior to 1940, pesticides were made from inorganic materials (mostly heavy metals, arsenic and sulfur) or plants. Just before World War II, it was discovered that DDT, a synthetic organic compound first made in 1874, had remarkable insecticide properties. Wartime conditions increased the demand for DDT, and, after the war, U. S. production soared from 9½ million pounds in 1944 to 179 million pounds in 1963.[5] Other requirements led to the development of more toxic insecticides, which included variants of DDT and certain nerve poisons such as the organophosphates (developed as by-products of nerve gas research during World War II) and carbamates.

The popularity of herbicides was inaugurated by a revolutionary chemical developed during World War II. The compound, 2, 4-D, was especially appealing because it acted like a plant hormone, selectively poisoning broad-leaf plants but not grasses. This was

	FUNGICIDES[a]	HERBICIDES[b]		INSECTICIDES			TOTAL
		2,4-D[c]	Other Organic Herbicides	DDT	Other Organic Insecticides	Inorganic Insecticides	(1000 tons)
1959	123.9	28.4	21.6	78.4	80.7	9.7	342.7
1960	147.5	35.1	16.1	82.1	93.4	8.3	382.5
1961	132.4	40.1	20.4	85.7	109.6	9.2	397.4
1962	98.7	40.0	35.4	83.5	119.2	7.3	384.1
1963	97.2	45.4	41.9	89.5	119.5	5.6	399.1
1964	98.2	54.0	59.2	61.9	128.1	8.1	409.5
1965	109.2	63.3	68.2	70.4	174.8	5.6	491.5
1966	120.4	--	--	70.7	205.3	5.1	
1967	112.3	80.4	124.3	51.7	196.2	3.9	568.8
1968	120.9	86.7	147.8	69.7	214.9	6.2	646.2
1969	120.8	52.0	144.7	61.6	209.4	5.2	593.7
1970	115.4	--	201.9	29.7	177.3	3.0	527.3

TABLE I. PRODUCTION OF PESTICIDES IN THE UNITED STATES (in 1000tons). Data for inorganic pesticides are from Agricultural Statistics, USDA;[6] data for organic pesticides are from U.S. Tariff Commission Annual Report[5].

a = includes: copper sulfate and organic compounds, excludes sulfur
b = organic compounds only
c = includes esters and salts

an important discovery, not only for the grain farmer but also for the military who used 2, 4-D to destroy millions of acres of farmlands and forests in South Vietnam.[b] Today, 2, 4-D is the herbicide most produced in the United States and the one most abundantly used by American farmers.

In many ways, World War II fostered an agricultural revolution. Since the introduction of DDT, 2, 4-D and organic phosphates, U. S. production of synthetic organic pesticides has increased from 33 thousand tons of DDT and one thousand tons of 2, 4-D in 1945 to 552 thousand tons of one hundred or so different pesticides in 1968.[6] Today there are over 100 industrial firms producing about 1000 pesticide chemicals variously combined in over 50,000 registered commercial pesticides. (Table I)

Most of the public debate concerning pesticides has centered on problems associated with their uses in agriculture. However, only about 50% of the pesticides used in the United States are applied to farms (Table II); the remainder is used by government, industry and urban dwellers. In fact, suburban lawns and gardens probably receive the heaviest applications of pesticides of any land area in the United States.[8]

Pesticides, nevertheless, are used extensively on U. S. farmlands, although exact figures are unavailable. Usually records of production, sales, imports and exports give some indication of farm usage, but these

TYPE OF PESTICIDE	TOTAL USE IN U.S. 1000 tons[a]		% USED BY U.S. FARMERS	
FUNGICIDES:[b]		63		27%
HERBICIDES:[c]		114		55%
2,4-D; 2,4,5-T	43		48%	
others	71		59%	
INSECTICIDES[d]		165		57%
DDT	25		54%	
Aldrin-Toxaphene	39		68%	
Other	101		54%	
TOTAL PESTICIDE		341		51%

TABLE II. Selected pesticides used by U.S. Farmers, 1966. From U.S.D.A. Economic Research Service.[7]

a = Calculated by subtracting exports from production.
b = Excludes: sulfur and pentachlorophenol
c = Includes: plant hormones, defoliants and desiccants.
d = Includes: fumigants, rodenticides, miticides.
e = Includes: aldrin, chlordane, dieldrin, endrin, heptachlor and toxaphene.

b. In his book *Defoliation* (Ballantine Books) Thomas Whiteside notes a 1968 statement by Samual Huntington, Southeast Asia advisor to the State Department: "In an absent-minded way the United States in Vietnam may have stumbled upon the answer to 'wars of National Liberation' ... forced draft, urbanization and modernization which rapidly brings the country in question out of the phase in which a rural revolutionary movement can... come to power."

are imprecise. The best estimates are for the years 1964 and 1966,[7,9] and even these are based on a limited survey of farmers. Still, there are some interesting facts from these surveys:

1. Over half of all pesticides used in agriculture are applied to three crops: cotton, tobacco and corn (Table III).

2. Most U. S. farmers use pesticides: 37% use herbicides, 29% use insecticides and 4% use fungicides.[9] These figures have undoubtedly increased since 1966, especially with regards to herbicides, which are used more and more as a substitute for machinery and labor. Use of organochlorides is decreasing somewhat, but use of the more toxic organophosphates is increasing.

3. A greater proportion of large farms use pesticides than small farms (Fig. 1).

4. Farmers in the Southeast and Delta states use over 40% of all insecticides. The corn belt accounts for nearly a third of the herbicides used.[7]

These facts suggest that farm use of pesticides is concentrated on a few crops, in specific regions and on large farms. However, many pesticides have been used so extensively that they must now be considered

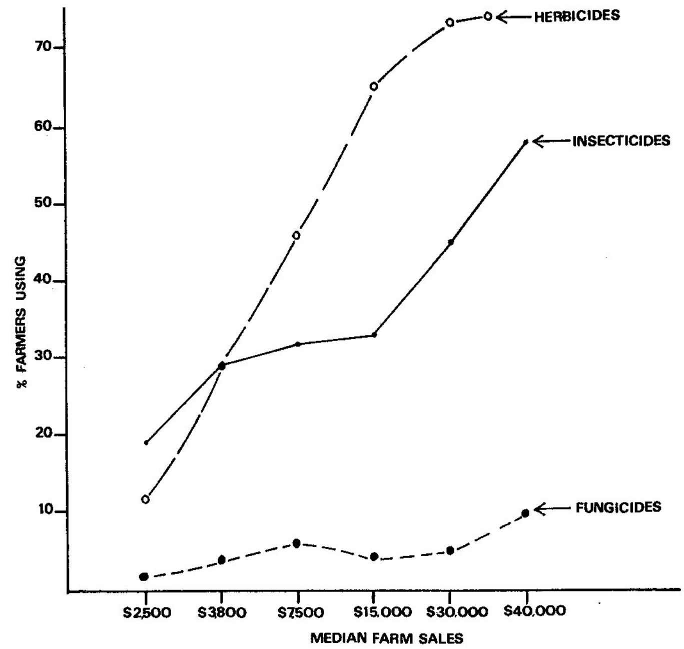


Fig. 1 Proportion of U. S. farmers using pesticides in 1966 according to size of farm operation. From USDA Agricultural Research Service.[9]

TABLE III. FARM USE OF DIFFERENT PESTICIDES ON MAJOR CROPS, 1966.
Adapted from USDA, Economic Research Service.[7]

	MILLION ACRES PLANTED (1966)	PESTICIDES USED (1000 TONS)				SUBTOTAL	% TOTAL PESTICIDES	CONCENTRATION (LBS./ACRE)
		FUNGICIDES	HERBICIDES	INSECTICIDES	MISC.[b]			
COTTON	10.3	.2	3.3	32.4	14.2	50.1	26.7%	4.9
CORN	66.3	--	23.0	11.8	.5	35.3	18.8%	.5
TOBACCO	1.0	--	--	1.9	13.4	15.3	8.2%	15.3
OTHER FRUITS & NUTS	2.6	2.1	1.4	3.3	8.7	5.5	8.2%	6.0
OTHER CROPS[a]	661.5	2.3	10.1	.8	.1	13.3	7.1%	--
PEANUTS	1.5	.5	1.4	2.8	7.0	11.7	6.2%	7.8
APPLES	.7	4.2	.2	4.2	1.1	9.7	5.2%	13.9
OTHER VEGETABLES	3.7	2.1	1.7	4.1	.4	8.3	4.4%	2.2
SOYBEANS	37.4	--	5.2	1.6	.1	6.9	3.7%	.2
IRISH POTATO	1.5	1.8	1.1	1.5	.4	4.8	2.6%	3.2
WHEAT	54.5	--	4.1	.4	.1	4.6	2.5%	.1
CITRUS	1.2	2.0	.2	1.4	1.1	4.7	2.5%	3.9
ALFALFA	29.0	--	.6	1.8	.3	2.7	1.4%	.1
SORGHUM	16.4	--	2.0	.4	.1	2.5	1.3%	.2
RICE	2.0	--	1.4	.2	--	1.6	.8%	.8
SUGAR BEETS	1.2	--	.5	.1	.1	.7	.4%	.6
	890.8	15.2	56.2	68.7	47.6	187.7	100.0%	.07 .26[c]

a = includes: misc. field crops, pasture, mixed grains, summer fallow, plus those crops not listed individually.
b = includes: rodenticides, fumigants, plant hormones, miticides, repellents, defoliants, desiccants.
c = excludes "other crops"

an integral part of our biological systems... present in our flesh, drifting in the air, flowing with the rivers and falling with the rain.[10-12] After more than a generation of unrestrained use, it is obvious that pesticides have produced..... and are still producing.... serious side effects the full consequences of which have yet to appear, but major areas of concern include:

1. *Pesticides are persistent:* Most pesticides are developed to withstand degradation by climate and microbes. Some are more persistent than others. Organophosphates break down in days or months while organochlorides can remain in the environment as poisons for years. One product of DDT.... DDE ... may be the most common and widely distributed synthetic chemical on earth.[13]

Herbicides are degraded quickly by soil microbes (i. e., soils rich with organic matter); but the by-products themselves are often toxic.[14] Chemical reports often recommend that farmers reduce their soil organic matter to make herbicides more effective! The general decrease in organic matter from U. S. farm soils suggests that herbicides will be more persistent in rural areas, in view of their increasing use.

2. *Pesticides affect public health:* There is a whole spectrum of opinion here. There are those who contend that no important human disease can be associated with pesticides.[15] There are the "objective" government reports which conclude that there is no danger of pesticides to public health but call for administrative controls and more research. The Mrak report[16] concluded that no one seems to have a clear picture of pesticide hazards in America and predicted that the number of accidents actually exceeds those reported. Others have tried to make correlations between increases in cancer, poliomyelitis, heart disease, hepatitis and other diseases and the increasing use of pesticides.[17]

Whatever one's opinion, some definite facts have been established:

a) Certain organophosphates, herbicides and other pesticides can cause cancer, birth defects and genetic mutations in animals.[16]

b) Organochlorides do accumulate in fatty tissues of livestock and humans.[18]

c) Organophosphates account for the majority of *known*[c] pesticide deaths in this country, particularly in farm workers.[19] Thus the trend to replace DDT with organophosphates has largely been a trade-off in health hazards.

d) There also seems to be a relationship between low protein diet and susceptibility to pesticide toxicity.[20] This means that pesticides may have a greater effect on poor people in rural areas. Most likely the total impact of pesticides on human health will not be realized for years to come.

c. The Mrak report (16) concluded that the majority of counties in the United States are not equipped to determine a pesticide as cause of death.

3) *Pesticides kill wildlife and jeopardize natural ecosystems:* Pesticides are poisons... they kill other things besides "pests." They are also mobile, chemically stable and have an affinity for biological systems. It is a combination of these characteristics which can cause unpredictable damage to wildlife:

Hundreds of papers have been written on the subject. [21,22]

Not well publicized, but of particular importance to agriculture is the effect that pesticides are having on honeybees.

> Large-scale monoculture, necessary for economic production... provides no continual source of pollen and nectar necessary to maintain strong colonies (of honeybees)... Use of herbicides... further reduces bee forage. The use of pesticides highly toxic to bees either weakens or destroys many colonies... This presents an impending dilemma, with a reduction of profitable beekeeping and native pollinators on one hand and an increased need for bees for crop pollination on the other.[23]

Even pesticides of low toxicity are known to reduce pollen and nectar gathering activity of bees.[24]

Most studies of pesticides and wildlife have focused on individual species of animals, notably birds and mammals. Much more important, and far less understood, are the effects of pesticides on the integrity of natural ecosystems. In living communities the activities of each organism impinge upon and interact with the activities of other organisms sharing the same general area. If a pesticide affects only a few individual species, this still has strong implications for the living community as a whole. Persistent pesticides are like to cause the most damage, but even rapidly degrading ones may have lasting effects. One study on a grassland ecosystem concluded:

> "... although the insecticides (Sevin) remained toxic in the environment for only a few days, long-term side effects on .... arthropod density and diversity, and mammalian reproduction were demonstrated."[25]

This and other studies suggest that the most meaningful way to assess the long-term effects of pesticides on wildlife is to study the ecosystems in which they live.

The impact of pesticides on the most complex and vital land ecosystem of all... topsoil... has serious implications for agriculture. The problem of determining effects is compounded by the incredible array of life forms living in the soil and by the many physical factors which influence the persistence of pesticides in the soil. Over 500 papers exist describing experiments on the effects of pesticides on various species or groups of soil flora and fauna.[26] However, as noted above, the combined reaction of an ecosystem is a far better indicator of the effects of pesticides than the responses of its individual members. The vigor of crops, their ability to resist diseases and pests, is dependent upon the complementary metabolisms of interacting soil microbes which provide a wide variety of major and trace nutrients to the plants.[27] Since pesticides tend to reduce the number of species of soil microbes,[28] it is also likely that they tend to upset the balanced nutritional relationship between soil and plant. The resistance of crops to pests may be the best measure of the health of a soil ecosystem and pesticides may impair this health which, in turn, will reduce the resistance.

Besides the effects of pesticide fallout on public health and natural ecosystems, there is the fact that, for ecological reasons, the single strategy of chemical control is rapidly becoming an economic disaster for agriculture. In most cases; pesticide use actually increases numbers of target pests, fosters new pests, and creates demands for new or more toxic pesticides. There are several reasons for this:

1. In many ways, pesticides free pests from control by their natural enemies (predators and parasites). First, pesticides accumulate at the end of food chains causing disproportionate mortality to the natural enemies. Second, most natural enemies have longer generation spans, are less abundant, and are slower to recover from the effects of poisons than pests. Third, natural enemies contact larger doses of pesticides than pests since they forage over greater areas in search for food. Fourth, herbicides often remove weeds which provide nourishment and refuge for beneficial insects.

2. Pesticides are not capable of "controlling" pests in the ecological and most meaningful sense of the word, i. e., over long periods of time.

3. In general, pesticides reduce biological diversity, which leads to less stable cropland ecosystems. This is a vague point to be discussed later.

4. Pests can become resistant to pesticides often to a greater degree than their natural enemies which have longer generation times and less opportunity to develop resistances through genetic adaptation. Of more than 225 species of arthropods in which resistant strains have been documented, only four are natural enemies of pests.[29]

5. Repeated pesticide treatments often produce outbreaks of secondary pests.... which would normally be kept in low numbers by natural enemies and competitors. A classic example involves the spider mites (Tetranychidae). A minor pest a quarter of a century ago, today they are the most serious insect pest affecting agriculture worldwide.[30]

These factors have precipitated a series of ecological backlashes which, in turn, have produced a definite pattern of pesticide failure and economic distress. For the farmer, the pattern usually starts with a desire for higher yields initiating intensive pesticide use on a regular schedule. Next, pest resistance compels the farmer to use larger doses or more toxic pesticides. In the meantime the numbers of old pests increase and new kinds arise. This forces the farmer to use still more pesticides at an increasing cost. Finally, the farmer exhausts his arsenal as pest problems become more severe and as spiralling costs of pesticides cut into his profits and simply ceases to be a farmer. Such economically depressed rural areas as the Rio Grande River Valley, the Lower Mississippi Valley, the Imperial and San Joaquin Valleys of California, the Canete Valley of Peru and many other once prosperous farm communities attest to the fact that the farmer has become a pawn of economic and corporate forces which have placed him on a costly pesticide treadmill. Claims by the USDA that the use of insecticides can produce a net return to the farmer of about $5.00 for every dollar invested[31] are shortsighted and grossly misleading. For over a generation, the agribusiness establishment, through economic incentives[d] and propaganda directed by the USDA and the petrochemical industry, has deluded farmers to accept pesticides with little regard for their long-term economic and ecological impact. The pattern becomes all the more absurd when we consider the many ways in which a farmer can reduce the use of pesticides without sacrificing yields.

SYNTHETIC FERTILIZERS: SALTING THE EARTH Prior to the mid-19th century, virtually all fertilizers were natural organic materials, plant and animal wastes, manures, etc. In 1840, a German chemist, Justus von Liebig, brought his findings together in a book[32] that was to change the course of western agriculture and lay the foundation for the modern chemical fertilizer industry. Simply put, Liebig's thesis was that plants could be rapidly nourished by mineral salts in solution instead of by the slowly available by-products of decaying wastes in the soil. Enormous yields could be produced simply by mixing inorganic salts of a few critical nutrients into the moist soils of farmlands. This applied especially to nitrogen, phosphorous and potassium — NPK.

The first chemical fertilizer was a phosphorous compound made by mixing sulfuric acid with bone materials.[e] The process was patented in England in 1842 and, by the end of the U. S. Civil War, tens of thousands of tons of "chemical manure" were being produced each year by the British fertilizer industry.

d. The post-war farm policy in which controls were placed on acreage instead of production forced farmers to use pesticides on their remaining land to increase yields.

e. This is an artifically refined version of the natural process in which acids from the metabolism of plant roots and soil microbes release nutrients held in reserve in the organic matter and minerals of the soil.

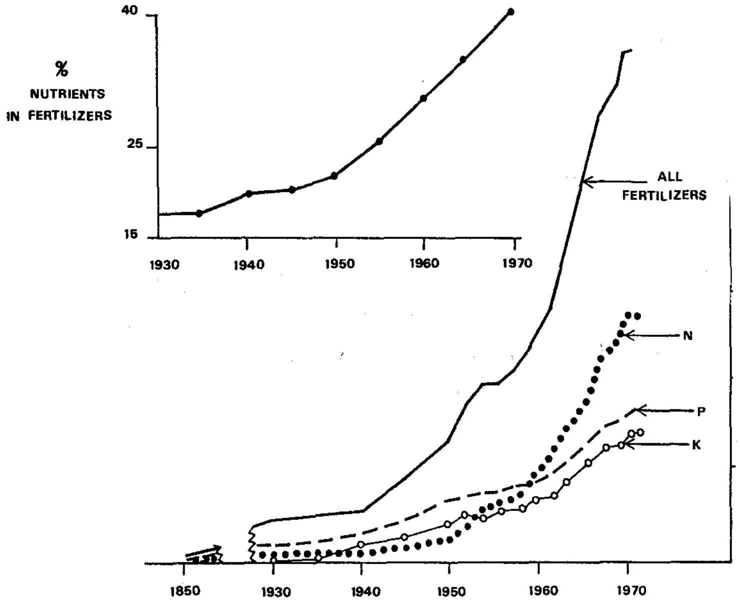


Fig. 2 Trends in the use of chemical fertilizers in the United States. Top graph shows the increasing concentration of primary nutrients (NPK) used in fertilizers. Bottom graph shows the total use of all fertilizers and primary nutrients. Adapted from USDA, Economic Research Service.[33]

Similar advances with nitrogen and potassium compounds provided the impetus for the complete substitution of synthetic fertilizers for natural fertilizers. By 1954, organic materials accounted for less than 3% of the total fertilizers used in U. S. agriculture. Further trends in the adoption of chemical fertilizers havebeen:

1. The rate of use has increased steadily since 1850 and even more rapidly since the beginning of World War II. Most forecasts predict a continued increase in use through the 1980's.

2. Since 1959, nitrogen has been the primary nutrient fed to U. S. crops (Fig. 2). Use has increased from 0.5 million tons in 1945 to 6.6 million tons in 1970. By 1980, U. S. Agriculture will be using over 11 million tons or about 10% of the total world consumption.[34]

3. New developments in production technology have increased the purity of chemical fertilizers and hence

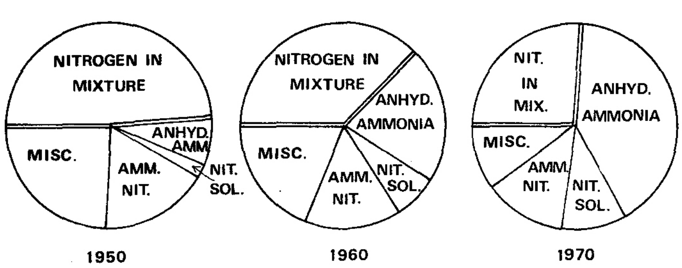


Fig. 3 Changing proportions of mixed and concentrated nitrogen fertilizer being used in U. S. agriculture. Concentrated forms include anhydrous ammonia, nitrogen solutions, ammonium nitrate and other miscellaneous types (aqua ammonia, urea, ammonium sulfate). Adapted from Tennessee Valley Authority, National Fertilizer Development Center.[35]

the concentrations at which they are used (Fig. 2). For example, nitrogen is being used less in mixed forms (combined with other nutrients) and more in concentrated forms like anhydrous ammonia, i. e., liquified ammonia gas (Fig. 3).

4. In 1970, about 70% of all chemical fertilizers used were applied to four crops: corn (95% of the corn acres received fertilizer); cotton (72%); wheat (59%), and soybeans (29%). For most crops, the proportion of acres receiving applications of chemical fertilizers increases each year.[33]

5. Cheapness and ease of shipment have made synthetic fertilizers most attractive. Still, prices appeared to bottom out around 1969. Because fertilizer production is so heavily geared to fossil fuel inputs, prices will certainly rise sharply in the coming years.[36] For example, the cost of natural gas as a raw material (source of hydrogen) and fuel (to fix atmospheric nitrogen) accounts for 60% of the manufacturing costs of ammonia which now supplies about 90% of all fertilizer nitrogen. Phosphorous and potassium fertilizer costs will also increase since they require fossil fuel energy for manufacturing and for the production and mining of raw materials (e. g., phosphoric and sulfuric acids, phosphate and potash rocks).

6. Future increases in chemical fertilizers are likely to occur on low fertilizer-using crops and areas, since many of the high fertilizer-using crops, such as corn, are approaching the maximum profitable rate of application.[37]

Because chemical fertilizers are highly soluble salts, used in large amounts they over-stimulate natural cycles and exaggerate amounts of certain chemicals in the environment. For example, before large-scale manufacturing of chemical fertilizers, there was a balance between nitrogen removed from the atmosphere by natural fixation and nitrogen returned to the atmosphere by natural denitrification. Today, due to extensive use of nitrogen fertilizers, there may be an accumulation of nearly 10 million tons per year of fixed nitrogen compounds in the biosphere.[38]

One consequence of this build-up of fertilizer salts has been the enrichment of local water reserves and the destruction of aquatic animals by eutrophication.[f] Another has been the accumulation of toxic forms of nitrogen in water supplies and crops. There are two major kinds of nitrogen toxicity: 1) The chemical reaction of nitrites (NO_2) with blood hemoglobin which impairs the circulation of oxygen in the blood

f. Some claim that carbon, rather than nitrogen or phosphorous is the primary cause of eutrophication. Although there is evidence to the contrary, this notion has been encouraged by the soap industry which has high stakes in the effects of phosphorous on water supplies.

(methemoglobin), or causes vitamin deficiencies. Nitrite concentration is common in some fodder crops where it poisons livestock, or in vegetables of the brassica or spinach family where it constitutes a real health hazard, especially in baby foods.[39,40] 2) Nitrites may react with amines in the body to form nitrosamines and related nitrosaminides. These compounds are known to induce cancer.[41] Concern that increased use of nitrogen fertilizer may be linked with the growing incidence of cancer in modern society has been expressed by even the medical establishment.[42]

Nitrites are found in large amounts in the soil, in crops and in ground water where nitrogen fertilizers are used extensively. Apologists for the chemical industry claim that organic wastes, industrial and domestic effluent and natural processes are more responsible for nitrate and nitrite accumulation in rural areas than fertilizers. But several studies have shown that nitrogen fertilizers can indeed percolate through soils and accumulate in local water supplies.[43-45] The long term effect of this contamination is virtually unknown, although one observation by the USDA is ominous:

> The rate of water recharge from deep percolation is so slow that the possible nitrate pollution of aquifers... will take decades. However, once nitrate gets into the aquifer, decades will be required to replace the water with low nitrate water.... By the time the trend was established, a dangerous situation could be in the making that could not be corrected in a time shorter than it took to create.[46]

Finally there is the whole controversial issue dealing with the effects of chemical fertilizers on soil fertility, as defined by the activities of soil microbes and soil animals, and the quality of crops, as defined by their nutritional value and their ability to resist diseases and pests. These questions represent fundamental gaps in traditional agricultural research and will not be dealt with here. Suffice it to say that heavy applications of chemical fertilizers may produce plants which are susceptible to attack by insect pests.[47,48] There appear to be at least three mechanisms involved: a) chemical fertilizers place metabolic stresses on plants which increase production of aromatic compounds that attract pests.[49] b) Chemical fertilizers cause plants to take up water and produce succulent growth favored by pests for shelter and food. c) The exclusive use of NPK chemical fertilizers reduces incentives for recycling organic material and trace minerals as part of a fertilizer program. Humus and trace minerals provide building blocks for plant enzymes that are important to a plant's defense mechanisms.

GENETIC EROSION AND MONOCULTURES For millenia people have domesticated wild species of plants and animals for food, selecting strains that were palatable and easy to grow. About 75 years ago genetic engineers began developing controlled breeding programs and selecting crop varieties that were resistant to some of the notorious diseases and pests which have plagued societies throughout history. These efforts continue today,[50] but they have taken a back seat to the development of a few high-yielding and uniform crops which meet the demands of mechanical harvesters and a competitive market economy. There have been three general approaches used to produce uniform strains: a) Reproduction from a single plant by vegetative cutting (e.g., potato), b) Reproduction by seeds from self-pollinating crops (e.g., lettuce, tomato, wheat, beans), c) Reproduction by seeds from controlled cross-pollination and inbreeding (e.g., hybrid corn, hybrid cucumber, hybrid onion).

On the surface, results have been spectacular. Yields of most major crops have soared,[g] and machines are now able to harvest "efficiently" and provide the finicky consumer and processor with an abundance of eye-appealing produce. But for several reasons the new genetic strategy has placed modern agriculture in perhaps its most vulnerable position by forsaking biological quality for yield and appearance:

1. The genetic base for most major crops has become dangerously narrow. As farming practices rely more and more on a few productive varieties (Table IV), the numerous strains once grown in local com-

g. For example, the yield of corn has risen from about 40 bushels/acre in 1950 to nearly 100 bushels/acre in 1970.

CROP	NUMBER OF POPULAR COMMERCIAL OR CERTIFIED VARIETIES	MAJOR VARIETIES	
		NO.	% OF CROP ACREAGE
Bean, dry	25	2	60
Bean, snap	70	3	76
Cotton	50	3	53
Corn[a]	197	6	71
Peanut	15	1	35
		3	70
Peas	50	2	96
Potato	82	4	72
Rice	14	4	65
Soybeans	62	6	56
Sugar beet	16	2	42
Sweet potato	48	1	69
		3	84
Wheat	269	9	50

TABLE IV. The extent to which a few crop varieties dominate American agriculture. Adapted from the National Academy of Sciences.[47]

a = Released public inbreds only, expressed as percentage of seed requirements munities and regions are being abandoned. Changing land-use patterns reduce the diversity and distribution of germ plasm further by destroying habitats of endemic wild plants. This combined loss of genetic diversity reduces the gene pool from which plant breeders can choose to breed future varieties resistant to future diseases. Such a genetic reserve is important because the evolutionary contest between disease microbes and cultivated stocks is a continuous exchange of mutual adaptations; short-lived microbes mutate and recombine to new diseases while longer-lived crops struggle to adapt resistance.[h] Likewise, the development of resistant varieties of crops is a continuous process and needs a diverse genetic base from which to operate. Unfortunately, a large proportion of the genes of old varieties has been discarded; the new varieties represent only a fraction of the gene pool once planted.[i] This loss, although not well publicized and understood by the public, has very serious consequences for the availability of future food supplies.

2. Most high-yield crops encourage the use of pesticides and synthetic fertilizers; in fact, they have actually been developed in concert with agricultural chemicals. The new varieties appear to be prone to pest attack (e.g., the dwarf IR-8 rice, the "backbone" of the Green Revolution, is susceptible to sheath blight and the brown leafhopper). This means that farmers are forced to use pesticides, including herbicides, to protect their high yields and to stretch production potential. In addition, high-yield varieties are productive only because they are responsive to heavy doses of chemical fertilizers; they are ineffective without this input. Thus, the abundance of high-yield crops has to be weighed against the hazards of the chemicals needed to make them so productive.

3. Planting large areas to the same kind of crop encourages the spread of disease and pest outbreaks. When the monocultures are extended over broad geographic areas, as they are today in the United States, the potential for crop epidemics is compounded. This is precisely the condition that precipitated the great Irish potato famine of the 1840's and the U. S. corn leaf blight in the early 1970's when over 15% of the total U. S. corn crop was destroyed. These and other examples show that crop monocultures and genetic uniformity actually invite crop diseases, increased pesticide use and the potential for higher food costs and food shortages.

Unfortunately, the market economy rather than common sense determines whether a new crop variety is used. The farmer requires uniform crops for tending and mechanical harvesting. The middlemen require uniformity for processing and mass merchandising. The competitive market permits no alternatives, in spite of the fact that our dependence on a narrow genetic base for our food supply destroys genetic reserves and encourages polluting inputs and crop epidemics. This fundamental dilemma was brought to focus by the 1970 U. S. corn leaf blight and was described in a report issued by the National Academy of Sciences, which concluded that:

a) .... most major crops are impressively uniform genetically and impressively vulnerable. b) This uniformity derives from powerful economic and legislative forces. c).... increasing vulnerability to epidemics is not likely to generate automatically self-correcting tendencies in the marketplace.[47]

FARM ENERGY, RISING FOOD COSTS AND CHANGING DIETS A characteristic of chemical farming is the close relationship between pesticides and synthetic salt-fertilizers. These two technologies were developed together and are interdependent. As noted earlier, the use of agricultural chemicals, together with crops geared genetically to their use, have forced the farmer onto a treadmill of chemical routines and resources. (Fig. 4)

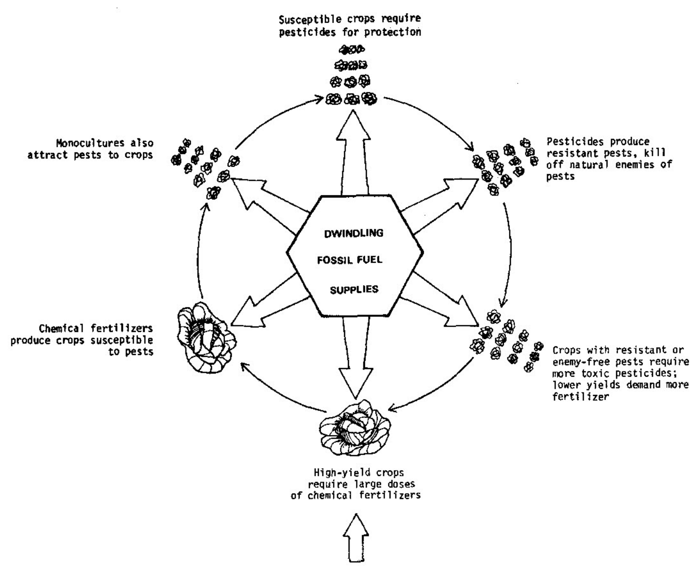


Fig. 4 The treadmill of chemical dependence fostered by the high-energy technologies of modern agriculture and nurtured by a series of ecological backlashes.

h. For instance, many patterns of human history reflect the gradual recurrence of wheat rust epidemics. Today, the survival of a given wheat variety in the Pacific Northwest is about 5 years (47), before a disease will force development of a new resistant variety.

i. As to the large world collections of germ plasm stored for future use at the National Seed Storage Laboratory, one agronomist writes: "If you are willing to entrust the fate of mankind to these collections, you are living in a fool's paradise... (they are) enormously redundant... some races are hardly represented at all and the wild and weedy gene pools are conspicuously missing. In no collection is there an adequate sampling of the spontaneous races that are the most likely sources of disease and pest resistance. On the whole, the collections we have are grossly inadequate for the burden they will have to bear."[51]

TABLE V. Fossil Fuel Requirements for different aspects of agriculture. Data are for California (1972). From Cervinca et. al.[54]

CATEGORY	ENERGY SOURCE (IN MILLIONS OF UNITS) NATURAL GAS THERMS	ELECTRICITY KWH	DIESEL FUEL GAL.	GASOLINE GAL.	LP GAS PROPANE BUTANE GAL.	AVIATION FUEL GAL.	TOTAL MILLION BBLS CRUDE OIL
Field crops	364.784	464.681	96.400	19.477	2.381	--	9.34
Vegetables	165.999	358.193	38.792	25.031	4.441	--	4.62
Fruits and nuts	127.168	410.773	26.158	12.602	3.296	--	3.39
Livestock	107.111	1,460.966	46.443	7.813	12.261	--	4.19
Irrigation	40.618	7,177.441	6.531	.487	4.521	--	5.16
Fertilizers	305.748	579.362	6.738	3.529	1.114	--	5.87
Frost protection	---	40.501	60.003	6.854	.904	--	1.63
Greenhouses	102.700	83.427	---	---	---	--	1.82
Agr. aircraft	---	---	1.072	1.607	---	8.994	0.25
Vehicles (farm use)	---	---	10.447	117.798	---	--	2.77
Others	---	---	---	---	23.711	--	0.39
TOTAL	1,214.128	10,575.344	292.584	195.198	52.629	8.994	
EQUIVALENT (Million bbls crude oil)	20.93	6.21	7.06	4.17	0.86	0.19	39.43

The chemical treadmill is only part of the regime of gas and oil technology that now fuels the fields and cares for crops. Virtually all of the agricultural tools used today depend on fossil fuel energy in one form or another (Table V). With possible fuel shortages, whether real or political, there seems little doubt that our present euphoria about farm production is ill-founded and that the energy crisis will have increasing effects on the production, consumption and price of food.

Agriculture, of course, is just the starting point of a large food industry that includes production, processing, transportation, marketing, plus domestic storage and cooking. In 1963, these food-related activities consumed about 12% of the total U. S. energy budget, or the equivalent of about 240 gallons of gasoline per person (Table VI). Assuming that one person eats about one million kilocalories of food energy per year, or about 29 gallons of gasoline, it seems that our notions about food as an energy supplier are largely an illusion.

Source	Million BTU's	Heat Equivalent Gal. Gasoline	% of Total
Agriculture	5.8	43.0	18
Food Processing	78.5	78.5	33
Transportation	0.9	6.7	3
Wholesale & Retail Trade	5.2	38.5	16
Domestic (Storing, Preparing, Transportating)	9.9	73.3	30
TOTAL	32.4 million BTU's per person per year	240 gallons of gasoline	100.0%

Table VI. Distribution of total per capita energy requirements for food consumption in the United States (1963). Adapted from Hirst.[52]

There is some evidence that agriculture itself has become an energy sink. Pimentel[53] has shown that, with regards to U. S. corn production, the ratio of energy in yields to energy in production inputs ("production efficiency") has started to decline in recent years (Fig. 5). This decline has a profound effect on other food industries since corn supplies livestock feed as well as oil and food.

The production efficiencies of other raw foods are listed in Table VII. Although there is considerable variation in energy intensiveness among different crops, on the average, most seem to use about as much energy for production as they provide for sustenance.[54,55]

Viewed in terms of an energy budget, then, modern agriculture does not seem so efficient. In fact, it may be less efficient than more "primitive" forms of agriculture:

> .... modern agriculture based on the exhaustion of fossil fuels may produce more than hand

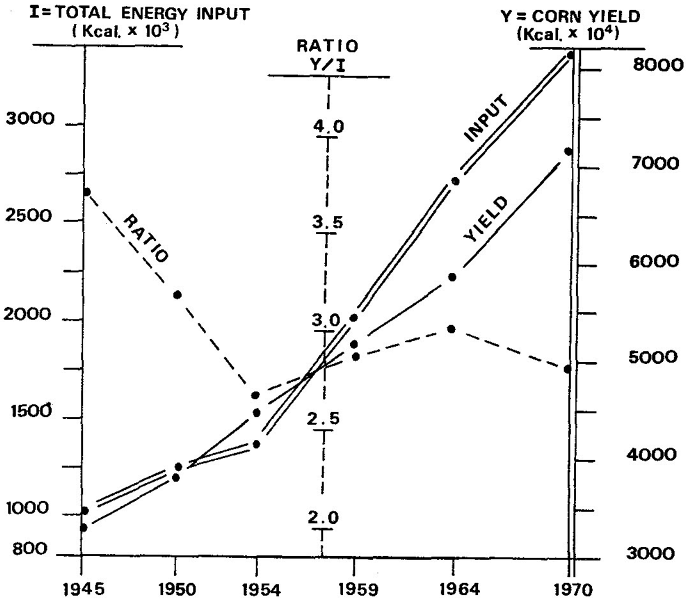


Fig. 5 Trends in the energy efficiency of U. S. corn production (1 Kcal = 3.97 BTU). Energy inputs include: labor, machinery, gasoline, NPK fertilizer production, seeds, irrigation, pesticides, crop drying, electricity and transportation. Note that,on scale, figures for yields are ten times greater than those for energy inputs. Adapted from Pimentel et al.[53]

cultivation, but it does not lead to improvements in the efficiency of energy use.[56]

Thus, despite the high yields of modern farm technology, there does not appear to be an obvious net return of energy to society. In effect, the benefits of solar energy fixed in our foods are offset by the subsidy of fossil fuel energy needed to produce them.

Obviously there are strong implications in the fact that the principal raw material of modern agriculture is a dwindling, non-renewable resource. For one thing, there is the relationship between the inevitable rise in fossil fuel prices and the availability of food... especially products that require high energy inputs like processed foods and animal protein.[j] In fact, meat may become so expensive in the future that it will probably be replaced entirely by vegetable protein in the diets of many people. But vegetable protein may also become hard to get as the United States implements its basic 1970's foreign policy, which uses domestic grains and legumes to reduce the balance of payments and to barter for oil and natural gas in foreign trade. Inevitably, the energy crisis will lower the quality of food for most people, especially the poor. For others, these changes could precipitate a renewed interest in urban "Victory Gardens" and microfarms and provide an impetus to develop food cooperatives and local food economies linking the inner city to suburbia.

On the positive side, the strain of fuel shortages on food production may ultimately stimulate a broad-based approach to the development of ecologically-sound and energy-saving approaches to agriculture. The above might include incentives for using cropping patterns that limit the scale of mechanization, the utilization of renewable energy resources (solar, wind, organic fuels) to supplement rural power needs, increased emphasis on integrated pest control, organic waste recycling and other low-chemical farming practices.[k]

AGRICULTURAL RESEARCH: RESTRICTING THE OPTIONS Unfortunately, little has been done to develop techniques to make farms more practical and productive within an ecological, renewable-energy framework. The agricultural research establishment continues to develop, promote and extend chemical, energy-consuming technologies in the name of pragmatism and economic "efficiency." The National Academy of Sciences has criticized the USDA and various state research institutions for supporting "pedestrian and inefficient work," for being guided by policies "repressive to the vitality of science," "detrimental to the interests of agriculture," and for neglecting basic research.[58] This last criticism is especially telling,

COMMODITY	CROP ENERGY VALUE GAL GASOLINE/TON	PRIMARY ENERGY INPUTS* GAL GASOLINE/TON	RATIO: CROP ENERGY/ INPUT ENERGY
Field Crops			
Barley	101.9	15.4	6.6
Corn	107.5	46.5	2.3
Rice	106.0	41.5	2.6
Sorghum	97.0	38.3	2.5
Wheat	97.2	18.1	5.4
Raw Vegetables	12.3	15.9	.77
Range	(5.0 - 35.9)	(8.4 - 65.9)	
Raw Fruits	15.7	28.8	.54
Range	(11.1 - 19.6)	(12.9 - 53.1)	
AVERAGE OF ALL RAW FOODS	29.9	21.9	1.36
Canned Vegetables	17.1	67.1	.25
Range	(6.1 - 28.0)	(36.7 - 97.3)	
Canned Fruits	12.3	48.7	.25
Range	(8.8 - 14.9)	(35.9 - 57.9)	
Frozen Vegetables	14.8	68.6	.22
Range	(6.4 - 29.8)	(52.2 - 92.0)	
Dried Fruits & Nuts	142.4	222.8	.63
Range	(93.6 - 170.9)	(133.4 - 322.4)	
AVERAGE OF ALL PROCESSED RAW FOODS	45.5	97.2	.47

Table VII. Energy efficiencies of different crops produced in California, 1972. Adapted from [54]. *Inputs include machines (planting, culture, harvest, transport, storage, processing); fertilizers (production, transport, handling, application); irrigation; farm vehicles; frost protection; airplanes.

j. In the U. S. it takes about 6500 Kcal. to produce one pound of beef or about 38,000Kcal per pound of protein.[57] In contrast, one pound of corn fed to the cattle requires from 514 Kcal[54] to 639 Kcal[53] to produce depending on the extent of energy inputs one plugs in.

k. In 1970, the proportion of energy inputs into U. S. corn production included the following: chemical fertilizers, 36%; pesticides, 1%; maintenance and operation of farm machinery, 42%; electricity, 11%; labor, seeds, irrigation, crop drying and transportation, 10%.[53]

since it points to the inability of conventional agricultural research to investigate and promote alternative methods of farming which stem from *basic* ecological principles:

> (the antitheoritical bias of agricultural science) is reinforced by the search for marketable products (mostly chemical) as the central strategy for improvement of agriculture.... and by a narrow acceptance of the present structure of agriculture as a given condition which restricts options. For example, the consideration of mixed plantings is inhibited by the present design of farm machinery. Therefore, research into the ecology of mixed sowing only makes sense as part of a broader program that must include an engineering effort to redesign the machines.[59]

In other words, much of agricultural research is heavily biased and restricted by a narrow set of technological assumptions. In contrast, a true agricultural science is not guided exclusively by economic restrictions, but also by biological realities; it examines the potentials of food production from an ecological point of view... from a self-sustaining point of view, realizing that applied ecology is nothing more than long-term economics.

ECOSYSTEM FARMING: A SELF-SUSTAINING TECHNOLOGY

> *When the practice of industrial agriculture is interpreted in the light of current knowledge of ecosystems, a picture emerges which suggests that the future dependability of such agriculture is in grave doubt.*
>
> – *Institute of Ecology*
> *Man in the Living Environment*

Agricultural systems are essentially artificial communities of domesticated plants and animals. In order to understand the use of ecological tools in agriculture, we might first consider briefly the ecological characteristics of natural plant and animal communities. These characteristics can then be used as models for our agriculture.

MODELS IN NATURAL ECOSYSTEMS Although not always obvious, wildlife communities have a biological integrity. Not only do particular groups of creatures usually live in a particular habitat, but the habitat is modified and new habitats created by the living community itself. The two dynamics evolve to form a self-sufficient habitat or "ecosystem." We have, for example, a grassland ecosystem, a forest ecosystem, a pond ecosystem.... an agricultural ecosystem.

The sun provides the energy for the running of ecosystems. This energy is stored by green plants and passed on through a food chain of plant-eaters and flesh-eaters. Wastes and dead bodies become food for microbes which decompose complex organic matter into simple materials that can be used again by plants. Available food energy is gradually lost as work and metabolic heat at each link along the food chain. *In ecosystems, then, matter cycles and energy flows.*

For the efficient conversion of matter and energy back into the life cycle, ecosystems are held together by very diverse but specific kinds of plant/animal relationships. Since energy and matter are lost as they pass along the food chain, plants are more abundant than plant-eaters and these, in turn, are more numerous than flesh-eaters. Since most animals have a variable diet, food chains intermingle in an ecosystem and form a complex food "web." Generally speaking, the more complex the food web, the less likely it is that a natural disturbance or outbreak will alter the integrity of the ecosystem or cause individual members to become extinct. Hence, in natural ecosystems, there is a strong relationship between biological diversity and internal stability.

Other important characteristics of natural ecosystems have been described by Pimentel:[60]

a. Animal populations in natural biotic communities are relatively stable; outbreaks.... are generally rare.

b. Most species are rare in relative numbers.

c. The majority of animals feed on living matter as opposed to non-living... Although many animals are associated with dead matter, most of these animals.... are feeding on microbes ... present in the decaying matter.

d. Population outbreaks frequently occur with newly introduced animal species. The plant hosts on which the newly introduced animal is feeding often lack resistance to it.

e. Resistance factors which limit the feeding of animals on host plants are common in nature, including spines, toxins, growth inhibitors, etc.

THE FARM AS AN ECOSYSTEM Farmlands, on the other hand, are artificial ecosystems. They reflect important differences from the workings of natural ecosystems:

a. Agro-ecosystems are open communities of limited duration. Because of cultivation and harvest, there is little opportunity for plant nutrients to be recycled. Natural ecosystems, however, are nearly closed communities since plants feed on the decayed bits of their recycled predecessors.

b. Cultivated plants and animals are particularly susceptible to attack from pests and diseases; most natural resistance has been bred out of them in favor of productivity and palatability.

c. Demands for agricultural efficiency are really demands for biological simplicity and uniformity. Hence, agro-ecosystems contain only a few species of plants and animals which are substituted for the more complex network of the wildlife community. Strong interactions often develop among these few species and their associated competitors and predators. The system is simple and unstable or easily disturbed. This is why pest populations are often larger in monocultures than in mixed-species stands.[61-63] This "simplicity" of agro-ecosystems takes on several forms: (1) *Crop Simplicity:* fields are usually planted to a single kind of crop, occasionally two (intercropping), very rarely several (mixed stands). Herbicides eliminate weeds so that only one crop prevails. (2) *Genetic Simplicity:* crops and livestock are usually of one high-yielding variety or inbred line of hybrid stock that often, in the name of production, forsakes disease resistance and adaptability. (3) *Structural Simplicity:* The farm landscape is structurally simple, without hedgerows, trees, weeds and other refuges of beneficial animals to interfere with efficiency. (4) *Ecological Simplicity:* the farm ecosystem is simple with respect to the number of relationships among links in the food chain. For example, in (1) above, or when livestock are moved to feeding lots so that manure can't be recycled locally, or when natural enemies of pests are eliminated by indiscriminate pesticides, etc., the farm is made unstable in an ecological sense and requires large inputs of synthetic chemical energy to replace the biological energy that usually maintains balance and stability.

Generally speaking, farming practices of fertilizing soils and controlling pests fall on a spectrum between the chemical and ecological extremes. Today, practically all farming is at the chemical extreme. But, as I have tried to show, there is a growing imperative for ecological alternatives in farming which foster a more stable and closed agro-ecosystem.

ORGANIC WASTE RECYCLING AND CONVERSION In 1971, the cities spent over $3.5 billion to collect and dispose of solid wastes. Next to schools and roads, this was the costliest of all public services. In that same year, the U. S. generated about 880 million tons of organic waste solids (Table VIII). Less than 0.1% of this was sold commercially as compost, dried manure and processed sewage sludge. A similar amount was used by farmers as fertilizer and soil conditioner (Table IX).

Source	Waste Generated	Readily Collectable
AGRICULTURE		
Crops & food waste	390	22.6
Manure	200	26.0
URBAN		
Refuse	129	71.0
Municipal sewage solids	12	1.5
INDUSTRIAL WASTES	44	5.2
LOGGING & WOOD MANUFACTURING	55	5.0
MISCELLANEOUS	50	5.0
TOTAL	880	136.3

Table VIII. Amounts (1 million tons) of dry, ash-free organic wastes produced in the United States in 1971. Adapted from U.S. Bureau of Mines (64).

Unfortunately, most organic waste is not returned to the land but is either burned or dumped into oceans, rivers and landfills. This unwillingness to close a basic ecological cycle occurs at both ends of the human food chain. On farmlands, the centralization of livestock production has produced a waste "problem" instead of a waste resource, while the expediencies of a few salt fertilizers have replaced the traditional patterns of crop rotation, green manuring and lea farming. In the cities, the return of organic wastes to farmlands is hindered by the attitude that municipal composting is economically inefficient and therefore not a viable alternative to simple dumping and burning.[66,67] True,

	1967	1968	1969
1. DRIED BLOOD	2154	2173	2251
2. CASTOR POMACE	2924	2584	1626
3. COMPOST	35,171	41,284	19,472
4. COTTONSEED MEAL	3,920	2,522	5,416
5. DRIED MANURE	366,013	363,418	350,557
6. SEWAGE SLUDGE	124,681	138,355	131,062
7. TANKAGE	9,407	6,606	6,732
8. OTHER	9,709	14,005	18,601
	553,979	570,947	535,717

Table IX. Natural Organic Materials Used (in tons) as Fertilizers in U.S. Agriculture. From Statistical Reporting Service, USDA[65] at this time, the composting process is expensive and there is little demand for the benefits of compost; operating costs range from about $5.00-$15.00 per ton, or about the same price as incineration.[68] Also the bulk of organic wastes makes them impractical to the farmer when compared to salt fertilizers that can be applied easily by machines or in irrigation water.

On the other hand, the shipment of millions of tons of agricultural produce from the country to the city and then into waterways or up into the air is a fundamental example of how rural and urban problems have been separated from their common ecology. The recycling of organic wastes on farmlands has the potential of creating new jobs, reversing the rapid loss of humus in farm soils and offering a low-energy alternative to agriculture (Table X). Most important, it provides the first positive step towards the much-needed integration of cities and farms and the mutual solution of urban and rural problems.

Organic matter is not only a valuable fertilizer and soil conditioner, it can also be converted into energy sources. For example, the U. S. produces about 136 million tons of easily available organic solids each year (Table VIII). This is equivalent to: 170 million barrels of oil (3% of 1971 U. S. consumption) or 1.36 trillion cubic feet of methane gas (6% of the 1971 U. S. consumption).[64] Put another way, it is equal to 150% of the energy used to run all U. S. farm tractors.

At the present there are few economic incentives to begin recycling and converting organic wastes. Broad-based changes will no doubt depend on the inevitably high costs of fuels and synthetic fertilizers, sufficient research rationale, the acceptance of municipal composting and sludging, and the decentralization of livestock production. Meanwhile, local efforts are possible.

ORGANIC FERTILIZER (10 tons of cow manure per acre)	CHEMICAL FERTILIZER (N=112 lbs; P=31 lbs; K=60 lbs per acre)	
HAULING AND SPREADING (Kcal/acre)	PRODUCTION (Kcal/acre)	APPLICATION (Kcal/acre)
398,475 (11 gal. gasoline)	1,415,200 (39 gal. gasoline)	36,325 (1 gal. gasoline)

Table X . Energy budget of organic and chemical fertilizer applications. Substituting cow manure for chemical fertilizers could save a potential 1.1 million kcal/acre. Adapted from Pimentel et al.[53]

DECENTRALIZED STOCK BREEDING - RESISTANCE AND DIVERSITY If genetic uniformity makes crops vulnerable to pests, then genetic diversity is the best insurance against outbreaks. There are several approaches:

a. The preservation of local plant life and wilderness ecosystems as genetic reservoirs.[69]

b. The selection and storage of crops with diverse gene pools.

c. The selection and rotation of varieties adapted to regional conditions and resistant to local as well as pandemic pests. This would establish buffer areas against widespread crop epidemics and provide more options for the success of local food production.

d. The re-integration of livestock with plant crops and the selection of animal varieties that can fend for themselves in reproduction, protect themselves from weather and disease and develop their own patterns of group behavior.[70]

Obviously these approaches are based on a dramatic decentralization of current plant and animal breeding programs and a sharp turn in research priorities from quantity to biological quality. Because the requirements for yield and crop uniformity are so ingrained in our food economy, it is difficult to imagine incentives for change, short of actual epidemics or radical economic reconstruction. Meanwhile, at the local level, community efforts in new rural areas and grass-roots research can promote the genetic diversity of crops by protecting indigenous plant life; by seeking adaptable crops from independent seed and livestock companies (especially out-crossing and non-hybrid types) and by selecting for local varieties and strains whenever possible. Cooperative gene banks may, in the future, have as much value for endemic agricultures as cooperative distribution groups have had in the past.

BIOLOGICAL CONTROLS AND DIVERSE FARMLANDS As pointed out by Rudd[13], any analysis of pesticide failure suggests three qualities to look for in alternative methods of pest control: 1) they should be capable of keeping pests at a harmless density; 2) they should not cause pests to develop resistances, and; 3) they should work with and not against the controls provided by natural enemies. Several methods fulfill these requirements in one way or another. Sex-scent attractant, reproductive hormones, sterile-male radiation, traps, etc., have all been used successfully. But by themselves these techniques are based on a strategy of *discouraging the pest.* A more permanent and stabilizing strategy in terms of closing the agroecosystem is based on *encouraging the natural enemies of pests:* their predators, parasites and diseases.

Pest enemies can be encouraged in two ways: they can be reared in large numbers under controlled conditions (insectaries) and released at strategic times into crop areas. Alternatively, crop patterns and local environment can be modified so as to favor the life histories of beneficial insects already in the fields. Changes might include the cultivation of companion crops, the maintenance of uncultivated areas or the establishment of permanent refuge habitats. There are several ways to improve the ecological stability of croplands; only a few specific relationships will be mentioned here for illustration:

a. *Flower-crops:* The nectar and pollen of many flowers provide food for adult beneficial insects.[71,72] In orchards, for example, wildflowers can nurture populations of parasitic wasps and thereby reduce certain pests.[72,73] Research in Russia has shown that, when the weed *Phacelia* was planted in orchards, a parasite of the tree's scale pest thrived in the orchard by subsisting on the nectar of the weed. When the population of the pest increased to dangerous levels, the parasite was in sufficient numbers to control the pest, thus avoiding the unpredictable lag period that normally occurs between the appearance of a pest and its natural enemy. Another Russian study showed that, when small plots of umbellifers were planted near vegetable fields in a ratio of 1 flower plant:400 crop plants, up to 94% of the cabbage cutworms were parasitized. Flowers of crop-plants such as brassicas, legumes and sunflowers can also serve as alternative food sources for beneficial insects.

b. *Repellent crops:* Most insects are selective as to the kinds of plants they eat. It is generally held that insects are attracted to the odors of "secondary" substances in plants rather than to the food value of the plant itself.[74]

Experiments have shown that odors given off by aromatic plants interplanted with crops can interfere with the feeding behavior of pests by masking the attracting odor of the crops.[75] This means that certain kinds of plant diversity *per se* may have a profound effect on pests over and above that conferred by natural enemies. Repellent crops so far described include various pungent vegetables *(Solanum, Allium)* and aromatic herbs *(Labiatae, Compositae and Umbelliferae)*.

c. *Trap crops:* Some plants can be used to attract pests away from the main crop. With careful monitoring these "trap" crops can also serve as insectaries for natural enemies. For example, when alfalfa strips were interplanted with fields of cotton, the Lygus bug (a serious pest in California) migrated away from the cotton and into the alfalfa.[77] With their concentrations of Lygus bugs, the alfalfa plots then provided a food source for several predatory insects in the area. Trap crops of alfalfa may also have applications in walnut and citrus orchards and bean fields. In the coastal climate of California, brussels sprouts, which attract large numbers of aphids, can function as overwintering insectaries for parasitic wasps. When aphids attack other crops in the spring, wasp populations, having fed on aphids during the lean winter, are large enough to respond quickly and control the aphids.

d. *Hedgerows and Shelter Belts:* For centuries hedgerows have been planted between field crops to slow down winds and thus reduce wind erosion and improve microclimates. The presence of uncultivated land near cultivated fields also has a profound effect on the distribution and abundance of insects associated with crops. Wild plant stands can provide alternative food and refuge for pests and their natural enemies alike. In fact, almost every advantage offered to the one is, to some degree, available to the other. Hence it is not always clear whether uncultivated land is beneficial or harmful to pest control. However, in England, where much farming is done near wild vegetation, pest problems are generally less severe than in the United States where monoculture farming persists.[78]

Many other kinds of plant relationships can be cultivated to advantage. Some "component" species probably serve more than one beneficial function. Repellent herbs, for example, also produce food-rich flower heads, as do many trap crops. Garden models (Fig. 6) exist for a variety of mixed cropping schemes,[79] and these undoubtedly could be tested and applied on a larger scale. Interest, however, will probably remain focused on monocultures until the "costs" of pesticides and poor farm management exceed the "costs" of ecological designs.

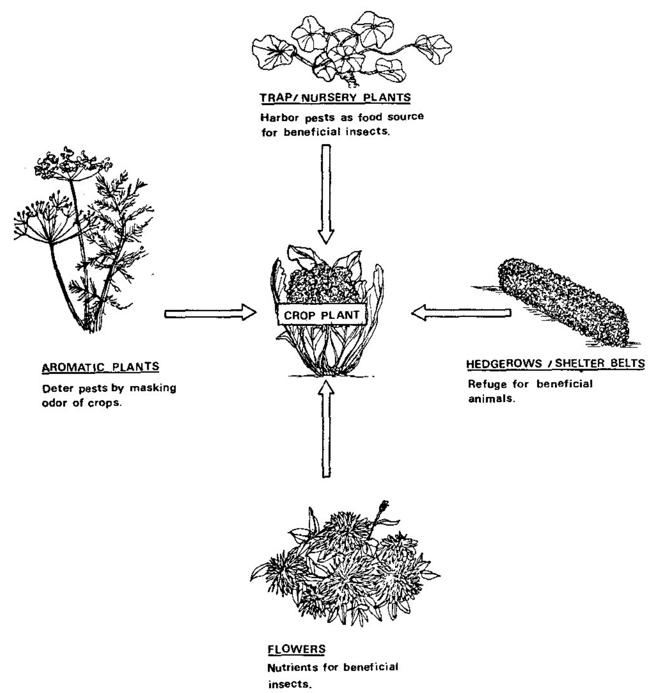


Fig. 6 Some possible components and plant interactions of a diverse cropping system, based on a garden model of "companion planting" arrangements.

Speaking generally, interplanting the farm landscape with trees, hedgerows and other perennial stands, together with rotations,[1] strip cropping and mixed stands will serve to promote stability and effective natural pest control. But diverse landscapes and mixed farming methods *per se* will not create stability. Sometimes diversity decreases pest damage, other times it may increase it. The web of possible plant/animal relationships is immeasurably complex, and each situation and crop ecosystem is unique. In other words, the right kind of diversity must be established, and we can only know that by practical experience in local areas and ecological studies of the agricultural environment.

1. There is some debate on the long-term effects of continuous rotations. From 50 years of 6 year rotations (corn, oats, clover and timothy), Albrecht (79) noted that the problem of returning fertility to exhausted soils may be easier if one used one crop and grew it continuously: "That procedure would seem a logical one when the evidence shows that rotations were the quickest way of mining the soil by calling in several different crops in rapid sequence, each for its different and added exploitive effects".

There is yet another level of ecological complexity in agriculture that has tremendous potential on a decentralized scale, but which is yet to be fully explored. This is the idea of the polyculture farm. The concept is borrowed from practices of the rice-vegetable-fish-livestock economies of southern and eastern Asia. Adapted to current information about ecological principles and a holistic science, modern polyculture farms would link several artificial ecosystems in a balanced and relatively self-sufficient complex of renewable energy systems, mixed crops, aquaculture plus livestock, and insect husbandry (Fig. 7). At the present, several grassroots groups in America and Europe are investigating various ways to integrate renewable food and energy systems into endemic polyculture schemes.

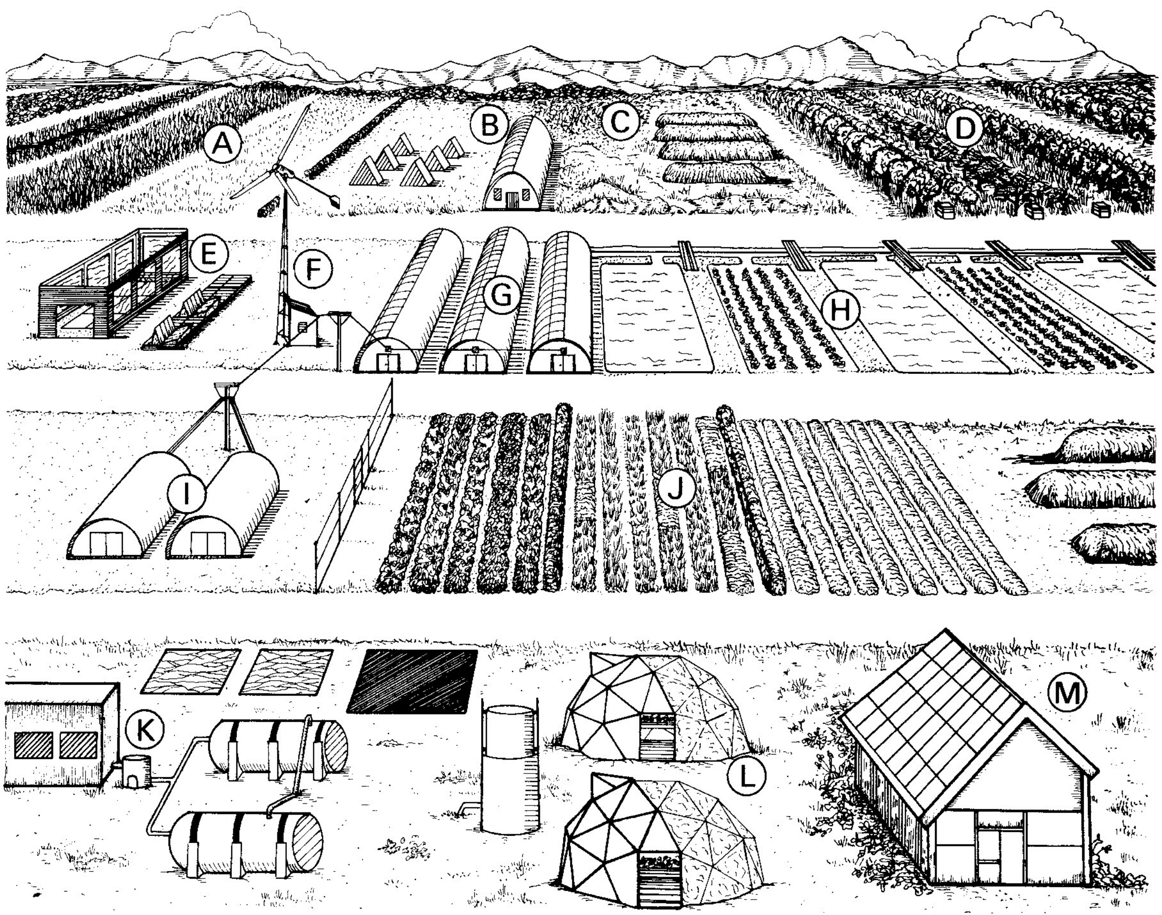


Fig. 7 An idealized polyculture farm and research center. A=Grains, green manure and forage crops. B=Solar grain-drying structures. C=Windrow compost piles on fallow section. D=Diverse, multi-storied orchards with undergrowth of refuge plants and green manure crops. E=Fish=food stocks; aquaculture insectary and worm cultures. F=Wind generator. G=Solar-heated Quonsets for rearing warm-water fishes and crustaceans. H=Outdoor fish ponds and row-crop fields. I=Agriculture insectary for rearing beneficial insects. J=Experimental vegetable/herb/flower/weed beds for investigating diverse cropping systems. K=Poultry shelter with methane digesters, sludge ponds and gas storage tanks. L=Dome-greenhouses. M=Solar-heated laboratory/homesite.

BACK TO THE LAND - FORTH TO THE LAND AND POST-INDUSTRIAL AGRICULTURE

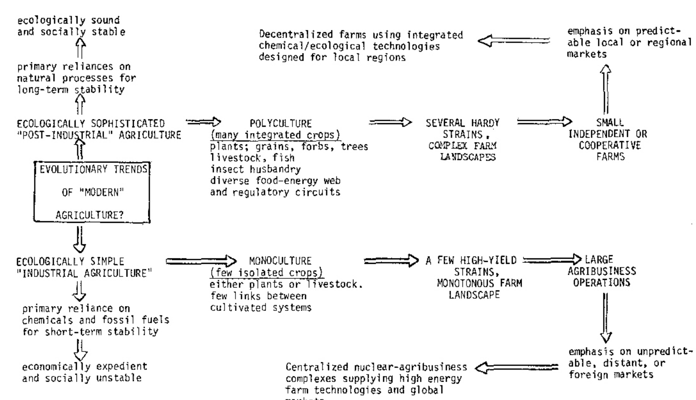
And so I believe that the Back to the Land idea is a long-term goal; no one now living will live to see it fully developed. It will be a long, slow movement... not, I hope, toward an Earthly paradise, urban or rural, but toward a new nativity of our people in the real world and in the scheme of things.

— *Wendell Berry*
The Long Way Back to the Land

Popular notions about agriculture in the future often depict great monoculture deserts, rows of high-rise livestock cages and antiseptic greenhouse complexes being nurtured by chemical robots and computers. But, as agriculture reaches its limits of space, resources and pollution, the course of agriculture will come to depend on the resolution of three fundamental issues:

1. The relationship between food production and energy. Agriculture has always depended on cheap energy: human labor, beasts of burden, or oil. As the world's fossil fuel reserves become scarce on a seller's market, industrial agriculture will be left with two alternatives... nuclear power and solar energy (meaning direct solar rays, wind generated by them and, indirectly, organic fuels). The use of nuclear energy in agriculture would accelerate the current monopoly of farmlands by corporations, industry and their esoteric technologies... it would take farming out of the hands of farmers once and for all. But the thought of radio-active wastes in the human food chain summons the hope that a solar energy technology for agriculture will return to agriculture its proper function... transforming mutation of the sun's power for human needs. Since solar energy is readily available and easily devised (compared to nuclear power) its application to farming practices will tend to keep agriculture in the hands of farmers and pace down the acceleration and monopoly of the high-energy farm factory. That is, a decentralized solar economy for agriculture would extend the role of the rural community from an independent social order and keep it from degenerating into a total extension of the industrial one.

2. The relationship between science and human needs. In recent years, conventional science has come under increasing attack for the moral implications of its basic inquiries and the long-term significance of its applied tools. There has been relatively little criticism of the agricultural sciences along these lines since the total external costs of modern farming practices are just beginning to surface with a broad impact. In light of these "costs" what is needed are ecological tools that keep farming productive and the economic incentives that make them practical. To do this, new questions have to be asked in the laboratories and, most importantly, in the fields. What are the long-term effects of farm chemicals on human health, and what are the options? How can diversified farms be integrated with adequate markets? How can renewable energy sources be integrated with crop production? Such questions reflect an agricultural science with a holistic and extended approach; that is a science which controls the questions being asked. Most likely new-farm research will be carried out at the local level, for local purposes. New models for a land-based agriculture are not apt to come from organized science, but from the ability of local groups to use their own kind of inquiry.



Evolutionary Trends of Modern Agriculture

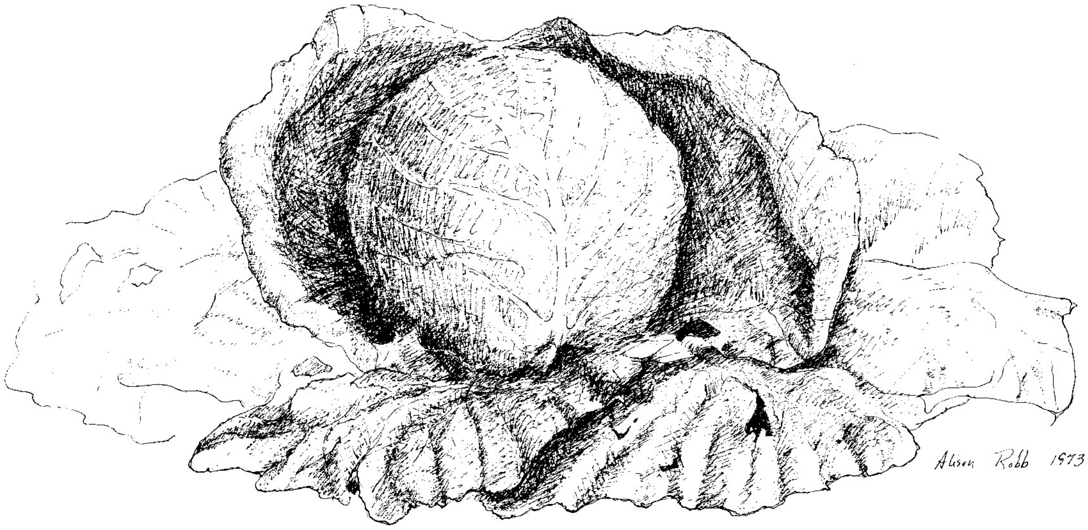
3. The relationship between people and land. During the last century, the United States has experienced one of the largest internal migrations in human history — from the farm to the city. But in our flight to convenience there is every indication that the changing relationship between people and land as well as the concentration of people into urban centers are at the heart of basic social problems. As a result, people are again looking to the land. In the 50's and 60's, a federal network of roads and reservoirs made it possible for people to retrace old trails to America's heartland with industry, recreation, second homes and retirement communities. But beyond this... way beyond... is the need to make productive land available to all people who wish to farm. Since 1967, the value of farmland has increased by nearly 80% and there is no end in sight. As long as there is speculation and land monopolies, agriculture will continue its course to the industrial state, and all visions of a self-sustaining agriculture will lie fallow in our hopes and dreams.

— *Richard Merrill*

REFERENCES CITED

1. Polanyi, Karl. 1944. The Great Transformation: The Political and Economic Origins of our Time. Beacon Press, Boston.
2. Sears, P. G. 1947. Deserts on the March. Univ. Oklahoma Press, Norman Okla.
3. Hyams, E. 1952. Soil and Civilization. Thames and Hudson, New York.
4. U. S. Department of Agriculture. 1971. Two-thirds of our Land: A National Inventory. SCS Program Aid 984.
5. U. S. Tariff Commission. Synthetic Organic Chemicals, U. S. Production and Sales, Washington, D. C., Annual Reports.
6. U. S. Department of Agriculture, *Agricultural Statistics.* Annual Reports, U. S. Gov. Print. Office, Washington, D. C.
7. U. S. Department of Agriculture. 1970. Quantities of pesticides used by farmers in 1966. USDA Economic Research Service, Agricultural Economic Report 179, Washington, D. C.
8. Environmental Protection Agency. 1972. The use of pesticides in suburban homes and gardens and their impact on the aquatic environment. Pesticide study series-2. EPA, Washington, D. C. (Super. Doc.).
9. U. S. Department of Agriculture. 1968. Extent of farm pesticide use on crops in 1966. USDA Economic Research Service, Agricultural Economic Report 147, Washington, D. C.
10. Cohen, J. & C. Pinkerton. 1966. Widespread translocation of pesticides by air transport and rain-out. *In:* Organic Pesticides in the Environment. Amer. Chem. Soc. Advan. Chem., Ser. 60:163-176.
11. Weaver, L., C. G. Gunnerson, A. W. Breidenbach and J. J. Lichtenberg. 1965. Chlorinated hydrocarbon pesticides in major U. S. river basins. Public Rep. 80:481-493.
12. Anderson, R. J. 1963. Statement of R. J. Anderson, Chief, Bureau of State Services, Public Health Service. *In* Interagency Coordination in Environmental Hazards (Pesticides). Hearings Part 3. U. S. Gov. Printing Office, Wash., D. C.
13. Rudd, R. L. 1971. Pesticides in the Environment. *In* Environment: Resources, Pollution and Society. W. W. Murdoch (ed.) Sinauer Assoc., Inc., Stamford, Conn.
14. Pramer, D. 1971. The soil transforms environment. Environment, 13(4): 42-46.
15. Hayes, W. J. 1960. Pesticides in relation to public health. Ann. Rev. Entomol. 5:379-404.
16. United States Dept. Health Education and Welfare. 1969. Report of the Secretary's Commission on Pesticides and their relationship to environmental health. (Mrak Report). USD HEW, U. S. Gov. Printing Office, Washington, D. C.
17. Bisland, Morton. 1953. Public health aspects of the new insecticides. Amer. Jour. Dig. Dis., Nov. 1953, pgs. 331-341
18. Fiserova-Bergerova, V., J. L. Radonski, J. E. Davies and J. H. Davies. 1967. Levels of chlorinated hydrocarbon pesticides in human tissue. Ind. Med. Surg. 36(65).
19. Committee on Labor and Public Welfare. 1970. Hearings before the subcommittee on migratory labor, parts 6A-C, Pesticides and the farm worker. U. S. Gov. Printing Office, Washington, D. C.
20. Boyd, E. M. 1972. Protein deficiency and protein toxicity. Charles Thomas Publishers, Springfield, Ill.
21. Cope, O. B. 1971. Interactions between pesticides and wildlife. Ann. Rev. Ent. 16:325-364.
22. Edwards, C. A. 1973. Environmental pollution by pesticides. Plenum Publ. Corp., N. Y.
23. Martin, E. C. and S. E. McGregor. 1973. Changing trends in insect pollination of commercial crops. Ann. Rev. Entomol. 18:207-226.
24. Todd, F. E. & C. B. Reed. 1969. Pollen Gathering of honey bee reduced by pesticide sprays. J. Econ. Ent. 62(4): 865-867.
25. Barre, H. G. 1968. The effects of an acute insecticide stress on a semi-enclosed grassland ecosystem. Ecology 49:1019-1035.
26. Helling, C. S., P. C. Kearney & M. Alexander. 1971. Behavior of Pesticides in soil. Adv. Agron. 23: 147-240.
27. Krasil'nikov, N. A. 1958. Soil Microorganisms and Higher Plants. Academy of Sciences, USSR. from: Office of Technical Services, US Dept. Commerce, Washington, D. C.
28. Kreutzer, W. 1963. Selective toxicity of chemicals to soil microorganisms. Ann. Rev. Phytopath. 1:101-126.
29. Georghiou, G. P. 1972. The evolution of resistance to pesticides. Ann. Rev. Ecol. Syst. 3:133-168.
30. Huffaker, C. B., M. van de Vrie and J. A. McMurty. 1970. Ecology of tetranychid mites and their natural enemies. A review II. Tetranychid populations and their possible control by predators. Hilgardia 40:391-458.
31. United States Department Agriculture. 1965. Losses in Agriculture. Agric. handbook 291.
32. von Liebig, J. 1840. Organic chemistry in its application to agriculture and physiology. Taylor and Walton, London.
33. U. S. Department of Agriculture. Fertilizer Situation. Economic Research Service. Annual report, 1971-1973.
34. Ibach, D. B. 1966. Fertilizer use in the United States -- economic position and outlook. U.S.D.A. Econ. Rep. No. 92
35. Tennessee Valley Authority. 1972. Fertilizer trends, 1971. National fertilizer development center, Muscle Shoals, Ala.
36. Humphrey, H. Fertilizer crisis presents latest threat to farm production. Congressional Record, vol. 119, No. 134. Sept. 17, 1973, S16625.
37. Nelson, Lewis B. 1965. Advances in Fertilizers. Adv. Agron. 17.
38. Delwiche, C. C. 1970. The nitrogen cycle. *In* The Biosphere, Scientific American, W. H. Freeman & Co., San Francisco.
39. Wright, M. J. and K. L. Davison. 1964. Nitrate accumulation in crops and nitrate poisoning in animals. Adv. Agron. 16:197-247.
40. Walters, H. 1970. Nitrate in soil, plants and animals. J. Soil Assoc., U. K. 16(3): 1-22.
41. Lijinsky, W. and S. S. Eptstein. 1970. Nitrosamines as environmental carcinogens. Nature, 225:21.
42. Common compounds linked to cancer. Jour. Amer. Med. Assoc. May 17, 1971, 216(7): 1106.
43. Harmeson, R. H., F. W. Sollo and T. E. Larson. 1971. The nitrate situation in Illinois. J. Amer. Water Works Assoc. 63:303-310.
44. Bingham, F. T., S. Davis & E. Shade. 1971. Water relations, salt balance, and nitrate leaching loss of a 960-acre citrus watershed. Soil Sci. 112:410-418.
45. Kohl, D. H., G. B. Shearer and B. Commoner. 1971. Fertilizer nitrogen: Contribution to nitrate in surface water in a corn belt watershed. Science 174:1331-1334.
46. Viets, F. G. & R. H. Hageman. 1971. Factors affecting the accumulation of nitrate in soil, water and plants. U. S. Dept. Agri., Agr. Res. Serv., Agr. Handbook No. 413.
47. National Academy of Sciences. 1972. Genetic Vulnerability of major crops. NAS, Washington, D. C. (Gov. Printing Office)
48. Mistric, W. J. 1968. Effects of nitrogen fertilization on cotton under boll weevil attack in North Carolina. J. Econ. Ent. 61(1):282-283.
49. Walters, H. 1970. Aspects of the use of organic and inorganic fertilizers. Journ. Soil. Assoc., U. K. April 1970.
50. Beck, S. 1965. Resistance of plants to insects. Annual Rev. Entomol. 10:207-232.
51. Harlan, J. R. 1972. Genetics of disaster. J. Environ. Quality 1(3): 212-215.
52. Hirst, Eric. 1973. Energy Use for food in the United States, Natural Science Foundation Environmental Program, Oak Ridge, Tenn.
53. Pimentel, D., L. E. Hurd, A. C. Bellotti, M. H. Forester, I. N. Oka, O. D. Sholes and R. J. Whitman. 1973. Food production and the energy crisis. Science, 182:443-449.
54. Cervinka, V., W. J. Chancellor, R. J. Coffelt, R. G. Curley and J. B. Dobie. 1974. Energy requirements for agriculture in California. California Department of Food and Agriculture, Sacramento, Calif. (with University of California, Davis.)
55. Blaxter, K. 1974. Power and agricultural revolution. New Scientist, 61(885):400-403, 14 Feb., 1974.
56. Black, J. N. 1971. Energy relations in crop production-- a preliminary survey. Annals Appl. Biol. 67(2): 272-278.
57. Slesser, M. 1973. Energy analysis in policy making. New Scientist, 60 (870): 328:330, 1 Nov., 1973.
58. NATIONAL ACADEMY OF SCIENCES. 1972. Report of the committee advisory to the U. S. Department of Agriculture PE 21338, PE 21339, from National Technical Information Service, Springfield, Virginia.
59. Levins, R. 1973. Fundamental and Applied Research in Agriculture. Science. 181 (4099): 523-524.
60. Pimentel, D. 1969. Animal populations, plant host resistance and environmental control. *In* TALL TIMBERS CONFERENCE on Ecological Animal Control by Habitat Management. I. Tall Timbers Research Station, Tallahassee, Florida.
61. Dempster, J. P. & T. H. Coaker. 1972. Diversification of crop ecosystems as a means of controlling pests. British Ecological Society, Symposium, Oxford.
62. Pimentel, D. 1961. Species diversity and insect population outbreaks. Ann. Ent. Soc. Amer. 54: 76-86.
63. Root, R. B. 1973. Organization of a plant-arthropod association in simple and diverse habitats: the fauna of collards *(Brassica oleracea).* Ecol. Monogr. 43: 95-124.
64. Anderson, L. L. 1972. Energy potential from organic wastes: A review of the quantities and sources, Bureau of Mines, Information Circular, 8549, U. S. Department of the Interior, Washington, D. C.
65. U. S. Department of Agriculture. 1968, 1969. Consumption of commercial fertilizers in the United States. Statistical Reporting Service, USDA, Washington, D. C.
66. McGauhery, P. H. 1971. American composting concepts. Environmental Protection Agency, Solid Waste Management Office Publication, SW-2r, U. S. Government Printing Office, Washington, D. C.
67. Breidenbach, A. W. 1971. Composting of municipal solid wastes in the United States. Environmental Protection Agency. Solid Waste Management Series Publication, SW-47r, U. S. Government Printing Office, Washington, D. C.
68. Golueke, C. 1973. COMPOSTING. Rodale Press, Emmaus, Pennsylvania.
69. Frankel, O. H. and E. Bennett (ed.) 1970. Genetic resources in plants — their exploration and conservation. F. A. Davis Co., Philadelphia.
70. Odum, H. T. 1971. Environment, Power and Society. Wiley Interscience, N. Y.
71. Leius, K. 1960. Attractiveness of different foods and flowers to the adults of some hymenopterous parasites. Can. Ent. 92: 369-76.
72. Tobias, V. I. 1959. Some questions concerning biology of adult hymenopterous parasites in connection with complementary feeding on flowering plants. Proc. Unit. Session—Problems of Biological Control, Kiev. 1958: 159-165. (In Russian).
73. Leius, K. 1967. Influence of wild flowers on parasitism of tent caterpillars and codling moth. Can. Ent. 99: 444-446.
74. Fraenkel, G. S. 1959. The raison d'etre of secondary plant substances. Science. 129: 1466-1470.
75. Tahvanainen, J. O. and R. Root. 1972. The influence of vegetational diversity of the population ecology of a specialized herbivore, *Phyllotreta cruciferae.* Coleoptera Oecologia (Berl) 10: 321-346.
76. Philbrick, H. and R. B. Gregg. 1966. Companion plants and how to use them. Devin-Adair Co., New York.
77. Stern, V. 1969. Interplanting alfalfa in cotton to control Lygus bug and other insect pests. *In:* Tall Timbers Conference on Ecological Animal Control by Habitat Management. Proceedings, No. 1: 55-69. Tall Timbers Research Station, Tallahassee, Florida.
78. van Embden, H. F. 1964. The role of uncultivated land in the biology of crop pests and beneficial insects. Scient. Hort. vol. 17.
79. Albrecht, W. A. 1958. Soil Fertility and Animal Health. Fred Hahue Printing Co., Webster City, Iowa.

New Alchemy Agricultural Research Report No. 1



A Preliminary Study of Resistance in Twenty Varieties of Cabbages to the Cabbage Worm Butterfly (*Pieris rapae*)

Background to the New Alchemy Agricultural Research

From its inception one of the long range goals of the Institute was to search for food crops including grains, vegetables and fruits that would be best adapted to an agriculture without poisons. We hoped one day to play a part in creating ecologically-inspired agricultures which would emulate nature, restore soils and be productive of nourishing foods.

To date we have had little opportunity to follow our agricultural plans. However, in 1972 and 1973, we organized a small research program to study companion planting and insect resistance in food crops which involved lay collaborators throughout the country working under our guidance. A "do-it-yourself" agricultural research manual was prepared by Richard Merrill and distributed to potential collaborators. We felt that only a widespread search for the best ways to farm or the finest food plants would reveal the answers we sought. The research manual, still available to those of you interested in garden research, allowed collaborators considerable leeway in determining the plants with which they wished to experiment. Unfortunately, when we tried to tally the results, we could form few conclusions, as a given crop or planting combination was rarely duplicated.

The initial failure of the program was our own. Although we had recommended focusing on cabbage varieties in the insect resistance study, we avoided being emphatic on this point, hoping that our fellow collaborators would be so numerous as to provide the sample sizes we needed to analyze the results. This was not the case, and we have learned that the "people as agricultural scientists" program must study initially only one or two quite specific problems and that the research should grow at a slower pace, one determined by our overcoming the pitfalls associated with learning to collaborate with people, often untrained, and situated from one side of the country to the other.

Because of these circumstances, we would like to confine our first agricultural report to our own findings in the New Alchemy East gardens. We carried out a small study to determine if there are any varieties of cabbage that are better adapted to fending off the pests under Cape Cod conditions. We also studied fourteen. varieties of lettuce, but found to our pleasure that all of them avoided serious damage by insects. Lettuce, grown in relatively small plots in close proximity to cabbages, seem to do well in our part of the country without the need for insecticides. Twenty varieties of cabbages comprised the insect resistance experiment reported here.

It is important to point out that I am not an experienced scientist or gardener, so that, in fact, I was playing a role not unlike our fellow collaborators in other parts of the country. I did, however, have access to scientists for tabulation of results and consultation as the study proceeded. I want to emphasize my newness to agricultural research so that others will feel encouraged to do likewise in their own backyards.

The Research Project: A Comparison of Insect Resistance in Twenty Varieties of Cabbages to the Imported Cabbage Butterfly, Pieris rapae

Although we originally planned to study the resistance of the various cabbage varieties to the gamut of cabbage pests in our area, in 1973 there was only one significant insect pest, namely, the imported cabbage butterfly *Pieris rapae.* The larval or caterpillar stages of the cabbage butterfly are notorious for the damage they inflict upon the crucifers including cabbages, collards, Brussels sprouts and broccoli. They are capable of consuming sizeable portions of the leaves and the developing heads of cabbages and other crucifer relatives. The cabbage butterfly worm is a major crop pest and therefore an appropriate subject for study.

There have been relatively few studies of the resistance of cabbage varieties to the cabbage butterfly. A notable exception is the work of Radcliff and Chapman (1965 and 1966) which is treated in a subsequent section.

It is appropriate at the outset to discuss the concept of insect resistance, about which there is so much misunderstanding. The term is frequently interpreted as meaning something precise, and an insect resistant variety of plant is often thought to be one that will not be damaged under any circumstances by a particular insect. But the actuality of the matter is very different and resistance is a relative term. Although resistance has a genetic or inheritable basis, it is often modified by environmental variables including weather, season, soils and so forth. The insect side of the coin is not necessarily stable either, and it is possible that some insects which are highly adaptive may change, and a resistant plant variety may at that point no longer be resistant to insect attack.

The very complexity of insect resistance necessitates definitions. The following are drawn from Reginald Painter's "Insect Resistance in Crop Plants" first published in 1951.

Insect Resistance: Some Definitions

Insect Resistance: Insect resistance is the relative amount of heritable qualities possessed by the plant

Photo by Alan L. Pearlman

which influence the ultimate degree of damage done by the insect. In practical agriculture it represents the ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level of insect population.

Highly Resistant Crop Variety: Is a variety which possesses qualities that result in little damage by a specific insect under a given set of conditions.

Low Level of Resistance: Is a variety that results in less damage or infestation by an insect when compared with non-resistant varieties, but which is not nearly as effective in combating pests under the same condition as a highly resistant variety.

Moderate Resistance: Moderate resistance is intermediate between the above.

Pseudoresistance: The apparent resistance is due to other factors which reduce pest damage and include:

1) Host Evasion: Some varieties evade insect injury by maturing before the pests are present in large numbers. If planted at a later date, they would be susceptible to attack.

2) Induced Resistance: This is resistance due to such factors as soil fertility and not due to genetic or "built in" factors.

3) Escape: Apparently some plants in field trials are known to escape infestation even when pests are present and damaging neighboring plants. Subsequent breeding tests have not indicated in these cases any resistant qualities. The actual cause of the "escape" in this case remains unknown.

Susceptibility: A susceptible variety is one which shows average or more than average damage by an insect.

High Susceptibility: A highly susceptible variety is one with much more than average damage caused by a given insect species.

Methods Used in the Study

NAI's experimental gardens are situated along the northwest edge of a ten-acre meadow which some years earlier was used as pasture for a dairy farm. The land is surrounded by a scrub oak-pine woods typical of many of the sandy soil areas on Cape Cod. The soils are generally acid, low in nutrients and relatively devoid of organic matter. The best soils on the farm are to be found in a depression, which was the area utilized for insect resistance research.

Prior to the experiments the plots were planted to a buckwheat crop which was turned under in the late summer. In the fall a mixed rye and hairy vetch crop was planted and rototilled into the soil the following spring. A layer of compost was applied, and the plots were limed with dolomite limestone before each crop, and again prior to the cabbage experiments.

The experimental area which comprised the study reported here was 85' by 50' and was bordered by marigolds, which were in flower throughout the latter two-thirds of the experiment. Neither adults nor larvae of the cabbage butterflies were observed to be attracted to or markedly influenced by the marigolds, however, the presence of these flowers may have been a factor in the absence of other pests.

Twenty varieties of cabbage (seventeen of the varieties from a single seed company, Twilley) were started indoors in four-hundred pots made of compressed peat (Jiffy Pot Co.) in a mixture of soil, farm compost, and "Earthrite", a biodynamic compost prepared by Zook and Rank Corporation. The upper layer of the pots in which three seeds of a given variety were placed was comprised of vermiculite. On May 20 the seedlings were placed in a coldframe and after the second pair of leaves appeared the two least vigorous plants from each pot were removed. On June 15 the cabbage plants were placed into the experimental garden.

Experimental Design

A randomized planting pattern was used for the study. Other methods (block designs) may be equally suitable and may entail less work in data collecting. For detailed discussion of experimental designs in agricultural research, see NAI's "The Agricultural Research Workbook for 1973: Insect Resistance and Companion Planting in Vegetable Crops" prepared by Richard Merrill.*

Fifteen plants of each of the twenty varieties were placed randomly in the experimental area. Five plants of each variety were held in reserve in the coldframe in case experimental plants were inadvertently damaged. Three hundred positions (equivalent to the number of plants) were delineated in the experimental area in rows 5' apart (running north and south) with 2½' between the positions within a row. Wooden markers were labeled as to variety and number (from one to fifteen) and placed in a box and scrambled. The position of each plant in the experimental area was determined by the drawing of the marker from the box. The cabbage plants were positioned sequentially beginning at one corner of the plot on the basis of the withdrawal of the markers.

Data Collection

During the coldframe period the following information was recorded: date of seeding, date and percentage of germination, weather and environmental variables

*The agricultural research workbook is available from NAI, Box 432, Woods Hole, Massachusetts 02543 for $1.00.

of particular note, and date of setting out.

In the experimental gardens, data was collected eight times from each plant through the period of the study. Included was:

1) Growth Information
   a. set of leaves
   b. time of heading
   c. comparison in size:
      i. head maturity
      ii. marketability
      iii. weight of the plant (at termination of experiment)
2) Condition of the Plant

Plants were compared on the following scale, based upon insect damage, health of the plant and a number of subjective factors which could be categorized as "appeal" of the plant for eating purposes.

   a. dead
   b. poor
   c. ok
   d. good
   e. excellent
3) Damage
   a. disease
   b. insect species
   c. density of eggs, larvae or adults depending on circumstances
   d. type of damage:
      i. sucking
      ii. chewing
      iii. wilting
   e. the amount of damage
   f. section of plant damaged

On the basis of the above, it was possible to denote the following categories into which the cabbages could be placed at the termination of the experiment.

Plant Categories

1) Marketable: those with
   a. a compact head
   b. minimum head weight of one pound
   c. very little or no damage to edible portion of the plant
2) Non-Marketable Plants:
   a. those that did not head
   b. head too small in size and weight
   c. head burst or split
   d. damaged by insects or diseases
   e. miscellaneous category in which some essential quality for marketability was lacking
3) Dead

Results of the Experiment

Germination rates in the coldframe were good with over ninety-five per cent germination in thirteen

Photo by Alan L. Pearlman

varieties, greater than eighty-five per cent in four and between forty-five and sixty per cent in the remaining three varieties. When the seedlings were first set out a number succumbed and needed replacing. The damage was mainly due to trampling by dogs and transplant errors. The cabbage butterfly worm was not a factor in these early mortalities.

The relationship between marketability of the cabbages and the presence of the larvae of the cabbage butterfly for all varieties considered together is illustrated in Table 1.

If the early mortality, not due to the cabbage worms, is subtracted from the total, the relationship between marketability and presence or absence of the cabbage worm becomes clearer (Table 2). Ninety-seven out of the total of one hundred and fifty-five marketable plants had cabbage worm populations, suggesting that when the data from all varieties is treated together the relationship between pest infestation and marketability is complex. More of the marketable plants had cabbage worms than those that were less marketable.

Table 1

The Relationship Between the Presence or Absence of Larvae of the Cabbage Butterfly and Marketability of the Cabbages. All twenty varieties are Treated Together.

Cabbages	No. of Plants With Cabbage Worms and Their Equivalent Percentages	No. of Plants Without Cabbage Worms and Their Equivalent Percentages	Totals
Marketable	97 = 32.33%	58 = 19.33%	155 = 51.66%
Non-Marketable	33 = 11%	43 = 14.33%	76 = 25.33%
Dead	16 = 5.33%	53 = 7.66%	69 = 23%
T o t a l s	146 = 48.66%	154 = 51.33%	300 = 100%

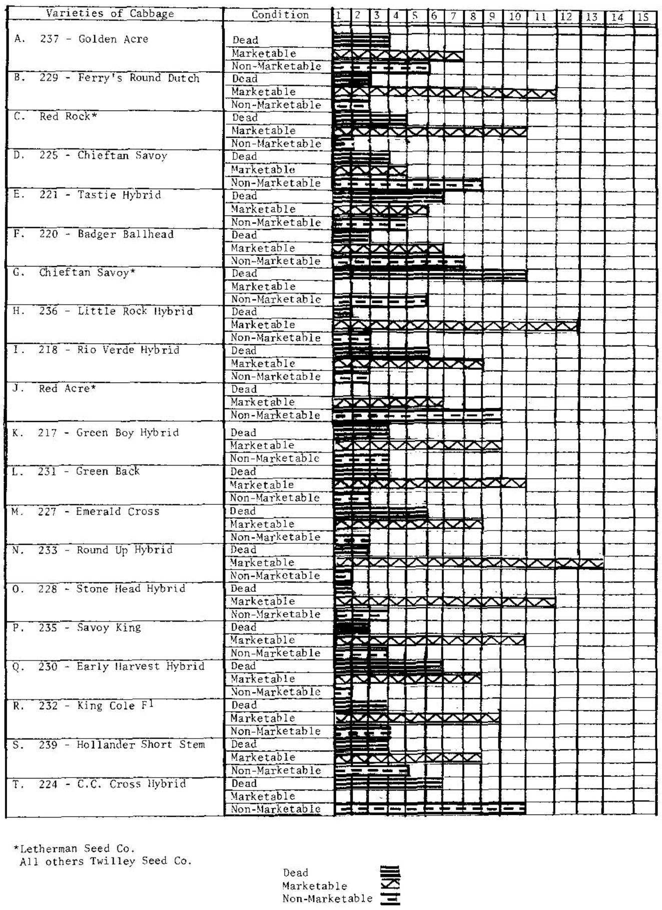
Table 2

The Relationship Between the Presence and Absence of Larvae of the Cabbage Butterfly and Marketability of the Cabbages, After Early Mortality Not Due to Cabbage Worms is Subtracted from the Total. Expressed in Percentages.

Cabbages	Percentage: With Worms	Percentage: Without Worms	Total
Marketable	42%	25.1%	67.1%
Non-Marketable	14.3%	18.6%	32.9%
T o t a l	56.3%	43.7%	100.0%

Figure 1

A Comparison of the Marketability of Twenty Cabbage Varieties. Seedling Mortalities are Also Shown.



A varietal comparison is presented in Fig. 1. Table 3 gives the varietal comparison coupled to the presence or absence of cabbage butterfly larval infestation. The preliminary evidence suggests that the number of worms and marketability may be related, with more worms on varieties with higher marketability. It should be added at this point that, while the total number of larvae per variety did not exceed twenty-eight individuals over the whole sampling period, an individual cabbage worm is capable, in some instances, of consuming the bulk of a cabbage plant as it matures. In most instances this is not the case as Fig. 1 and Table 3 show.

When the twenty varieties are compared and ranked in terms of marketability, they line up as is shown in Table 4a. Table 4b illustrates in percentages marketability ranking after early mortalities not due to the cabbage butterfly larvae are subtracted from the calculations. Table 4b more accurately reflects marketability ranking when one is considering the impact of the pest on the crop. Round-Up variety had the largest number of marketable plants.

Varieties are ranked in Table 5 according to their yields. Table 5a represents total production per variety, while 5b represents the average weights. Savoy King was the highest yielder, had the highest average weight and housed the largest pest population.

A preliminary ranking of the twenty cabbage varieties most suited to culture without insecticides in our area is denoted in Table 6. A simplified ranking system was employed, summing the ranks from Tables 4 and 5. It should be strongly emphasized, however, that variables unknown to us may have played an important factor in marketability and yield, consequently the following ranking is preliminary. As with all agricultural research, several years of careful experimentation are needed before definitive statements about

Table 3

Cabbage Varieties as Hosts to Larvae of the Cabbage Butterfly: A Comparison Between Marketability and Larval Populations. Larval Numbers Represent the Sum of Eight Larval Counts Per Variety.

Varieties of Cabbage	Marketable Plants Without Worms	Marketable Plants With Worms	1 Number of Worms	Non-Marketable Plants Without Worms	Non-Marketable Plants With Worms	2 Number of Worms	Dead Plants With Worms	3 Number of Worms	Totals of 1, 2 and 3
A. 237-Golden Acre	1	6	8	4	1	1	1	1	10
B. 229-Ferry's Round Dutch	4	7	14	0	2	3	1	1	18
C. Red Rock*	4	6	14	0	1	1	1	1	16
D. 225-Chieftan Savoy	3	1	2	5	3	3	1	1	6
E. 221-Tastie Hybrid	1	4	9	2	2	4	0	0	13
F. 220-Badger Ballhead	3	3	5	4	3	6	1	1	12
G. Chieftan Savoy*	0	0	0	3	2	3	0	0	3
H. 236-Little Rock Hybrid	5	7	15	1	1	1	0	0	16
I. 218-Rio Verde Hybrid	3	5	10	2	0	0	2	3	13
J. Red Acre*	1	5	6	5	4	7	0	0	13
K. 217-Green Boy Hybrid	5	4	8	2	1	1	1	1	10
L. 231-Green Back	6	4	8	1	1	1	0	0	9
M. 227-Emerald Cross	6	2	2	2	0	0	2	2	4
N. 233-Round Up Hybrid	7	6	10	1	0	0	0	0	10
O. 228-Stone Head Hybrid	5	6	11	2	1	2	1	1	14
P. 235-Savoy King	2	8	21	0	3	5	2	2	28
Q. 230-Early Harvest Hybrid	0	8	16	1	0	0	1	1	17
R. 232-King Cole F1	2	7	18	1	2	3	1	1	22
S. 239-Hollander Short Stem	0	8	16	2	2	2	0	0	18
T. 224-C.C. Cross Hybrid	0	0	0	5	4	5	1	1	6
Totals	58	97	192	43	33	48	16	17	257
	155			76					

*Letherman Seed Co.
All others Twilley Seed Co.

Table 4

Marketability Rankings

Table 4a

Cabbage Varieties Ranked as to Number of Marketable Plants (Maximum Possible = 15)

Variety	Number of Marketable Plants 15P/Variety	Worm Count
Round Up Hybrid	13	10
Little Rock Hybrid	12	16
Ferry's Round Dutch	11	18
Stone Head Hybrid	11	14
Savoy King	10	23
Red Rock*	10	16
Green Back	10	9
King Cole F[1]	9	22
Green Boy Hybrid	9	10
Hollander Short Stem	8	18
Early Harvest Hybrid	8	17
Rio Verde Hybrid	8	13
Emerald Cross	8	4
Golden Acre	7	10
Badger Ballhead	6	13
Red Acre*	6	13
Tastie Hybrid	5	13
Chieftan Savoy	4	6
C.C. Cross Hybrid	0	6
Chieftan Savoy*	0	3

*Letherman Seed Co.
All others Twilley Seed Company

Table 4b

Cabbage Varieties Ranked as to Percentage of Marketable Plants Minus Those Which Died Prior to Cabbage Butterfly Larvae Infestation

Variety	Percentage of Marketable Plants Minus Dead	Worm Count
Round Up Hybrid	92%	10
Red Rock*	90%	16
Early Harvest Hybrid	88%	17
Little Rock Hybrid	85%	16
Ferry's Round Dutch	84%	18
Green Back	83%	9
Emerald Cross	80%	4
Rio Verde Hybrid	80%	13
Stone Head Hybrid	78%	14
Savoy King	76%	28
King Cole F[1]	75%	22
Green Boy Hybrid	75%	10
Hollander Short Stem	66%	18
Badger Ballhead	60%	13
Golden Acre	58%	10
Tastie Hybrid	55%	13
Red Acre *	40%	13
Chieftan Savoy	33%	6
C.C. Cross Hybrid	0%	6
Chieftan Savoy*	0%	3

*Letherman Seed Co.
All others Twilley Seed Company

Table 5

Yield Rankings

Table 5a

Cabbage Varieties Ranked as to Weight of Marketable Plants

Variety	Total Marketable Weight lbs	oz	Worm Count
Savoy King	42	10	28
Round Up Hybrid	37	4	10
Little Rock Hybrid	30	14	16
Red Rock*	29	11	16
King Cole F[1]	27	4	9
Green Boy Hybrid	26	15	10
Ferry's Round Dutch	26	5	18
Rio Verde Hybrid	25	7	13
Stone Head Hybrid	20	10	14
Green Back	19	5	9
Hollander Short Stem	16	--	18
Golden Acre	15	15	10
Early Harvest Hybrid	15	12	17
Chieftan Savoy	11	--	6
Emerald Cross	10	2	4
Tastie Hybrid	8	14	13
Badger Ballhead	6	11	13
Red Acre*	4	14	13
C.C. Cross Hybrid		0	6
Chieftan Savoy*		0	3

*Letherman Seed Co.
All others Twilley Seed Company

Table 5b

Cabbage Varieties Ranked as to Average Weight of Marketable Plants

Variety	Average Marketable Weight lbs	oz	Worm Count
Savoy King	4	4	28
Red Rock*	3	11	16
Rio Verde Hybrid	3	10	13
Green Boy Hybrid	3	8	10
King Cole F[1]	3	--	22
Golden Acre	2	14	10
Round Up Hybrid	2	13	10
Chieftan Savoy	2	12	6
Little Rock Hybrid	2	3	16
Ferry's Round Dutch	2	6	18
Hollander Short Stem	2	--	18
Early Harvest Hybrid	1	15	17
Stone Head Hybrid	1	14	14
Green Back	1	14	9
Tastie Hybrid	1	12	13
Emerald Cross	1	4	4
Badger Ballhead	1	1	13
Red Acre*		13	13
C.C. Cross Hybrid		0	6
Chieftan Savoy*		0	3

*Letherman Seed Co.
All others Twilley Seed Company

Table 6
Preliminary Ranking of Cabbage Varieties Exposed to Cabbage Butterfly Larval Infestations. The Four Ranks from Tables 4 and 5 are Summed. Best Performers at the Top of the Scale.

CABBAGE VARIETIES					
Best		Intermediate		Poor	
Round Up		Ferry's Round Dutch		Chieftan Savoy	
Red Rock*		King Cole F^1	Identical Rank	Badger Ballhead	
Savoy King	Identical Rank	Rio Verde Hybrid	Identical Rank	Tastie Hybrid	
Little Rock Hybrid	Identical Rank	Green Boy Hybrid	Identical Rank	Red Acre*	
		Stone Head Hybrid		C.C. Cross Hybrid	Identical Rank
		Green Back		Chieftan Savoy*	Identical Rank
		Early Harvest Hybrid			
		Hollander Short Stem			
		Emerald Cross			

*Letherman Seed Co. All others Twilley Seed Co.

relative resistance can be made. We can say, however, that the best varieties listed in Table 6 performed well in our 1973 field trials.

I was interested in determining from the first year's results the biological relationships between the larvae of the cabbage butterfly and the marketability and yields of cabbages. Three correlations were tested for significance by the Spearman rank test (Siegel, 1956). The correlation between worm density and the number of marketable plants was suggestive ($P < 0.1$). Worm density was significantly correlated with percentage of marketable plants and with average marketable weight ($P < .05$ in both cases). It would appear that the larvae of the cabbage butterfly have a tendency to prefer the higher yielding and more marketable varieties we studied. This strongly suggests that cabbage butterfly resistance in cabbages is not some factor which causes the butterfly to avoid a resistant variety. The contrary seems true. Resistance seems to involve some ability on the part of the plant to head, mature and avoid destruction in the presence of feeding larvae.

Discussion

Radcliffe and Chapman (1965 and 1966) studied the resistance of sixteen varieties of cabbages to the worm of the cabbage butterfly. The study was carried out in Kenosha, Wisconsin, over a two-year period. The first year they used ten plants per variety and the second year fifteen. A complete comparison of the two studies is not possible for at least two reasons; firstly, only two varieties, Red Acre and Hollander, were common to the two studies; and secondly, Radcliffe and Chapman provided no yield or marketability information on the varieties they studied, despite Painter's (1951) definition of resistance as:

> "The ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level of insect population."

Instead Radcliffe and Chapman determined resistance exclusively on the basis of density of pest infestations, determining relative resistance by the numbers of cabbage worm larvae on a given variety. The varieties with the least numbers of worms were scored as the most resistant. Determined this way their findings are misleading, especially to practicing farmers who need resistance information based on yields and marketability. Radcliffe and Chapman ranked the Red Acre variety as one of the most resistant to the cabbage worm larvae, as it had a low infestation of worms. I also found that Red Acre had a relatively low worm count but ranked it as a poor variety because only forty per cent of the Red Acre plants were marketable and the yields were very poor, less than one-eighth that of the best yielding variety. Both studies showed that there were fewer pests on the Red Acre variety, but my work indicates that the few pests that were present were enough to affect severely production and marketability.

Acknowledgments

I should like to thank those who helped me with the study. Prof. E. O. Wilson at Harvard University and Prof. Richard Root at Cornell University introduced us to the literature on cabbages and their insect associations.

Dr. Woolcott Smith and Ms. Mary Power of the Woods Hole Oceanographic Institution assisted in interpreting the data and the statistical analysis.

Ms. Cynthia Knapp provided invaluable guidance on the preparation of the tables and figures.

Last, but not least, I should like to thank all the Alchies who helped me plant, transplant and count bugs.

- Hilde Atema

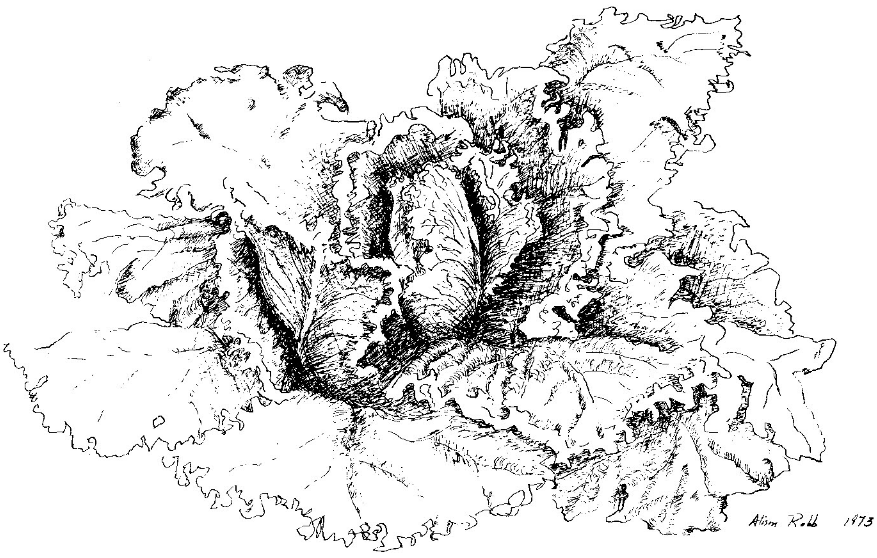
References

Painter, R. H. 1951. Insect Resistance in Crop Plants. The University of Kansas Press. 520 pp.

Radcliffe, E. B. and R. Keith Chapman. 1965. Seasonal Shifts in the Relative Resistance to Insect Attack of Eight Commercial Cabbage Varieties. Annals Entomological Society of America, Vol. 58: 892-902.

Radcliffe, E. B. and R. Keith Chapman. 1966. Plant Resistance to Insect Attack in Commercial Cabbage Varieties. Journal of Economic Entomology, Vol. 59(1): 116-120.

Siegel, S. 1956. Non-parametric statistics for the behavioral sciences. McGraw-Hill, New York.



A Brief Natural History of the Imported Cabbage Butterfly, *Pieris rapae*

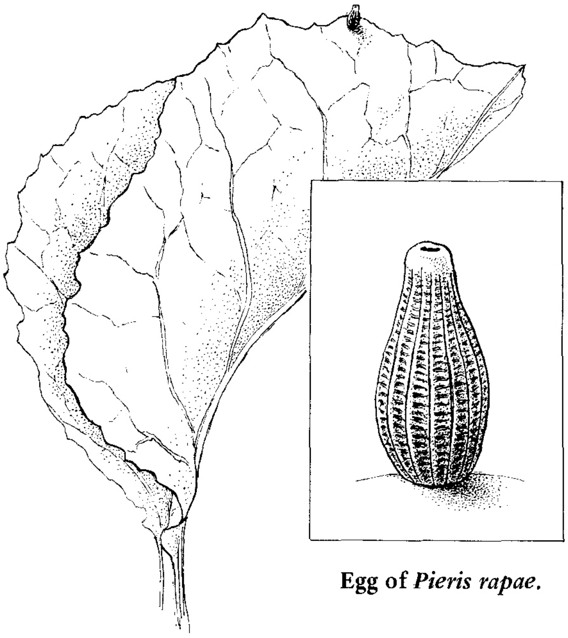
On a particularly warm day at the end of April, the first cabbage butterflies appear on New Alchemy's Cape Cod farm. In the spring sun they hover and flutter over patches of early winter cress, *Barbarea verna,* the first crucifer or mustard plant to flower in our area. The winter cress is an early season host for this notorious butterfly whose larvae are despised as a major pest of cultivated cabbages and their relatives. From spring to the first frosts, this black-dotted, white butterfly is very much with us and, while their larvae can and do damage our crops, we would be unhappy if this beautiful creature were to become absent from our gardens. They are a dance.... light and movement... and our insect resistance research is a way for us to accommodate ourselves to their presence.

The following is a brief description of the natural history of the imported cabbage butterfly, *Pieris rapae.* It is presented because we believe that stewardship must be preceded by learning as much as one can about the living world which sustains us. Most of the information comes from Richard's paper "The Biology of the Small White Butterfly" and Harcourt's "Biology of Cabbage Caterpillars in Eastern Ontario." These are supplemented by my own observations. The biology of this butterfly as given here is only an introduction; those who wish to glean more of the subtle relations between cabbage butterfly and the plants which influence them would do well to read Richard Root's outstanding, if somewhat awkwardly-titled, paper, "Organization of a Plant – Arthropod Association in Simple and Diverse Habitats: The Fauna of Collards (*Brassica oleracea*)" as well as other related scientific papers. The papers are not too difficult for the uninitiated, armed with an insect field guide and an elementary ecology text, to understand. You will discover within Root's ecological studies of food plants and their insects the first patterns of an adaptive agriculture.

Pieris rapae, the imported cabbage butterfly, originated in Eurasia and has appeared only within recent times in North America. The first known specimen was captured in 1860 by William Couper of Quebec. The species spread rapidly; within three years, it had become a serious pest within a forty-mile radius of Quebec city and by 1886 had reached as far as the Gulf of Mexico in the south, Hudson's Bay in the north and the valleys of the Rocky Mountains in the west.

The life cycle of the imported cabbage butterfly involves a complete metamorphosis through four stages: egg; caterpillar with five instars or molts; pupa; and butterfly or adult. In climates comparable to New England there are, on the average, four generations a year, with the last generation overwintering as dormant pupae. The pupae which overwinter emerge as adults during the month of May.

Pierid butterflies are good flyers. Migrations of *Pieris rapae* have been documented. It has been suggested that, at the beginning of a season, the adults present are those which have emerged from pupae within the immediate area, but, as the season proceeds, recruits are drawn in from outside. Late summer populations may include individuals who have migrated considerable distances.



Egg of *Pieris rapae.*

Egg

Pieris rapae eggs are attached by their bases to the underside of crucifer leaves. They are flask-shaped, about 1 mm long and 0.5 mm in diameter, and pale when first laid. Just before hatching they are a straw-yellow color. The female lays the eggs singly before moving on to another site. The number of eggs laid varies considerably. Estimates range from less than twenty to more than four hundred per female. Richard was not able to find any correlation between the abundance of eggs and the number of larvae or caterpillars.

The speed at which the egg hatches is temperature-dependent. Under laboratory conditions they have been shown to hatch in as little as two days at 32°C but may take as long as twenty-seven days at 7°C. During the summer the average egg hatches during a four to eight day period. Eggs are found on most members of the cabbage or crucifer family, but preferences between family members range widely. Cabbage, turnips, mustard, horseradish, bitter cress, broccoli, cauliflower and nasturtiums are common hosts, while shepherd's purse and wallflowers, amongst the crucifers, are avoided. Eggs are laid on sea kale, *Crambe maritima,* but apparently the larvae are unable to survive on a sea kale diet.

Larvae

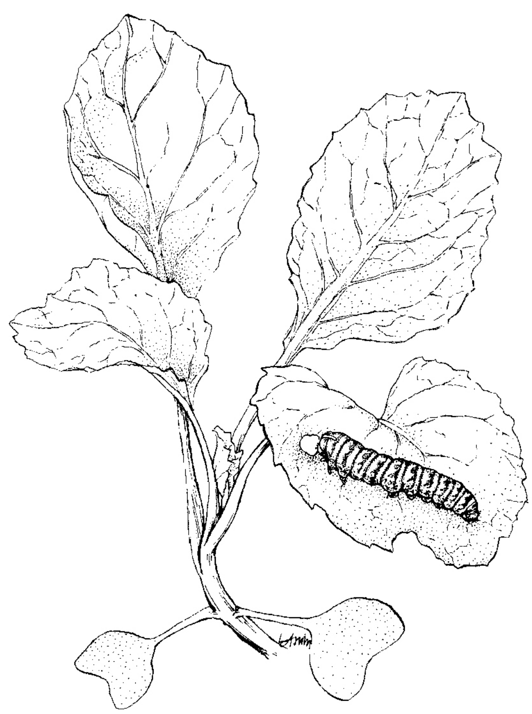
The larvae or caterpillars are cylindrical in shape. Their head and body are pale green with a lemon-colored stripe over the middle of the back. They blend exquisitely with the foliage of most crucifers and it takes a practiced eye to detect their presence. Often their location can be spotted by the presence of their greenish excrement or droppings.

As soon as the larvae emerge they begin feeding, remaining on the outer leaves of the plants during the first two instars (an instar is an intermolt period). During the third instar the larvae move inward towards the more central region of the plants. In the final two instars the caterpillars feed voraciously, gnawing big holes in the leaves and edible portions of plants such as the heads of cabbages. At this point their presence is readily detected by the mounds of droppings; however, in some instances they burrow so far into the head that their presence is almost impossible to detect, short of removing the head and cutting it open.

The first four instars pass in a brief period of between two and five days. The final instar may last up to fourteen days and, during this period, larvae may grow from 3.2 mm to 30 mm. A caterpillar will live for between 11 and 30 days before pupating. The lifespan is dependent upon food resources, while the climate remains the ultimate regulator of the life cycle.

Larvae have been known to migrate from their food plant to another plant upon which to pupate. This makes good sense for a food crop pest as it is adaptive for the population to have an alternative host. Crops are usually removed for transport to market and, if the pest population was removed with the crop each time, it would fall into hard times.

We have been unable to learn if larvae migrate from food plant to food plant in search of the tastiest variety. I observed that larvae, when removed from their host plant, were capable of returning over a short distance to the original plant; but I have no idea if they use this talent to move on to better



Young cabbage plant with caterpillar (*Pieris rapae*) feeding grounds. Larvae normally stay on the plant where they hatch until it is time to pupate, but it would be interesting to determine how fixed this behavior is. I can think of one possible instance when only one stage of larval migration might be of value. Red cabbage are not as attractive as green ones to the female butterfly; however, it has been determined that larval survival rates are higher on red cabbage, perhaps because of its higher nutrient levels which include vitamin C. It might make sense for a larva to migrate to red cabbages under certain circumstances. However, the low worm counts on our red varieties tend to support the traditional notion that larvae stay put until it is time to pupate.

The number of larvae depend upon many factors, including nutritional value and palatability of the food plant as well as its condition. The weather also has a profound influence and, during heavy rains, it has been found that the larvae often perish by drowning.

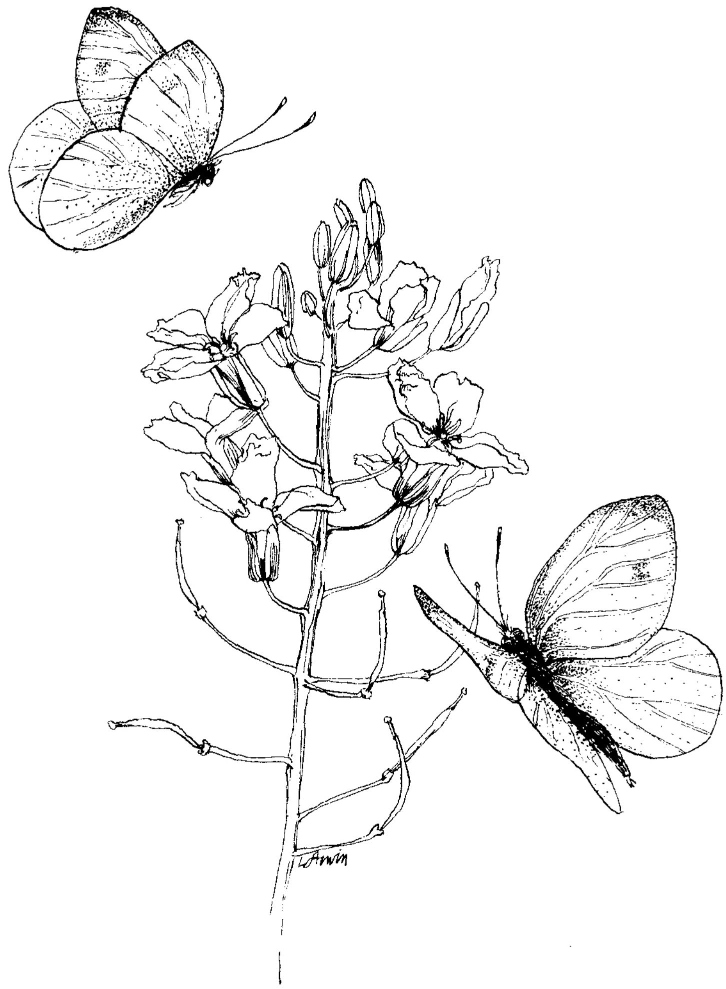
The worms of the cabbage butterfly do not suffer a large degree of predation due to their toxic body fluids. Birds, chiefly brown-headed cowbirds, song sparrows and redwing blackbirds, are known to eat cabbage worms, but to what extent has yet to be determined. Spiders may prey on the larvae, especially along the edge of cultivated areas where there are suitable spider habitats.

The larvae are parasitized by at least six species of insects with the most important cause of death, due to parasites, being caused by the braconid wasp, *Apanateles goleratus.* The female braconids lay their eggs in the first two larval instars of the cabbage worm and the parasitic larvae feed upon their insides. The satiated parasitic predators remain until the hosts spin their pupal mat. In most instances, the life cycle of the cabbage butterfly is interrupted at this point.

The caterpillars of the cabbage butterfly are killed in large numbers by a highly virulent granulosis disease and, in southern Ontario, mortalities due to the virus have ranged as high as ninety-four per cent. The presence of the disease can be spotted by the occurrence of dead and blackened larvae. The contents of their bodies ooze out over the leaves.

Pupae

The pupal stage of the cabbage butterfly is passed as a chrysalis, or naked pupa, which is attached to a spun cushion by hooklets. The head is beaked in front and the pupae measures 18 mm in length. Chrysalis blend subtly with their environment and range in color from pale green to speckled brown. They can be found on fence posts, outbuildings and stumps, as well as on a variety of host plants. It is difficult to determine the pupal densities because of this propensity to locate upon a diversity of plants and objects. *Pieris rapae* overwinter as pupae.



Cabbage butterflies around kale flowers in early season.

Butterfly

The male cabbage butterfly is white with a black spot in the middle of each forewing and a less prominent spot on each of the hindwings. The female is slightly larger than the male and is a creamy-white to yellow-buff color. There are two black spots on the forewings and one black spot on the hindwing.

Within twenty-four hours of emergence from the chrysalis, mating begins and is very soon followed by oviposition or egg laying. While in copula the female sits passively with her wings closed on the host plant waiting for a male. The males flutter from plant to plant and are attracted to the females by visual signals. Sexual odors or pheromones may also play a role in the mating behavior.

A female, over her approximately three-week life span, can lay up to four hundred eggs. Most are laid singly or on occasion in pairs. Egg laying is a fascinating act. The females hold on to the edge of the leaf and bend their abdomens around so that they can deposit their eggs on the underside of the leaf. After an egg is laid, she will fly and feed upon the nectar of flowers and the honeydew of aphids before repeating the process.

Courtship behavior occurs throughout the day during the warm summer months. Cabbage butterflies start flying about two hours after sunrise and their activity peaks at about noon. High temperatures and low wind velocities provide the optimal conditions for mating and on cold, rainy and windy days courtship slows or ceases.

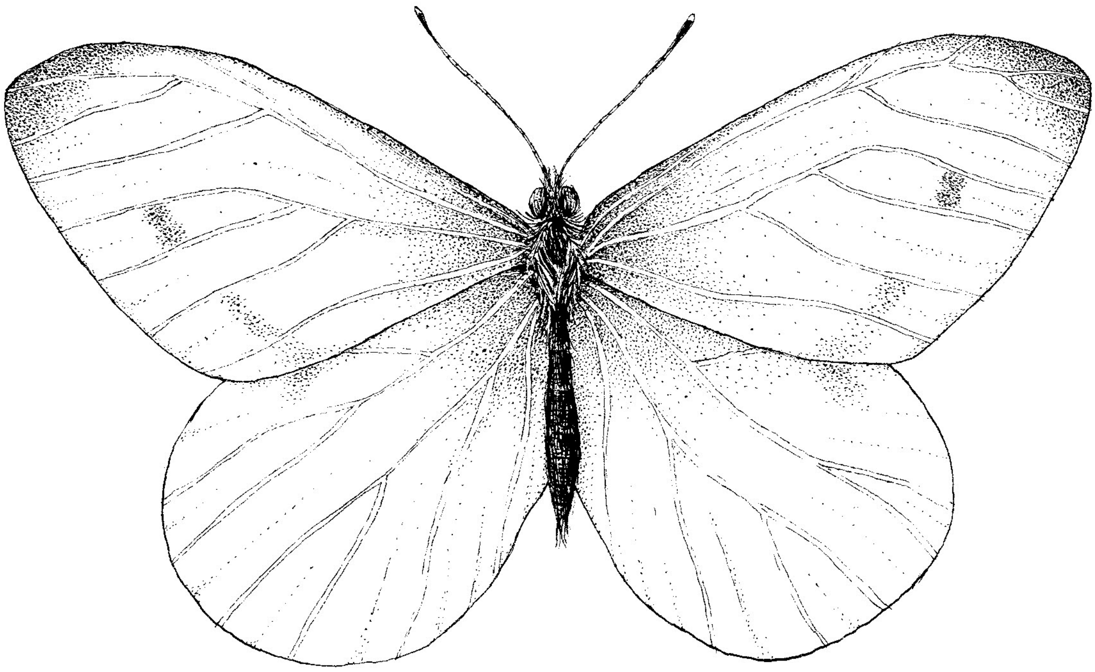
Our studies and observations upon the cabbage butterfly have helped to guide us in trying to learn a little about an agriculture which works in tune with nature. As we discover the delicate machinations of an insect and its host, we begin to admire the whole, and we are inspired to look for modes of growing foods within an ecological framework.

In our gardens, we should be growing those varieties that the cabbage butterflies survive upon, without destroying, or we should grow sea kale which the butterflies do not like. At the same time, we should let the wild crucifers flourish, so that we will be assured that the little white butterfly, with dots on the wings, will remain with us.

How then can the harvest fail?

—Hilde Atema

— Artist: *Leslie Arwin*



Adult of the *Pieris rapae.*

REFERENCES

Harcourt, D. C. 1963. Biology of Cabbage Caterpillars in Eastern Ontario. Proc. Entomological Soc. Ont. 93: 60-75.

Richard, O. W. 1942. The Biology of the Small White Butterfly *(Pieris rapae)*. Journ. Animal Ecology 9: 243-288.

Root, R. 1973. Organization of a Plant - Arthropod Association in Simple and Diverse Habitats: The Fauna of Collards *(Brassica oleracea)*. Ecological Monographs 43: 95-124.

Irrigation of Garden Vegetables with Fertile Fish Pond Water

Introduction

The use of fish pond water to irrigate vegetable crops is fairly widespread, particularly in the Orient, but there has been no systematic investigation of its effect on plants. In certain cases, fish pond water is used primarily because of convenience, but some agriculturists have made a conscious effort to irrigate with this source of nutrients, as opposed to unenriched water. The only mention of the practice in the literature (Potter, 1902) deals with the well-known farmer McGregor, who used fish pond water on his garden. Data as to McGregor's yields are not available, nor were controlled experiments carried out, but it is generally acknowledged that McGregor enjoyed considerable success.

In 1971 we decided to investigate in a systematic way the effect on plant growth of water enriched by fish. Lettuce and parsley were grown in fertile soil in flower pots. Half the pots were watered with tap water that had been allowed to stand for twenty-four hours to remove chlorine and had been brought to room temperature. The other half were watered with water from an aquarium containing a heavy algae bloom and a dense population of brown bullheads (*Ictalurus nebulosus*). Figure 1 illustrates two pots from this experiment. While the data from this pilot study were insufficient to justify statistical analysis, it certainly appeared that the fish tank water promoted growth of lettuce and parsley.

There are two possible ways in which aquarium water could enhance the growth of plants: Fish metabolites (and algae) could act as a fertilizer or they could retard evaporation, so that a greater percentage of aquarium than tap water is made available to the plants. Retardation of evaporation by fish was demonstrated by placing an aquarium containing brown bullheads beside a similar tank containing no fish. The water level in the fish tank dropped much less rapidly, apparently due to inhibition of evaporation by lipids.

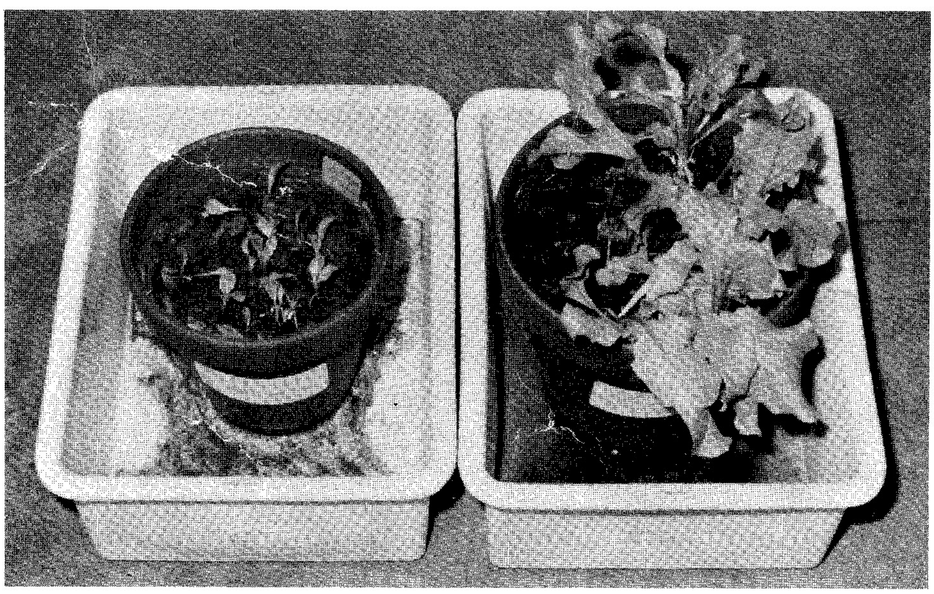


Fig. 1. The lettuce plants in the pot at the left were watered with tap water; the ones at the right, of the same age, were watered from a densely populated aquarium.

Methods

The informal pilot study just described was the inspiration for the controlled watering experiments carried out at New Alchemy's Cape Cod Farm in 1972 and 1973. The 1972 experiments in which zucchini and kale were used showed no significant differences in growth between plants watered with pond and tap water. However, the mean weight, minus roots and fruits, of both kale and zucchini was greater for plants watered with pond water. It was felt that the non-significance of the data was due to poor experimental design, and thus the experiment was rerun in 1973.

The 1973 study area was an oblong plot 102' x 16', on which were constructed three rows of twenty 3' x 3' raised hills. Half of the hills were watered with tap water and half with water from a highly fertile pond containing a dense population of fish (*Tilapia aurea, Tilapia zillii* and *Malacca hybrid tilapia*) and a heavy algae bloom. Three types of plant were selected for the experiment – a vine crop (Hybrid Zucchini, W. Atlee Burpee Co.), a root crop (Golden beets, Burpee) and a leaf crop (Bibb lettuce, Burpee). Location of each type of plant and the type of water applied to each hill were assigned on a random basis. The plot had been covered with a thin layer of compost the preceding fall and spring and was limed and rototilled before planting, but was otherwise untreated apart from the experimental watering.

Planting from seed was done on June 2. Prior to planting each hill was sprayed lightly with tap water to compact the soil slightly and promote the growth of natural microorganisms which might contribute to the stability of the hills. For the same reason, weeds, with the exception of tall, shading ones, were not removed from the sides of the hills, though the centers were kept weeded.

Lettuce seeds were scattered in the hills and the seedlings thinned to the four largest widely spaced plants on July 28. Beets were planted nine to a hill, evenly spaced, and thinned to the three largest plants on July 30. Zucchini were planted three to a hill and not thinned.

Watering was started on the day of planting and was carried out daily for the first week, after which it was cut back to twice a week. The amount of water applied was the same for all hills on any day, but the daily amount was determined empirically according to soil and weather conditions.

Results

Data were kept on rate of germination and the length of the longest leaf on each plant was measured periodically, but the only data which seem worthy of presentation are the harvest data. By far the most encouraging results were obtained with lettuce.

Harvesting of lettuce commenced when the first plant was seen to go to seed, on August 2. Subsequent harvests were made on August 5, 8 and 11. (Harvests were spaced to insure that the lettuce would be eaten, not wasted.) At each harvest the largest plant in each hill was selected unless there was serious crowding within the hill, in which case the plant which would best alleviate the crowding was removed. At each harvest the weight of edible material (total weight minus roots and dead leaves) was determined for each plant (Table 1 and Fig. 2). The mean edible weight of plants

MEAN EDIBLE WEIGHT OF BIBB LETTUCE WATERED WITH FISH POND WATER AND TAP WATER

Type of Water	Date	No. of plants	Mean Weight (g)
Pond	August 2	7	116.2
Tap	August 2	9	97.7
Pond	August 5	9	178.2
Tap	August 5	9	116.7
Pond	August 8	8	132.8
Tap	August 8	9	85.9
Pond	August 11	9	95.8
Tap	August 11	9	64.1
Pond	TOTAL	33	131.5
Tap	TOTAL	36	91.1

TABLE 1

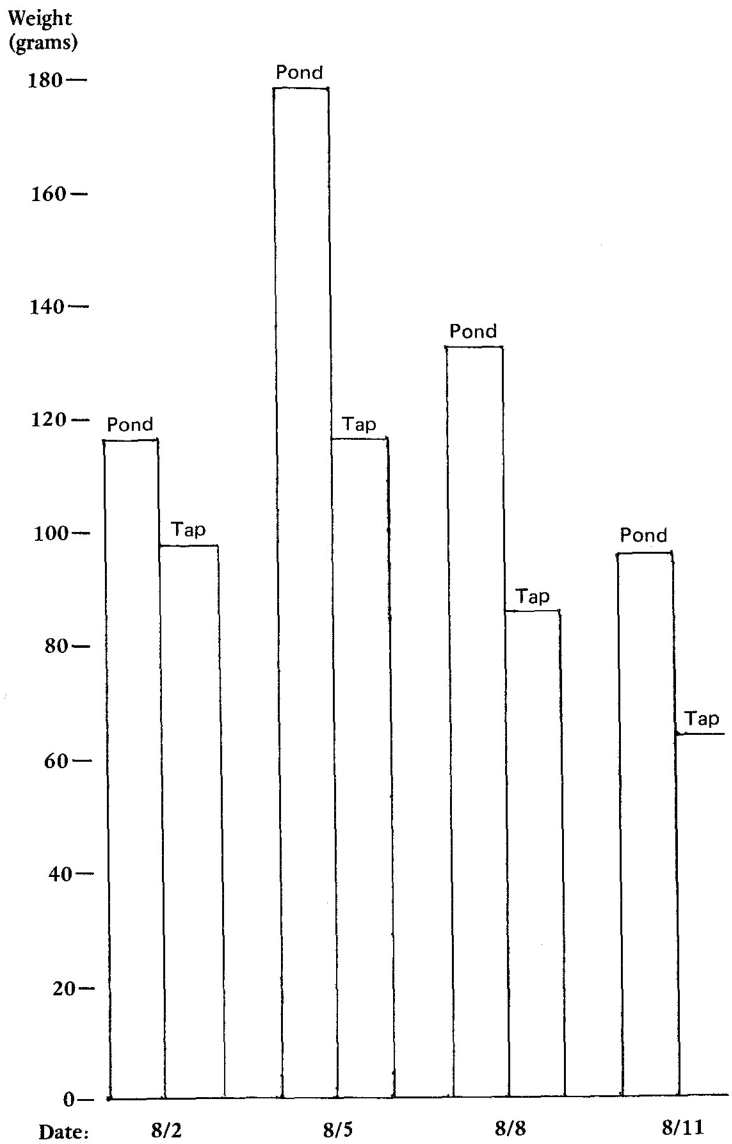


Fig. 2 – Mean edible weight of Bibb lettuce watered with fish pond water and tap water.

watered with pond water exceeded that of those watered with tap water by 44.3%. Due to the high variation in the weights of individual lettuce plants, an analysis of variance was not performed on the data. A non-parametric rank sum test (equivalent to the Mann-Whitney test) (Siegel, 1956) was carried out on the median weight of lettuce from each hill; the difference between the two treatments was significant at the 10% level and fell just short of significance at the 5% level.

The lettuce hills were replanted on August 10. For this late crop Grand Rapids (Greenhart Brand, Burpee) was the variety chosen. Planting and treatment were the same as before, except that the lettuce was thinned to five plants per hill, and on October 2 a temporary polyethylene greenhouse was constructed over the plot to protect against frost damage. On August 18 a second series of twenty hills (the hills originally planted to beets) were planted to lettuce. This was done to check the possibility that the lettuce hills randomly chosen to receive pond water were somehow more fertile, or otherwise more conducive to growth of lettuce, than those which received tap water. Harvest data for the Grand Rapids lettuce are given in Table 2 and Fig. 3. The greater weight of plants receiving pond water was more pronounced than in the Bibb lettuce. Mean edible weight of pond-watered plants exceeded that of tap-watered plants by 121.6% in the first planting and 67.9% in the second, or 90.9% overall. The data were analyzed

MEAN EDIBLE WEIGHT OF GRAND RAPIDS LETTUCE WATERED WITH FISH POND WATER AND TAP WATER

Type of water	Date	No. of plants	Mean weight (g)
Pond	October 29	9	21.0
Tap	October 29	10	14.1
Pond	October 31	10	23.3
Tap	October 31	10	16.1
Pond	November 2	10	27.0
Tap	November 2	10	9.6
Pond	November 4	10	26.4
Tap	November 4	10	6.4
Pond	November 6	10	15.4
Tap	November 6	9	4.1
Pond	TOTAL	49	22.6
Tap	TOTAL	49	10.2
Pond	November 8	10	26.2
Tap	November 8	10	20.7
Pond	November 9	10	27.8
Tap	November 9	10	16.9
Pond	November 10	9	27.8
Tap	November 10	10	14.1
Pond	November 11	9	21.6
Tap	November 11	9	10.2
Pond	November 12	8	12.2
Tap	November 12	8	6.4
Pond	TOTAL	46	23.5
Tap	TOTAL	47	14.0
Pond	GRAND TOTAL BOTH PLANTINGS	95	23.1
Tap	GRAND TOTAL BOTH PLANTINGS	96	12.1

TABLE 2

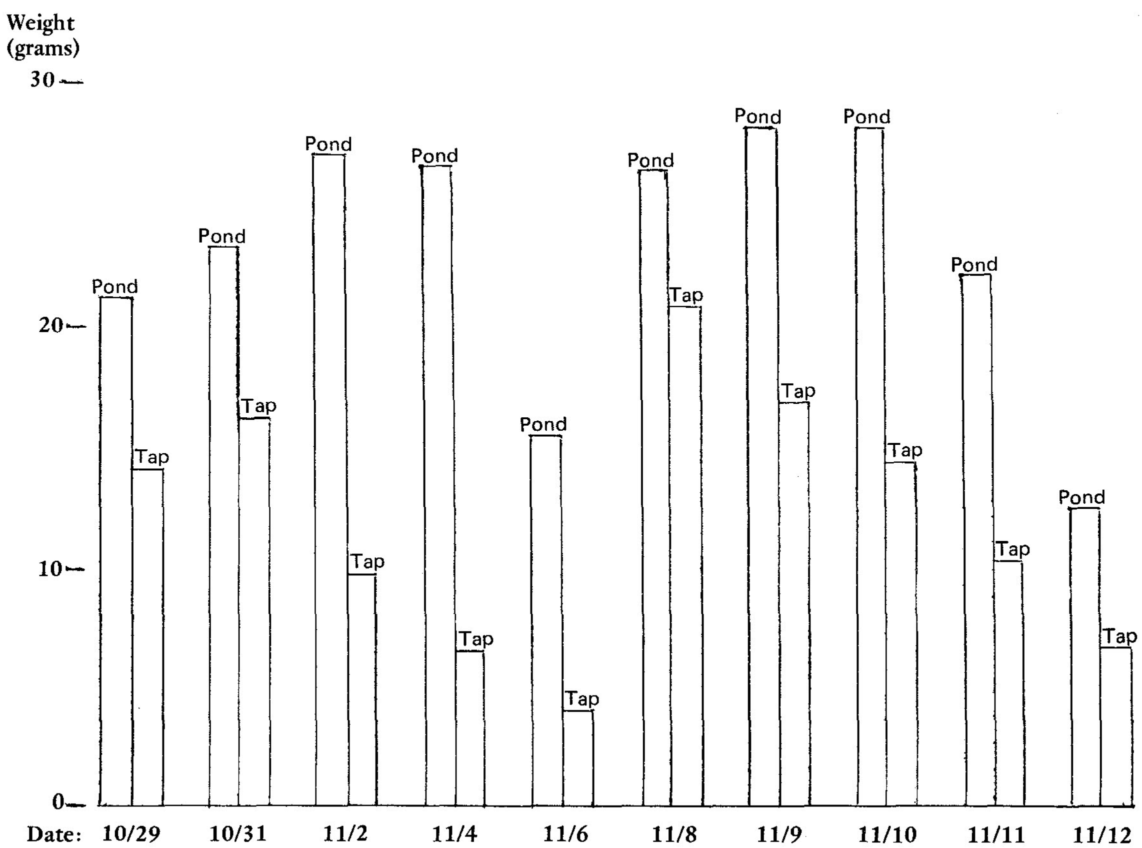


Fig. 3 — Mean edible weight of Grand Rapids lettuce watered with fish pond water and tap water.

WEIGHTS OF GOLDEN BEETS WATERED WITH FISH POND WATER AND TAP WATER

Type of Water	No. plants	Mean Weight (g) of tops	Mean Weight (g) of roots	Mean Weight (g) total	Ratio of Root:top
Pond	22	28.5	41.7	70.2	1.47:1
Tap	26	51.4	50.3	101.7	0.98:1

TABLE 3

as described for the Bibb lettuce. The difference in weight between treatments was significant at the 2.5% level for the first series. In the second series the results were similar to those for the Bibb lettuce. The difference was significant at the 10% level and barely missed being significant at the 5% level. When the data for the two series of Grand Rapids lettuce are combined, the results are significant at the 5% level.

The results achieved with the beets and zucchini do not parallel the lettuce data. Beets were harvested on August 15 and weight of roots and tops recorded (Table 3).

One might have expected the beets watered with pond water to have larger or proportionately larger tops; from Table 3 the opposite appears to be true. However, the differences shown were not statistically significant. To test the slight possibility that the non-significant differences observed in the beets were the result of some undetected difference between the beet hills randomly selected to receive tap water and those receiving pond water, the beet hills were used in the second planting of Grand Rapids lettuce (Table 2 and Fig. 3). The results of this planting favored pond water.

Zucchini fruits were checked daily and harvested as soon as they reach 180 mm. Due to the dense foliage a considerable number of zucchini fruits were overlooked for days at a time and harvested at a considerably larger size. On September 29 all the remaining zucchini plants were removed and total weight determined. Table 4 summarizes the zucchini data.

The apparent greater number of fruits and greater weight of vegetation in zucchinis watered with tap water is not significant and may be explained by the fact that, at the conclusion of the experiment, twenty-three of the original thirty tap water zucchini plants remained, but only eighteen of thirty which had received pond water. One of the chief causes of mortality in zucchini plants on Cape Cod is wind damage, which chiefly affects the larger plants. It may be that, had the zucchini plants been sheltered to protect against this selective destruction of large individuals, the pond water plants would have in fact exceeded the tap water plants in weight and fruit production.

FRUIT PRODUCTION AND WEIGHTS OF ZUCCHINIS WATERED WITH FISH POND WATER AND TAP WATER

Type of water	No. fruits (180 mm or more) harvested	Total weight (kg) (all fruits)	Mean weight (kg) (fruits between 180 and 250 mm only)	No. Plants at end of experiment (Sept. 29)	Mean weight (g) of whole plants
Pond	123	84.9	0.40	18	977.7
Tap	166	95.0	0.39	23	1103.2

TABLE 4

To provide another, and perhaps more meaningful, measure of production, the average weight of fruits was determined. Large fruits which had escaped detection for several days after reaching the minimum harvest size were not considered. The average weight of eighty-four fruits from plants which received pond water and one hundred and thirty-four fruits from tap water plants was virtually identical – 0.40 kg and 0.39 kg respectively.

Conclusions

Our results could perhaps be improved by repeating the experiment using paired hills rather than a randomized planting pattern. It would also be advisable to repeat our experiment with other leaf crops and to perform similar experiments with lettuce and other crops in a dry climate where watering is a more critical part of agricultural practice.

Acknowledging the need for more research should not impede the practical application of what has been learned. We have shown that the practice of watering with enriched fish pond water is not universally effective in increasing growth and production of garden vegetables, but we have also shown that it is effective with two varieties of lettuce. We tentatively conclude that it would be beneficial to most shallow-rooted, leaf crop vegetables, particularly those which, like lettuce, favor abundant moisture and high levels of nitrogen. It would certainly be worthwhile to further explore the technique described and other possible linkages of agriculture and aquaculture with the goal of developing new, highly productive, and ecologically-sound food-raising systems.

Acknowledgments

As usual at New Alchemy far more people assisted in the work than can be mentioned. I would like to acknowledge Rich Merrill and Shelly Henderson for their efforts in designing, setting up and carrying out the 1972 study. John Todd performed the pilot study which inspired my work and made valuable suggestions in the current study. Woolcott Smith assisted with the statistical analysis of the data.

– William O. McLarney

References Cited

Potter, B. 1902. *The Tale of Peter Rabbit.* Frederick Wayne and Co., London and New York.

Siegel, S. 1956. Non-parametric statistics for the behavioral sciences. McGraw-Hill, New York.

Aquaculture

Whether it was born of a desire to add an element of excitement to the daily rounds of caring for the fish or bred of scientific curiosity, the aquaculture program last summer was divided. One lot of fish, as in previous summers, was housed in a pond protected by a dome and administered to by Bill McLarney and Marc Sherman. John Todd and Earle Barnhart covered their pond with a low, flat-topped structure that they christened the Alter-Ego. Each team had its own opinions on diet on which they compared notes, rather like young mothers vying to see whose babies would be the first to get vegetables. The rest of us managed to remain somewhat impartial and so the rivalry never became too intense. At the final harvesting and weigh-in neither side, it turned out, could claim to have proved conclusively the superiority of its methods, as the total weights were very close. Competition aside, we had our best growing season so far, with tilapia reaching edible size in as short a period as ten weeks.

Three members of the aquaculture teams, John Todd, Bill McLarney and Earle Barnhart, have in the article entitled "Walton Two, A Compleat Guide To Backyard Fish Farming" set to paper their accumulated experience of three years of working with tilapia. It is, in essence, a working manual which provides all the information necessary for a reader to set up a system of his own. Many of us feel that our tilapia research has been, to date, our most valuable, offering techniques of self-sufficiency that have not been piloted elsewhere.

The second article in this section, Bill McLarney's report on his midges, describes two summers' work. Tilapia, although mainly vegetarian, are not exclusively so. They do need some animal protein, especially as fry. Bill has long felt that the culture of midge larvae might offer the simplest means of providing the animal protein. With the harvesting method that he has developed which is much less laborious than others, this may well prove to be so.

— NJT

Photo by Alan L. Pearlman

Photo by John Cressey

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 mankind'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 mankind 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

Illustrations by Earle Barnhart

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

Sir Izaak Walton, The Compleat Angler, 1653

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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.

McLarney, W. O. 1968. Spawning Habits and Morphological Variation in the Coast-range Sculpin, *Cottus aleuticus* and the Prickly Sculpin, *Cottus asper.* Trans. Amer. Fish. Soc. 97(1): 46-68.

** 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 22415: 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 stores. . . fraught with possibilities.

Thus we were inspired to delve into intensive fish culture. But the tropics of the Far East are far away 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

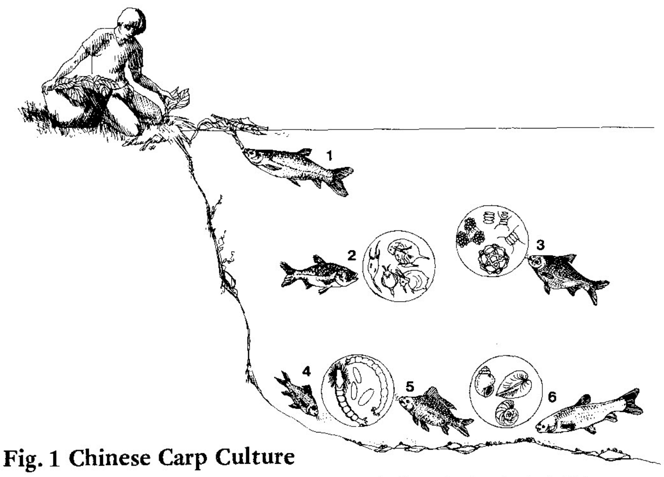


Fig. 1 Chinese Carp Culture

Habitat and feeding niches of the principal species in classical Chinese carp culture. (1) Grass carp (*Ctenopharyngodon idellus*) feeding on vegetable tops. (2) Big head (*Aristichtys nobilis*) feeding on zooplankton in midwater. (3) Silver carp (*Hypophthalmichtys molitrix*) feeding on phytoplankton in midwater. (4) Mud carp (*Cirrhinus molitorella*) 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 (*Mylopharyngodon 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 windmills 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.

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

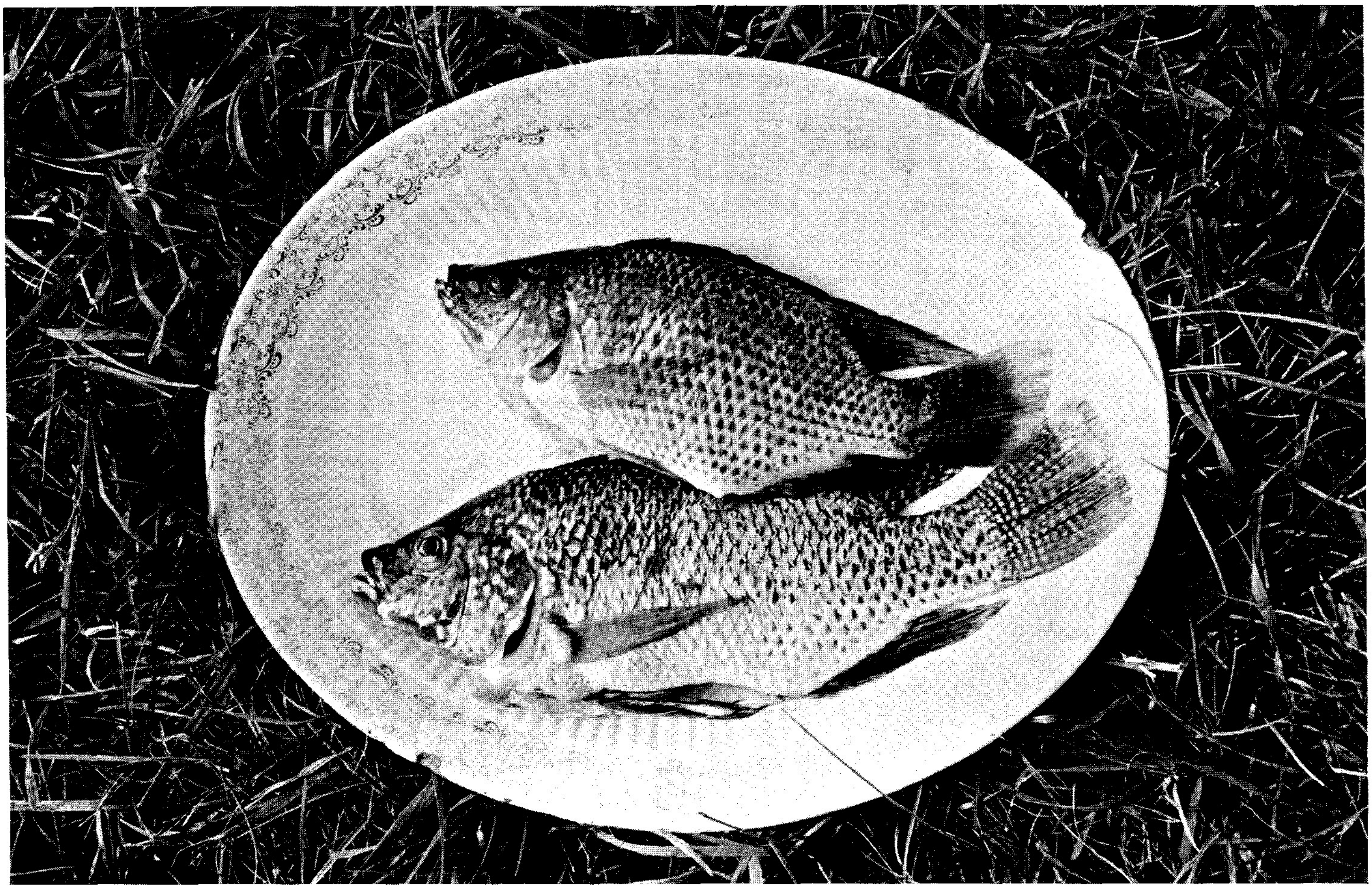


Photo 1 - *Tilapia* — *Photo by John Cressey*

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

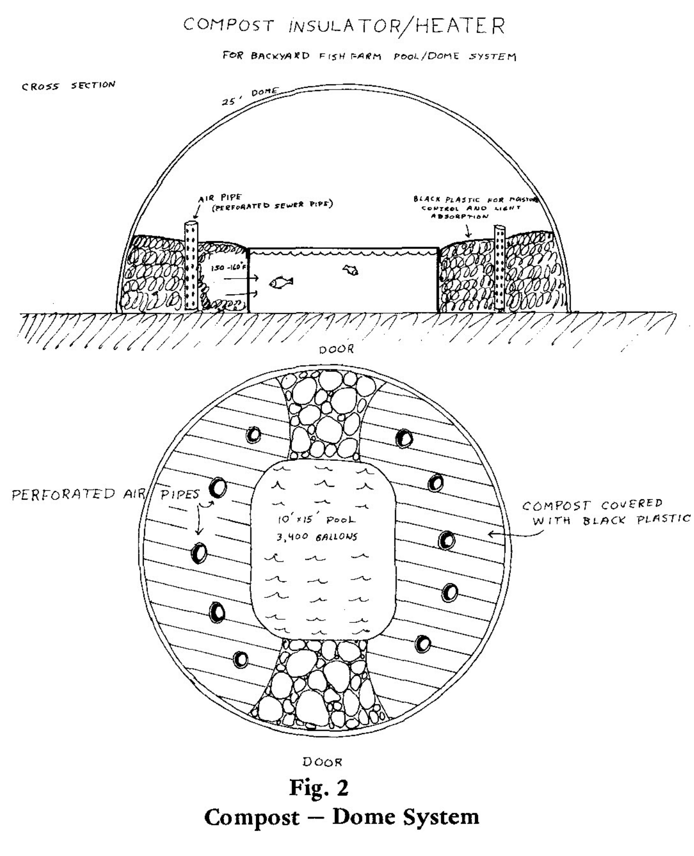


Fig. 2
Compost — Dome System

FALMOUTH, MASSACHUSETTS
MONTHLY AVERAGE MAXIMUM
& MINIMUM TEMPERATURES,
MONTHLY MEAN & PRECIPITATION
1973
Air Temperatures in Degrees Fahrenheit

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

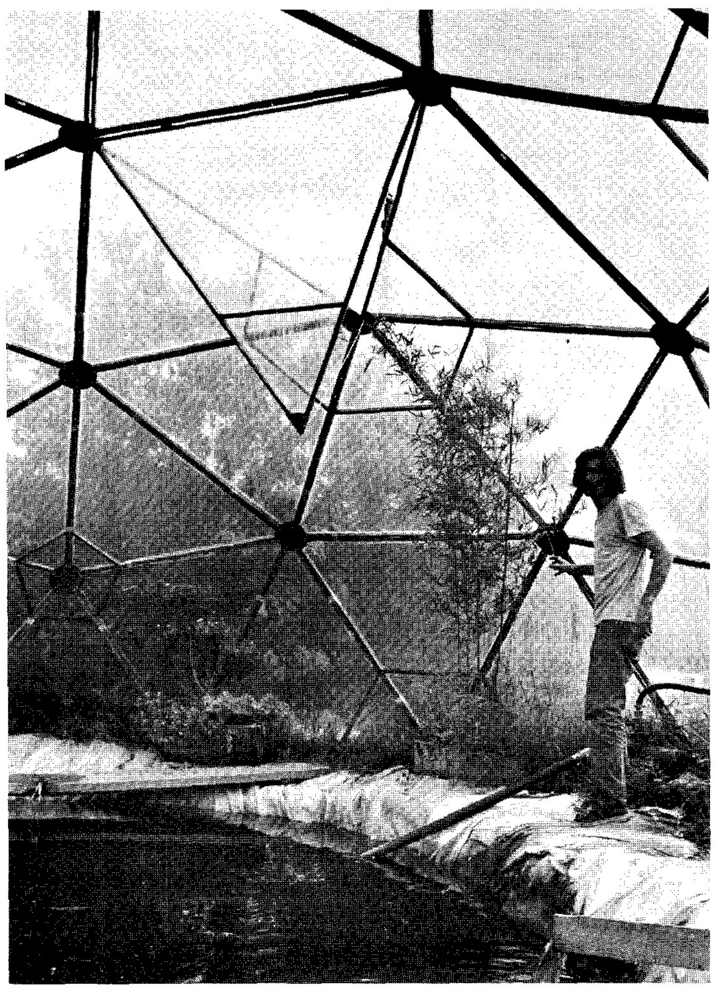


Photo 2 *Photo by Alan L. Pearlman*

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 Bucky 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

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.

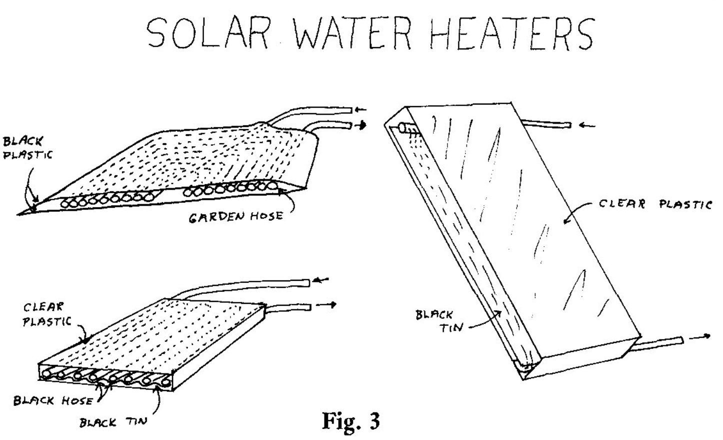


Fig. 3

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.

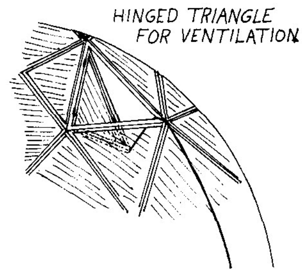


Fig. 4 — Ventilation

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

*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.

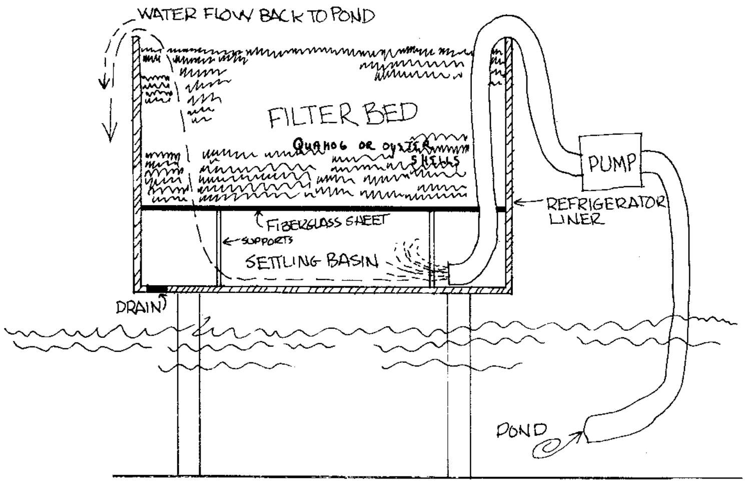


Fig. 5 – Filter

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 1¼" 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 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-

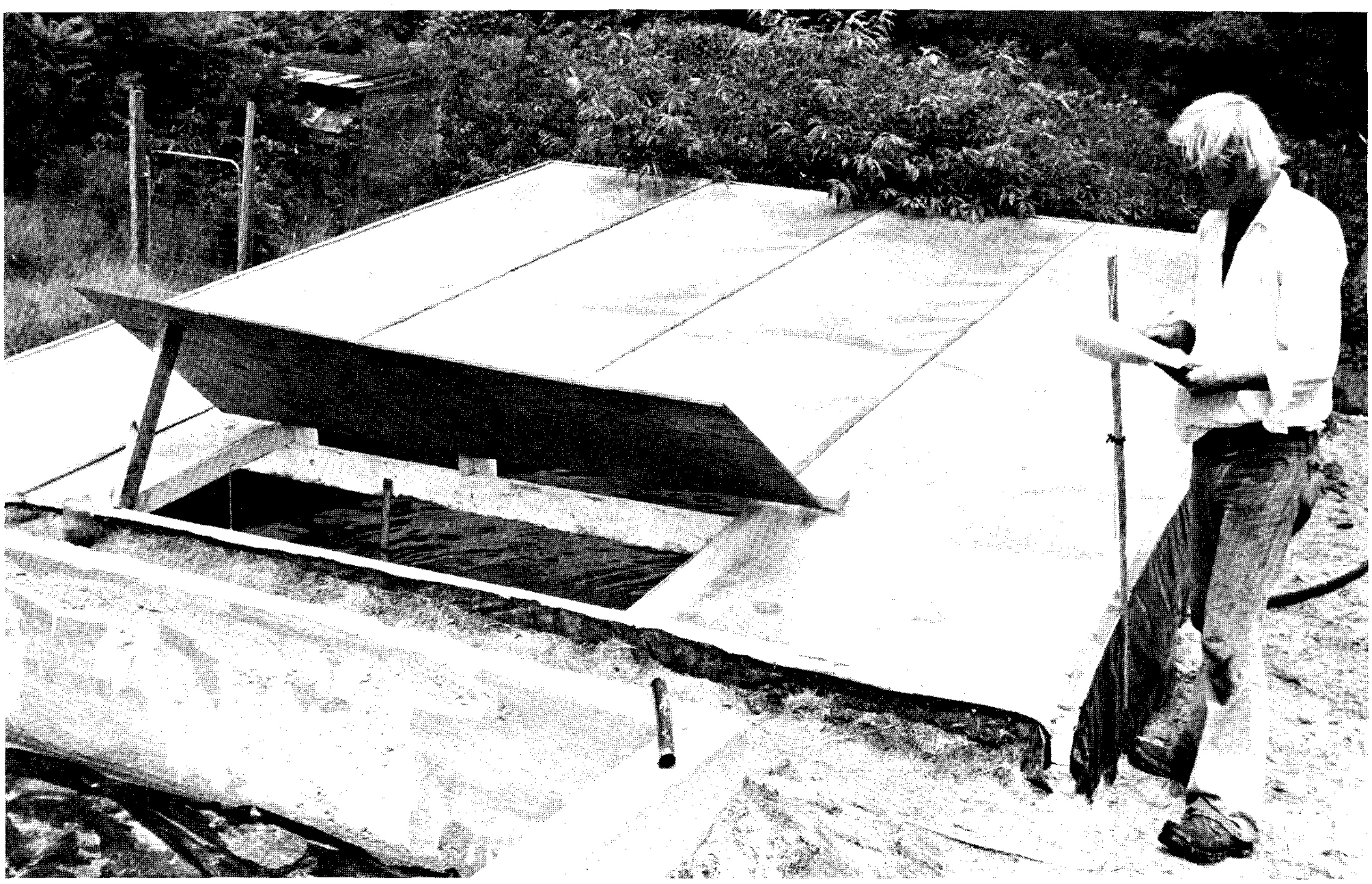
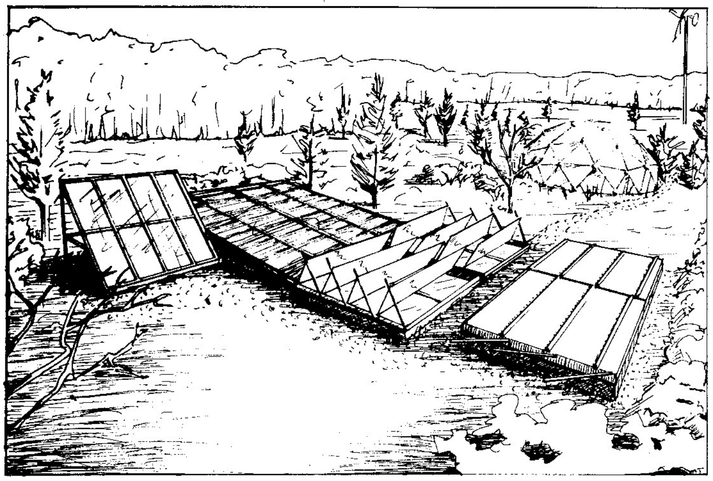


Photo 3 – Flat Top Backyard Fish Farm *Photo by Alan L. Pearlman*



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 centrigrade 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.

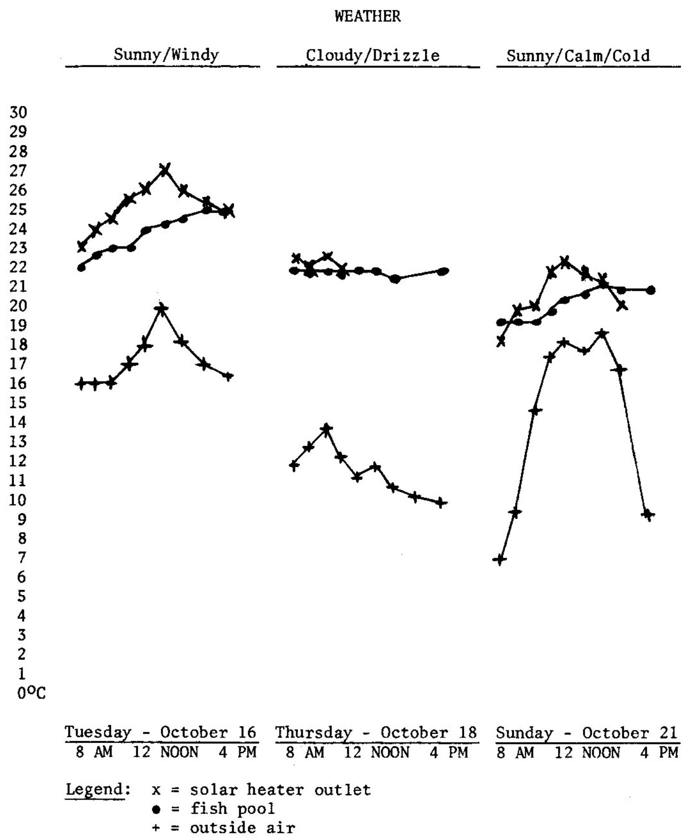
The growing season in the Dome with its internal umbrella was not quite as long as within the Flat Top. However, in more clement or sunnier parts of the country the choice between the Dome and Flat Top becomes a matter of taste. A double-skinned 2" x 4" x 30' dome might perform equally well or better. 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



Temperature Regime in 5,000 Gallon Solar Heated Aquaculture System During Differing Weather Conditions

Fig. 7

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)

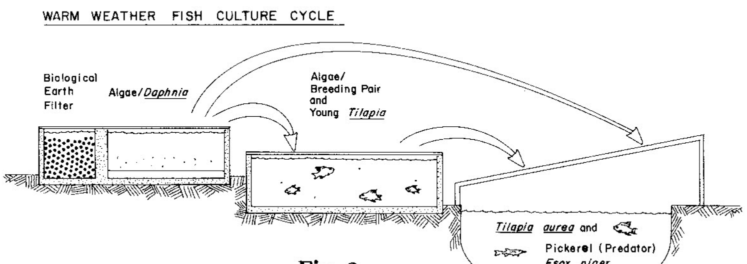


Fig. 8

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 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.

Photo 4 *Photo by John Cressey*

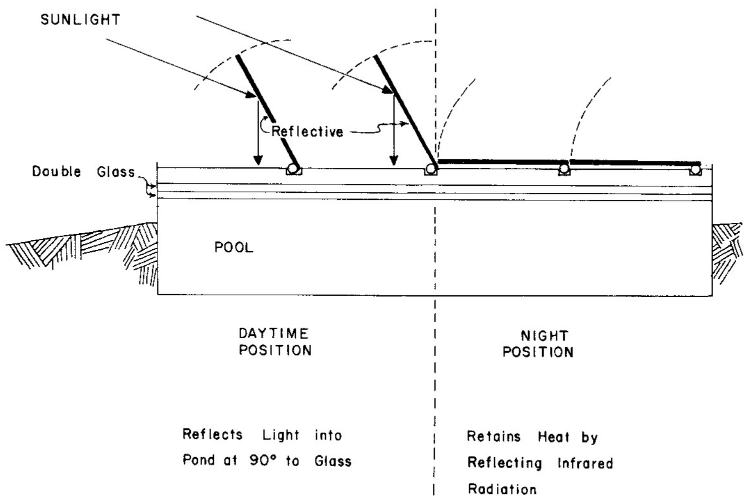


Fig. 9
Night Blind - Reflective
Pool Tops

Photo 5
Interior Flat Top

Photo by John Cressey

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.

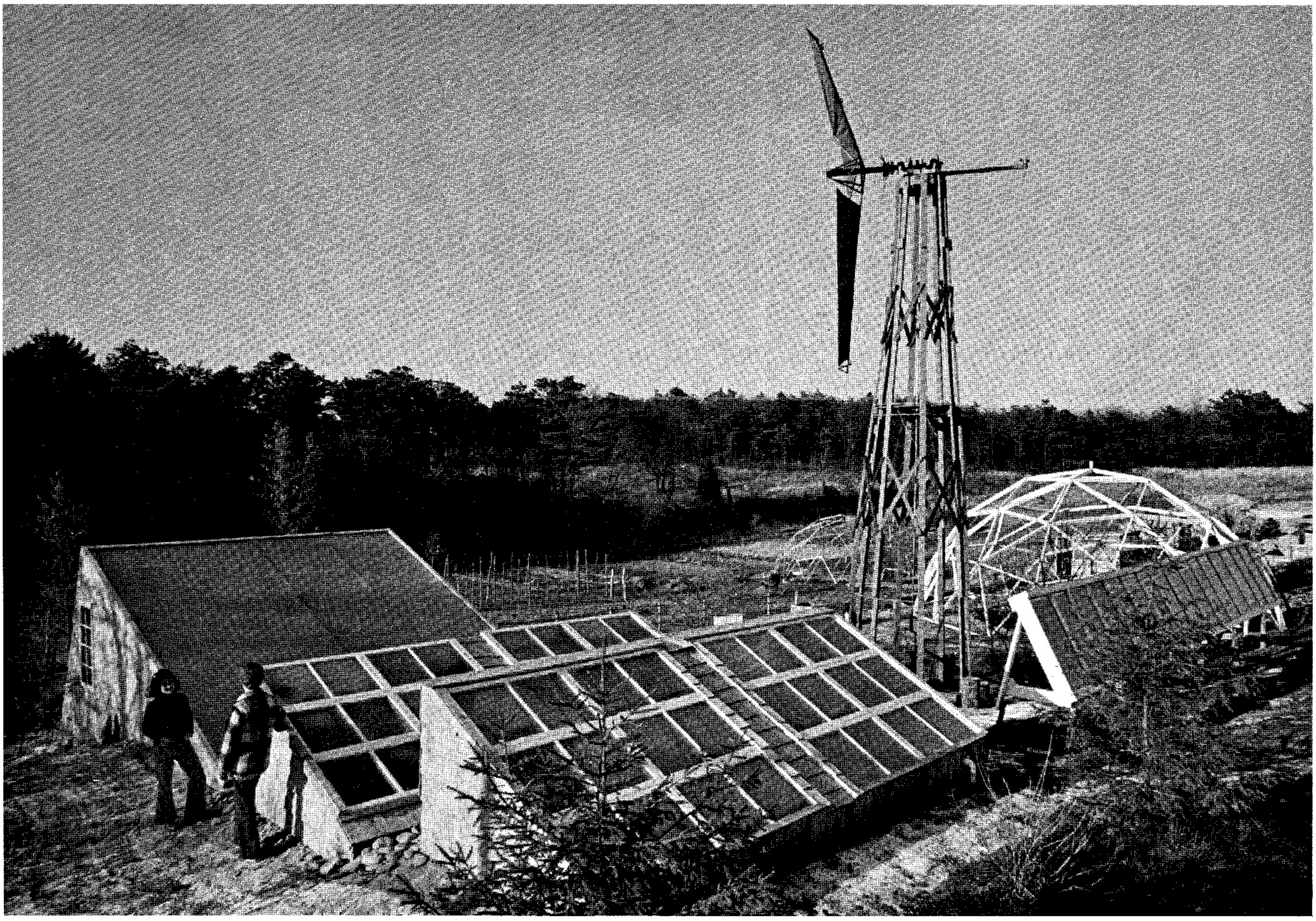


Photo 6 *Photo by Ken Kobré*

MINIATURE ARK

Photo 7 *Photo by Ken Kobré*

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 sailwing 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

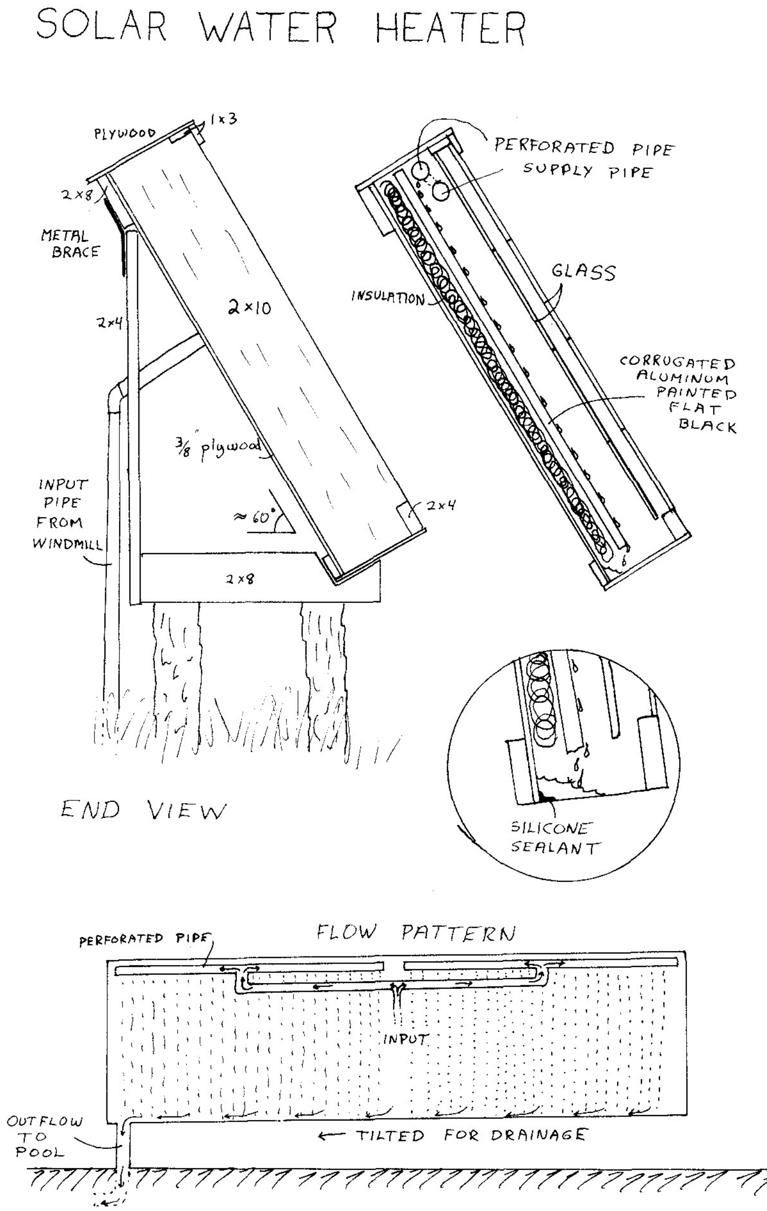


Fig. 10

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.

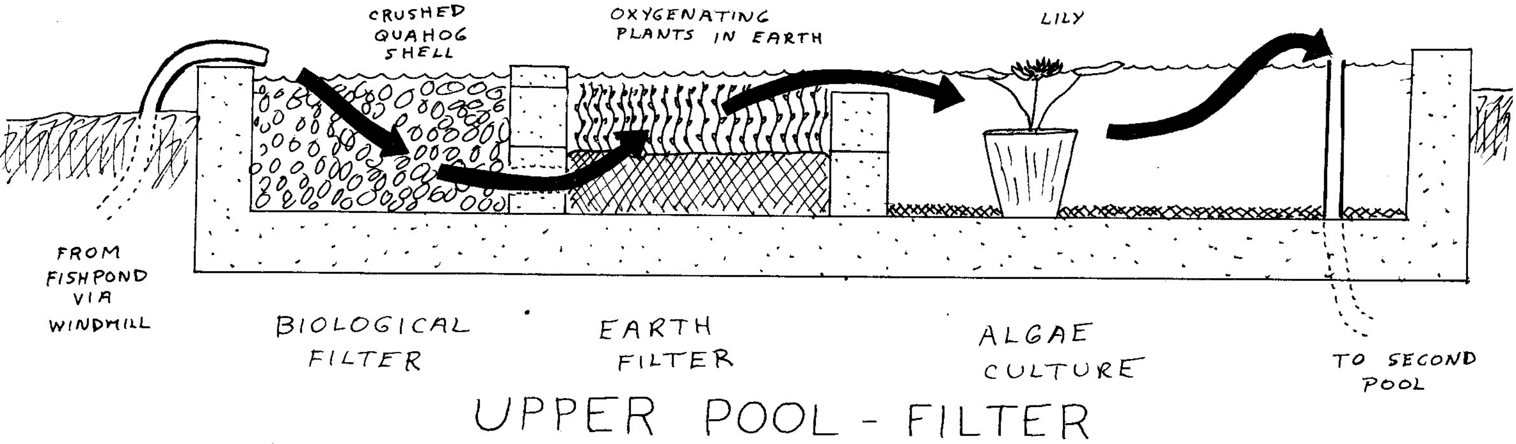


Fig. 11

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

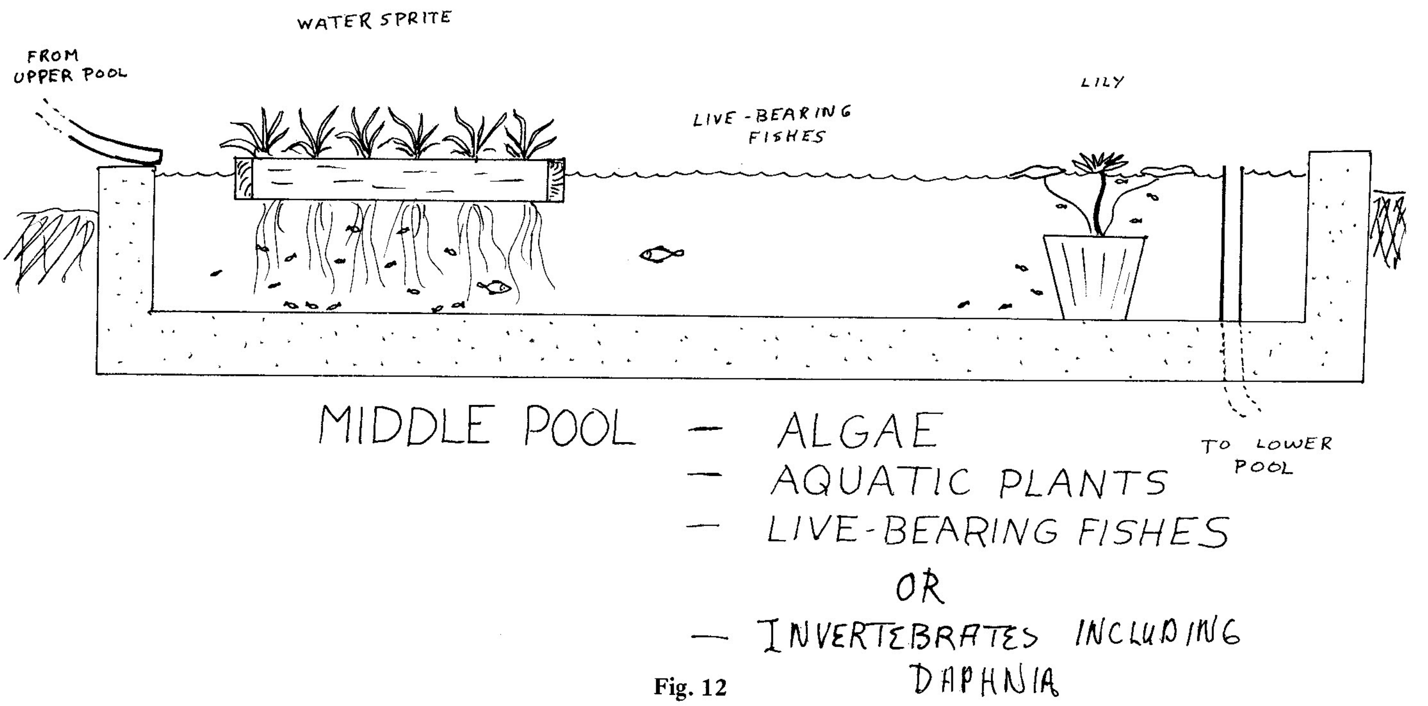


Fig. 12

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 technics.

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 though 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 intermediate 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 5½' 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

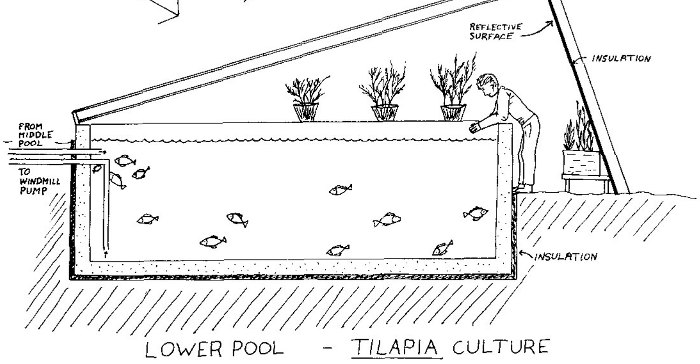


Fig. 13
Greenhouse - Fish Culture Structure

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 acceptibility 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

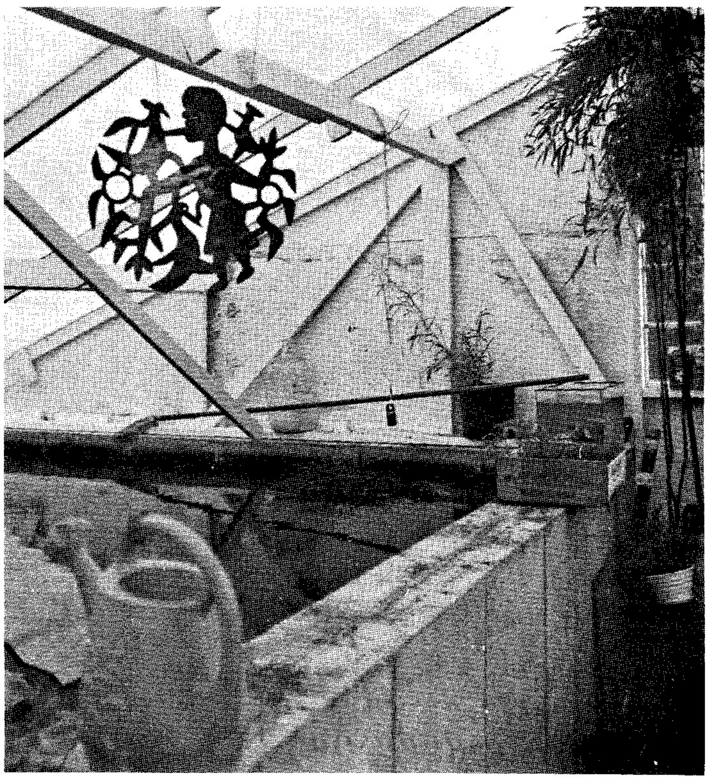


Photo by Peter Sherman

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.

COST COMPARISON OF THE THREE NEW ALCHEMY BACKYARD FISH FARMS

Dome Backyard Fish Farm

Dome Backyard Fish Farm	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.	$ 35
Dome Frame — For 25' or 30' dome, 25 footer can be built with 1" wood. Subject to snow collapse - Price Est. = $50.00. For 30 footer, 2" x 4" frame - Price Est. = $134.00. 2" x 4" more permanent solid frame which permits installation of fiberglass and plywood panels, and thence to more permanent structure.	50 to 134
Piping — Piping for hubs was scrounged from dump and cut for us by a friend	Scrounged
Dome Cover — The cover is 10 mil vinyl. Don't use polyethylene as cover, as it only lasts a few months. Vinyl may last several years. Fiberglass, plywood panels on north face best if funds available.	128
Filters — Filters are patched metal refrigerator liners. Long-lived.	Scrounged
Pump and Motor — A ¼ hp motor and pump. These things can be scrounged.	Scrounged
Miscellaneous Costs — Including paint, etc.	20
APPROXIMATE TOTAL COSTS	$283 /$370

Flat-Top Backyard Fish Farm

Flat-Top Backyard Fish Farm	Costs (Materials)
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.	$100
Lower Pool — 16' circular, 5' deep. Pool lined with black polyethylene. Lasted only one season.	35
Tops — Upper pools covered with two layers of storm windows and reflective panels (discarded windows @ $1.00).	48
Lower pool covered with sheets of fiberglass - two layers - semi-permanent materials.	167
Sides and north face - scrounged plywood.	Scrounged
Filter — One refrigerator liner and the upper pool.	
Pump and Motor — A ¼ hp motor and centrifugal pump such as exist in some washing machines.	Scrounged
Solar Heater — Wood frame, aluminum roofing backing and double plastic covering.	40
Miscellaneous Costs — Including paint, etc.	35
APPROXIMATE TOTAL COSTS	$425

Miniature Ark

Miniature Ark	Costs (Materials)
Upper Two Pools — Concrete, same as Flat-Top - Dimensions are 6½' x 16' x 2½'	$ 100
Upper Pool Covers — Two layers of storm windows facing south at an angle of approximately 60°. Sides and back plywood, covered with shingles. Four doors along north side of each pool.	146
Lower Pool — 15' x 15' x 5'6" deep, reinforced concrete. Had the job done 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.)	930
Greenhouse Top — South face - two layers fiberglass.	167
Sides and north face plywood, and shingles. Quality materials throughout. Built to last and includes benches for plants.	195
Solar Heater — A 4' x 32' solar heater, double glass front, aluminum-insulated backing. Water flows down troughs in aluminum sheets. Long-lived.	204
Windmill — Tower	119
Crankshaft	Scrounged
Bearing turntable	130
Two pumps	48
Dacron blades and associated structure and rigging	200
Piping for system	15
Miscellaneous Costs	42
APPROXIMATE TOTAL COSTS	$2,296

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 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

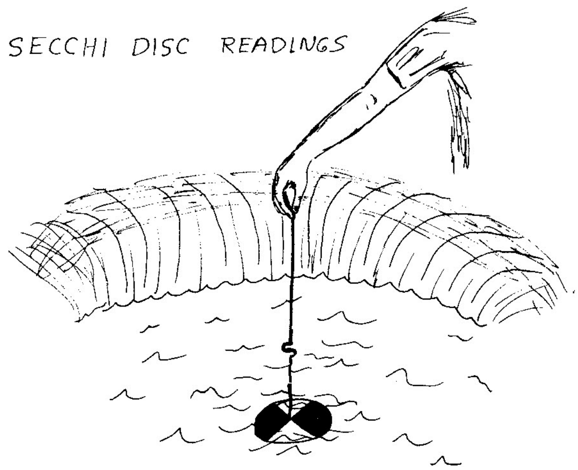


Fig. 14

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

T. aurea and *T. zillii* may be difficult to turn up in the aquarium trade. If so, we know of two fish breeders who *may* be able to supply your requirements for a pair of breeders or a small batch of young.

Ray Fuller	Cal Hollis III
EasTex Tropicals	R. D. 1, P. O. Box 65
P. O. Box 352	Houston, Delaware 19954
Carrollton, Texas 75006	

Ray Fuller has *T. aurea* and *T. mossambica.* Cal Hollis has an unidentified species which is peaceful and does well in his excellent backyard fish farm. We are not sure that either of them can provide the fish you need and we don't want to be responsible for a lot of inconvenience and paperwork for them if they are out of stock. Drop them a note, and include a self-addressed, stamped envelope so that they can reply quickly to your inquiry about fish.

They set their own prices which include shipping costs. Their prices may seem high but are quite realistic and if you care for and breed your initial stock properly, you should never have to order tilapia again.

The New Alchemy Institute will provide free a small batch of young tilapia to those who have built a backyard fish farm and are willing to drive to the center on Cape Cod and pick them up. If stock is limited, preference will be given to Institute Associate Members. You *must* call first to determine whether fish are available and to arrange a time for pickup. You will need to provide yourself with fish-shipping bags (see your aquarium dealer) and oxygen tablets available from bait dealers. We keep neither of these on hand.

On the west coast you might want to check with New Alchemy-West, P. O. Box 376, Pescadero, California 94060 to see whether they have extra fish and if there is a cost for them. At the present they do not, but by 1975 their tilapia research program will be under-way.

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 nebulosis)* 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, *Astronotus 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. Draining 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 ¼ 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 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 criterea for determining animal feed requirements 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. Hairy 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 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. hornorum* (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.

REFERENCES

McBay, L. G. 1961. The biology of *Tilapia nilotica* . Linnaeus. Recently redescribed as *T. aurea* (Steindachner). Proc. Fifteenth Ann. Conf. SE. Assoc. Game and Fish Commissioners 208-218 pp.

St. Amant, J. A. 1966. Progress report of the culture of *Tilapia mossambica* (Peters) hybrids in Southern California. Calif. Dept. Fish and Game. Inland Fisheries Admin. Report No. 66-9

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.

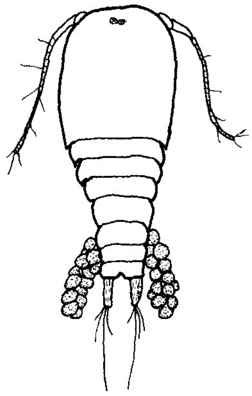
Collecting the Organisms: Before becoming a great hunter-gatherer, you will need to learn when collecting from ponds how to determine amongst these very small aquatic animals which are the good and which are the bad guys. This knowledge is critical and not hard to acquire.

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.

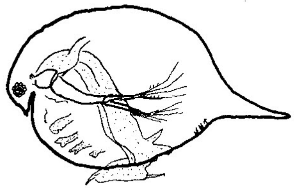
Preliminary identifications of algae, protozoans, rotifers, molluscs, crustaceans, insects and fishes can be made using the keys in the book. You may also need an "old-fashioned" introductory zoology or biology text to learn enough about the structure and morphology of each taxonomic group to be able 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



Cyclops
(pin-head size)



Daphnia
(pin-head size)

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.

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 over-wintered 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 considered 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*
Tilapia aurea	33	4.22	0.13	18.6	17.1-20.8
Tilapia sp.	94	13.13	0.14	20.6	16.0-23.1
Tilapia zillii	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 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*
Tilapia aurea	29	6.59	0.23	22.2	18.0-27.0
Tilapia sp.	11	1.52	0.14	20.5	18.5-23.1
Tilapia zillii	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 29¾ 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 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 certainly 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	32.0-22.0
October - (up to Oct. 22)	16.5 - 7.5	25.5-21.0	25.0-19.5

Temperatures in Degrees Centrigrade

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.

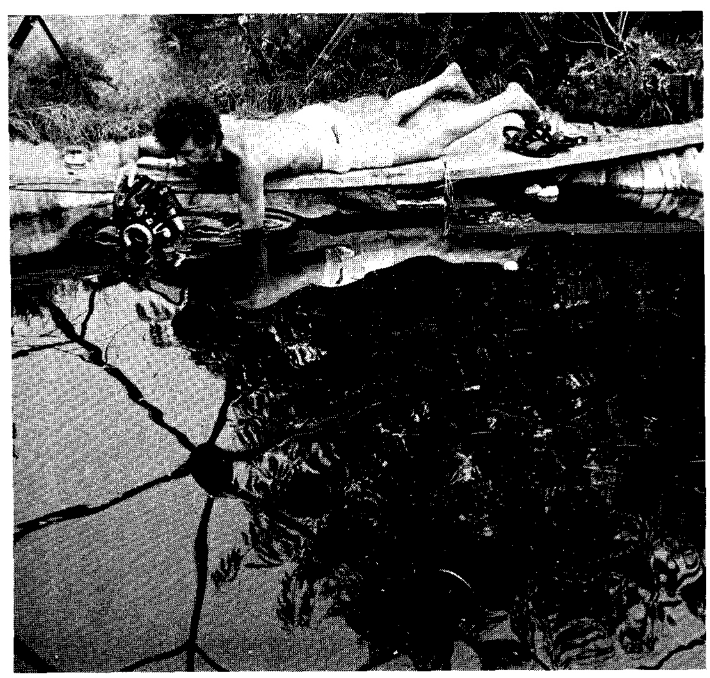


Photo by John Cressey

Section 5 Beyond New Alchemy

COLLABORATION WITH NEW ALCHEMY IN THE DEVELOPMENT OF BACKYARD FISH FARMS

We are interested in having the research extend beyond ourselves and in collaborating with people throughout the country in backyard fish farm research. We will compile the information collected by those of you who become investigators. We will also evaluate the findings and then make them available to the public at large. If many cooperate with us, a genuine research-for-people program might develop that is directed towards solving the problems of today, and in shaping a finer tomorrow.

To become involved you will need to keep good records. Every time we have skimped on data-keeping, we have regretted our ways afterwards. You will need to maintain charts on EXPENSES, LABOR, STOCKING AND BREEDING, TEMPERATURE, FERTILIZATION AND ALGAE BLOOM, FEEDING AND YIELDS. Establish for yourself monthly data sheets for the above. Temperature and feeding information should be kept *daily*, and be sure and include outside temperatures in your records. Keep accurate notes on your management practices. Yield information should include date of harvest, total number of fish, total weight, and numbers large enough to eat. Don't forget your expenses and stocking and breeding information including dates.

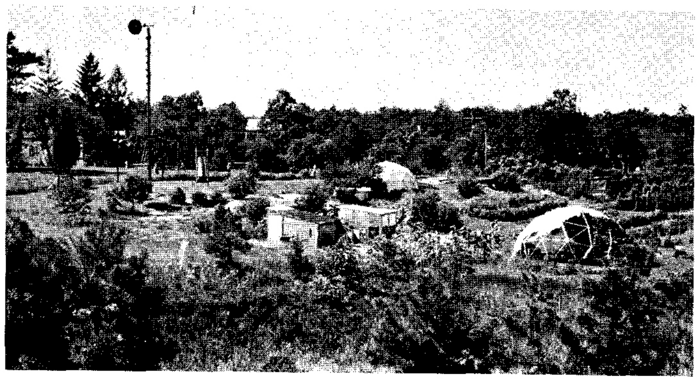


Photo by John Cressey

SEND YOUR FINDINGS TO:
Backyard Fish Farm Research
The New Alchemy Institute
P. O. Box 432
Woods Hole, Massachusetts 02543

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REFERENCES AND AN INTRODUCTORY BIBLIOGRAPHY OF RELEVANT INFORMATION FOR BACKYARD FISH FARMERS

1. Bardach, J. E., J. H. Ryther and W. O. McLarney. 1972. Aquaculture - the farming and husbandry of freshwater and marine organisms. Wiley Interscience. 868 pp. $37.50.
2. Heidinger, R. C. 1971. Use of ultraviolet light to increase the availability of aerial insects to caged bluegill sunfish. Progressive Fish Culturist, 33(4): 187-192.
3. Kuronuma, K. 1966. New systems and new fishes for culture in the Far East. FAO World Symposium on Warm Water Pond Fish Culture. FR: VIII-IV/R-1.
4. Lomax, K. M. and O. R. Harman. 1971. A small unit closed system for catfish. Bull. 394, Univ. of Delaware, Agriculture Experiment Station, Newark, Delaware.
5. McLarney, W. O., S. Henderson and M. M. Sherman. In press. A new method of culturing midge larvae, *Chironomus tentans*, using burlap substrates hanging in fertilized pools.
6. Meske, C. 1968. Breeding carp for reduced number of intermuscular bones, and growth of carp in aquaria. Bamidgeh - Bulletin of Fish Culture in Israel, 20(4): 105-119.
7. Spotte, S. H. 1970. Fish and invertebrate culture: Water management in closed systems. Wiley Interscience. 145 pp. $8.95.
8. Yashouv, A. 1970. Propagation of chironomid larva as food for fish fry. Bamidgeh - Bulletin of Fish Culture in Israel, 22(4): 101-105.
9. Yashouv, A. and R. Ben Shachar. 1967. Breeding and growth of Mugilidae, II. Feeding experiments under laboratory conditions with *Mugil cephalus L.* and *M. capito* (Cuvier). Bamidgeh - Bulletin of Fish Culture in Israel, 19(2/3): 50-66.
10. *Publications* with some materials on intensive fish culture. None of these are directly applicable, but many issues contain very valuable information.
    i. *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.
    ii. *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.
    iii. *Catfish Farmer and World Aquaculture News* - Bimonthly @ $6.00 per year, 530 Tower Building, Little Rock, Arkansas 72201.
    iv. *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.
    v. *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.
    vi. *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.

Section 6 The Great Challenge and Bio-Race

The white glove has been raised, the call to choose one's weapons heard far and wide. We have been challenged and our efforts questioned. Dan Hemenway, a man who has yet to show himself, has had the audacity to declare by every hark, toot and whistle at his disposal, that backyard fish farming with tilapia is not the way. Yes, dear reader, he was saying *not* the way and we were shaken. And this critic, unlike most of the same ilk, knew whereof he spoke.

In a letter Dan announced we were on the wrong track, which is not an uncommon tack amongst adversaries, even noble ones, and then he had the gumption and the gall to describe something he claimed would work better. He was recommending a mode of fish farming that would steal its food and energy from cycles already existing within a given environment. To him this is a far superior approach to the culture of foods.

We don't mind admitting that we were struck to the quick and we had to reply and defend ourselves. After all, this heretic wasn't even allowing us heretics time to pass through the usual course of events and end up as passé establishment. He was so unmannerly as to overlook the fact that we haven't even been accepted yet. Didn't he know we were poor and unloved too, being fellow outriders in the sun?

However, we gallop ahead and lest we adopt his tactics, let the noble Mr. Hemenway speak.

Williamsburg, Massachusetts
January 27.

Dear New Alchemists:

I do think your approach to growing fish for table is less efficient than you contend. First and primarily, the Tilapia farm is monocultural, at least within the space occupied by the fish and their requisite apparati. Second, and almost as important, concern for efficiency is limited strictly, or at least overwhelmingly, to one factor - the feed conversion ratio. This can be an economically disastrous over-simplification in my view.

I am sure, from the style of your thinking, that you are convinced of the advantages of polycultural activities. I contend that these advantages are multiplied by an order of magnitude in aquaculture simply because the medium is one of volume as opposed to merely one of area.

For someone such as myself who depends on his cultural activities for more than three-quarters of his food, the paramount immediate advantage of polyculture is that it is a hedge against failure of any one crop. Utilization of non-hardy crops that must be pampered is for me appropriate only as a form of entertainment which must be apportioned a small percentage of suitable space and time for cultural activities.

Considering what I regard as the excessive capital and maintenance costs of a tilapia system, I regard their culture as non-cost-effective for this latitude. Small artificial ponds could reliably yield large poundages of carp without benefit of enclosures and with only a windmill required to stir the water in the winter to avoid complete freezing and suffocation.

Feed-conversion, though of great importance, is but one factor in total system efficiency. A system that utilizes only herbivorous animals is, in my view, in trouble - too many by-products end up as waste, short-cycled, as it were, back into ambience (earth, water, air) before being utilized. Furthermore, control of herbivorous pests is left to wild animals, taking food out of the system, or simply goes to hell without drastic measures. Omnivores, notably pigs and chickens, are of great help in plugging such leaks. Limited carnivore maintenance, dogs are more useful systemically than cats, may prove cost effective in such areas as where I live where woodchucks, rabbits, porcupines and wild carnivores can be a problem requiring excessive human attention without such help.

Unfortunately, though some fish such as bullheads and bluegills will eat some vegetation, native omnivores among fish are hard to find, if they exist at all. However, a system utilizing bluegills and bullheads appears, from what I have been able to piece together, to have some comparable advantages. I have a distinct and reasoned preference for open systems which leak into and are somewhat fed by the environment at large (the rest of the world). They limit progressive accumulation and deficiency problems which otherwise are, in my view, inevitable. They also afford opportunity to capitalize on inefficiencies in the environment at large. In the case of my impoundment great volumes of surface runoff, carrying hosts of living and dead small animals as well as fertilizers, etc., will greatly increase the productivity of these two classes of fish. Native species of minnow-size fish from beaver impoundments nearby will provide ample capability for utilization of algae. These small fish can be used directly as poultry feed (almost 100% fish to chicken conversion, incidentally) as well as feed for perch. Aquatic insects nourished by the some 30-odd beaver ponds in flying range will also input small but significant protein and mineral contributions. Further, the pond will provide an optimum environment for geese, which being voracious herbivores will hold down pond weeds and filamentous algae and yielding a 12-pound bird in 12 weeks of growth, sans grain. (Except what water grains I may establish for perennial feeds.) Compared with tilapia, geese are undoubtedly less efficient at feed conversion, but they are almost indestructible from environmental causes and easy to hold from year to year. They require input of scarce commodities only when outputting eggs (and immediately prior to that time), when the value of grain consumed is less than that of eggs produced, both from an economic and palatability standpoint. Furthermore, this happens to be the brief interval when forage is essentially unavailable, so little is sacrificed by confinement to secure the eggs. Furthermore, geese, goose eggs, and goslings all are more suitable as cash crops than tilapia or any other fish. Ducks, which are omnivores, can also be introduced to such a system, but with fewer advantages than the more specialized roles I plan. Ducks can gain otherwise lost food value from pools for watering stock which are too small for all but the hardiest type small fish (goldfish, maybe) and perhaps madtoms. This arrangement has the advantage of keeping ducks in tighter confinement — useful because they lay year-around.

All of these arrangements feature two systemic efficiencies which can overwhelm in importance raw feed conversion efficiency. First, they maximize utilization of abundant commodities — perennial vegetation and plant and animal life which could otherwise be classed as weeds and pests. Within very broad limits, these food resources are self-renewing. Their variety can be increased by prudent stocking to maximize systemic resilience. In the case of fish, capital costs are a moderate one-time investment requiring no housing but the water itself. Livestock utilizing the pond must be contained/ protected by fencing (lumberslabs are free hereabouts) until a rose hedge can be grown. (With goats, this may not be enough.) Depending on experience, a windmill powered water fountain may be required to aerate and stir waters. However, this cost may be broadly distributed by use in irrigation and stock watering. (It is imprudent to utilize one continuous pasture for mammals.)

Second, the whole system operates generally unattended as a free forage arrangement. (There are polycultural methods to optimize forage yields, but that's even further afield than I have yet gone.) Maintenance efforts and costs are mainly harvest. While it is true that a pond of this type could fill by siltation, silt-traps are easy to build, furnish excellent forage and, in season, water sites, and yield a resource valuable in additive grading - the easiest kind. Harvesting may be done by draining the pond so that effluent passes through a wire-mesh cage. Pigs and chickens will harvest and store smaller fish flipflopping in mud. (Some losses in my area will be attributable to herons, osprey, king fishers, crows, bluejays, raccoons, etc., but aesthetic gains outweigh losses.) Fish for restocking — particularly pickerel — necessary to prevent over-population — will have to be preserved in submerged wire cages to avert predation prior to refilling the pond. The windmill pump that keeps the water stirred could also be used to refill the pond. (Obviously, not all of the water need be removed since it is undesirable to harvest all of the fish.) In all, harvest/maintenance would require one day — presumably during the uncomfortably hot weather — of wallowing in the water. I would not view that as lost time. Moreover, such a system would bear sustained harvest by hook and line — possibly, if people in the family feel like fishing a lot, obviating the need to harvest every year by drainage. Cage-type fish traps may be sufficient for feeding warm-blooded omnivores such as pigs, this component of their diets.

Finally, it would be hard to convince me, from what I have read of tilapia experiments thus far, that these fish are the best choice for people with even minimal (half-acre or so) home lots. I see an exposed pond dug into the ground 6 or 8 feet with a year-around carp population as a preferred system because it could also water stock and accommodate geese or ducks. Recirculation such as you have described with tilapia could be carried out via windmill. Child-proofing could be done by affixing a removable metal grid two-feet below water surface. Using water in the pond for garden and lawn irrigation and control of pond level via float valve would avoid cumulative disorders of concentration. Geese (or, less effectively, ducks) could harvest lawn areas and fertilize the pond therefrom by shitting as they swim. The grid would protect goslings from large carp. White clover sown into the lawn could input sufficient nitrogen for the geese. Carp could be fed household wastes of many kinds. Etc., etc. The pond could also be designed to serve as a wading pool. Because carp are hardy, they could be harvested by netting 9 months of the year (except the coldest months).

A properly landscaped one-half acre lot thus furnished could yield 100% herb and vegetable needs, 100% fruit and berries needs, also 100% fish needs and either 25% of the egg requirements or six roasting geese (from purchased eggs or goslings) for a family of five. The eggs will require some grain. Replacing geese with ducks will yield 100% of egg requirements but require a small continuous input of grain in addition to lawn, fish scrap, and garden pests and wastes. Chickens interface with this scale much more poorly and are much less likely to be acceptable in regions thus zoned.

Tilapia would be of considerable value for utilizing light from a skylight or such within an actual dwelling. Given suitable structural support for the volume of water required, a population could be maintained on a year-around basis using mollusks, madtoms, and perch to control cumulative variables. A well-designed heating system could maintain the tank at a temperature well above that necessary for human comfort and allow the tank to contribute to household heating by radiation and somewhat by convection. Possibly, also, heat could be supplied from refrigeration/freezer devices, particularly in the summer. Sources of waste heat are surely abundant enough. Intermittent harvest could be done by feeding fish in a water-lock to be pumped dry and opened from the outside when the pan is hot. However, a home would have to be designed with such projects in mind.

Regards,

Dan

Despite our better natures we liked Dan Hemenway's strategies for the raising of foods, even if some of his tactics were a little shady. We too like to dovetail backyard fish ponds and Arks with the exterior world in a mutually sensitive way, and we have long been exponents of polyculture fish farming (see The Journal of The New Alchemists (1) — for discussion of advantages of polyculture) and at the present we have three species of Tilapia, Israeli carps, bullheads, mollies and shortly we will introduce grass carp *(Ctenopharyngodon idellas)* into the tiny fish farms. In this country grass carp are called White Amur. In brief, we found our paths have much in common, but unlike our worthy opponent, we don't believe that every householder, especially New Yorkers, can tap off thirty beaver ponds, nor do we believe they would know what to do with them if they could.

And his roving dogs — carnivore maintenance — turn us off, especially as dogs are the number one scourge of everything at our research center. They kill the rabbits, eat the chickens, crap on the walk ways, stomp on our seedlings and piss on and destroy the new shrubs. There are other details with which we can find fault and our waggish editor has suggested that "Mr. Hemenway might use his large carp to eat the smaller children, and by so doing eliminate the metal grid and relieve the population pressure upon the system."

Nevertheless, we would like to see "cat and rat" farm concepts like Hemenway's developed and extended and analyzed, as in many ways they represent a mirror image or a tiny reflection of how the world works. Still we had to prepare a rebuttal to our noble and worthy combatant. Scenarios like these must be enacted, if not for form's sake, then for the learning and knowledge that will grow out of the contest.

We wrote describing what our backyard fish farms could do that his could not. The following is a précis of our reply:

The New Alchemy Institute
Woods Hole, Massachusetts
Ground Hog's Day

Dear Sir:

Your challenge was most eloquent. Our reply will be brief, although we ask you not to equate brevity with bafflement.

New Alchemy's backyard fish farms are at an early evolutionary stage and are therefore very susceptible to criticism, especially since their productivity is still relatively low. At this point in time they are but survival tools and providers of elegant foods for the tables of the discriminating. But, dear sir, we believe that this will shortly change as we gather the wisdom necessary for the concepts to flourish. Pray, be tolerant of us, as you would of a child making its first fumbling steps. Our science is yet young, and if we look foolish at times, please remember that a few years ago we were told on very excellent authority that intensive fish farming, based upon algae-driven food chains, was an impossibility. Surely our modest success suggests that while we have not travelled far, we have overcome many of the hurdles the pedants laid before us.

We believe a time will come in the not-too-distant future when these humble tools, themselves miniatures of the larger sphere, will be very much needed, as men without wisdom are destroying, misusing and abusing those very things that sustain us and by so doing lead us rapidly into the night. To seek the day during these strange times is our quest, though many will laugh at the relevance of such tiny endeavors. Our reply will always be that the whole can be no greater than its parts. Tending one's garden is not to be despised, as it is a most creative act. Would not the besieged earth sing again if we all tended gardens?

In more concrete terms these backyard fish farms have the possibilities of aiding people most everywhere, and advantages not extant in the intriguing food web you have so ably placed before us.

Our fish farms:

1. Shorten food chains so that we humans eat the primary consumer (tilapia) instead of secondary or tertiary level creatures such as the bass or trout.

2. There are fewer possibilities of poisons accumulating in the flesh of vegetarian fishes, like tilapia, existing low on the food chain.

3. Self-contained fish farms and greenhouses can avoid contamination by pesticides, herbicides and industrial toxins because of their semi-closed nature. When you borrow energy and food from other ecosystems for your farm, you also take in their contaminants as well. Purity is beyond your control.

4. Backyard fish farms can be tucked into alleyways, onto rooftops or vacant lots. Your strategies on the other hand require a rural setting. The water conservation capabilities of our systems may also make them more suited to arid areas.

5. New Alchemy's backyard fish farms could provide climates within for the growing of vegetables throughout an extended season. Eating fresh, organically-raised lettuce, parsley, onions and spinach on a bleak winter's day is a memorable treat.

6. One day we suspect that backyard fish farms will be well enough designed so that they provide the climates for adjacent living structures. In other words, they may contribute in many ways to the vexing problem of waning fuel resources, a point to which you allude.

Having made our case, although perhaps too ineptly for your learned tastes, we would like to suggest to you, wise critic, that the answer lies in a fusion of our ways. We should not be enemies, but rather crafty and rivalrous allies along the path ahead. The place we find ourselves should dictate whether semi-autonomous food chains or the wildness strategy is best. Let the living mantle where we dwell guide us here. May a growing sensitivity to nature's forces lead us to an understanding of how best to sustain and support ourselves.

Having said this, kind sir, we would not like to let your challenge go unheard, for much sweetness lies within the chase.

Vacant lotters, erect your domes! Purify the fouled rains and foods within will flourish and nurture you.

Hamlet dwellers amidst the oaks and pines, rise up and gather your fishes, tend your geese and train your dogs!

The race is on, and perhaps we can hope that this time round there will be no losers. Above all let us work to restore the planet. There is hunger afoot and while the genteel folk don't yet feel it, the shadow grows.

May the geese not rise up and bite ye, dear friend.

Towards a kinder, greener world,

The New Alchemists

Section 7 Apologia

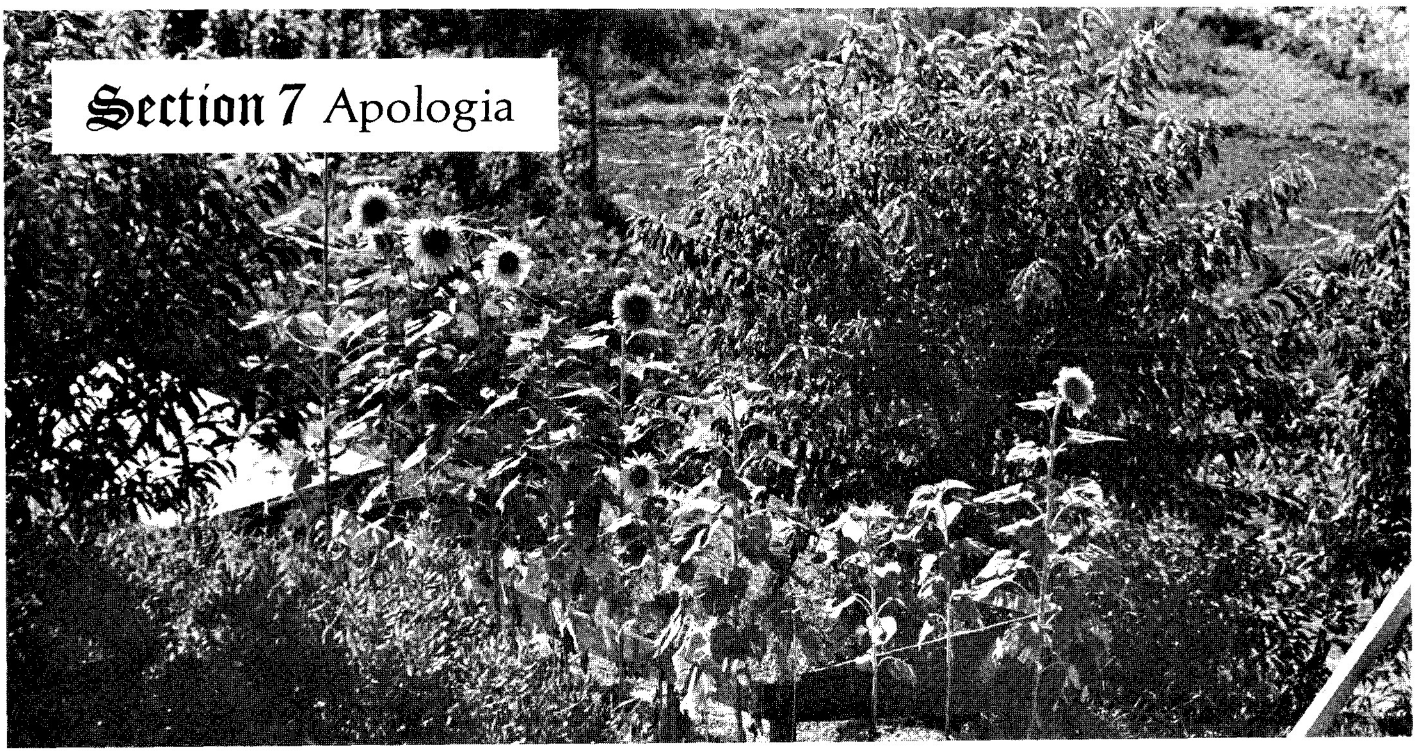


Photo by Alan L. Pearlman

Every Compleat Guide needs an Apologia. This Compleat Guide *is not* a complete guide. It is a beginning; an introduction to the fascinating art and science of the intensive culture of aquatic organisms, especially fishes and particularly tilapia. We are publishing this guide in an early form for a variety of reasons:

i. We have learned enough for others to follow suit and produce good fish.

ii. Social or economic collapse or severe resource shortage could result in widespread hunger. Backyard Fish Farms could alleviate hardship in this country were they widely employed.

iii. There are now many places in the world where there are many people and few foods.

iv. Our own financial house is not in order and our future is uncertain for lack of support. Because of this we want to publish what we have learned while there is still an opportunity. As of the summer of 1974 we have not been able to find enough support to continue our research for much longer. Until now the

Institute has operated upon a shoestring, but the string has snapped and no new laces are in sight.

Possible explanations for our financial plight are many; New Alchemy is a small and unaffiliated non-profit organization; our name is queer to some folk; New Alchemy's scale is defined by very human proportions and is smaller than those institutions that large foundations or government agencies seek to support. Yet we cost more to operate than small, socially or artistically-oriented foundations can afford. Finally, those of us who were scientists in more orthodox institutions have not yet learned how to transfer our fund-raising skills to the more precarious milieu in which we now find ourselves. In any event if some of what we have written seems premature, or conjectural, or if the data appear sparse, we would like to acknowledge these weaknesses, knowing that they can and should be corrected in the years ahead.

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 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.

* * * * *

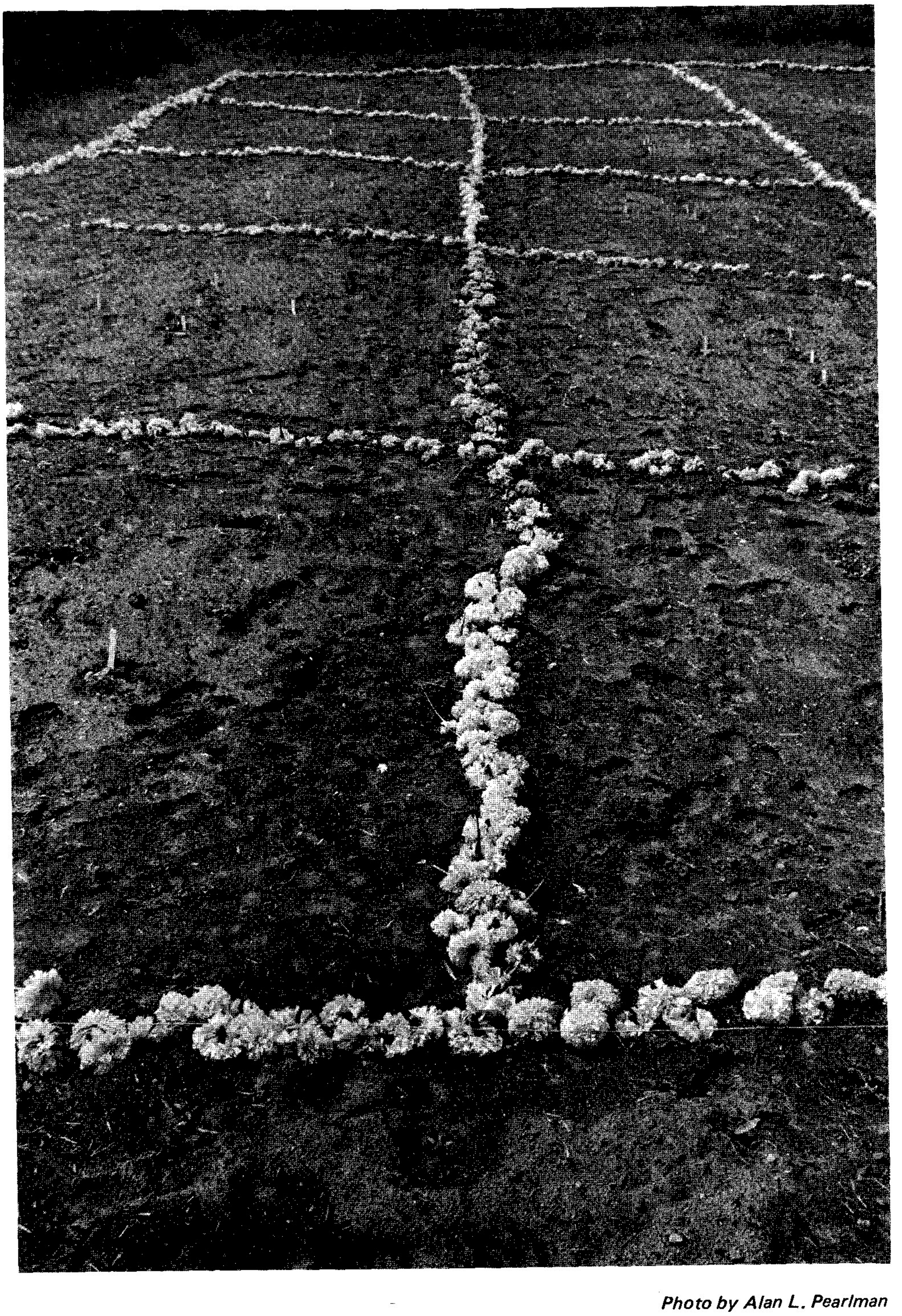


Photo by Alan L. Pearlman

An Improved Method for Culture of Midge Larvae for Use as Fish Food

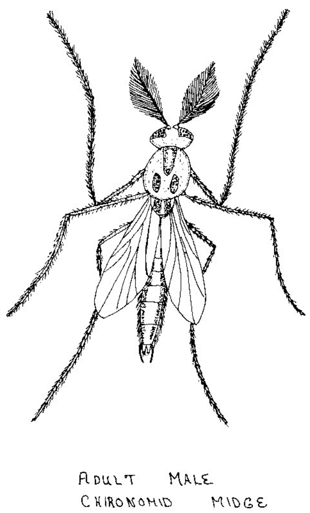


Fig. 1

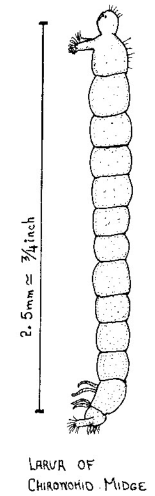


Fig. 2

Photo by John Cressey

"Midges" are the tiny flies (family Chironomidae), similar in appearance to gnats or mosquitoes (Fig. 1), but lacking their obnoxious habits, which you sometimes see dancing in swarms around dusk during the summer and even on warm winter days. Their brilliant red, translucent, aquatic larvae, sometimes called "bloodworms" (Fig. 2), are among the most important natural foods of many fishes. Experiments carried out in Israel (Yashouv, 1956; Yashouv and Ben Shachar, 1967) indicate that midge larvae in small quantities (in terms of percentage of the total diet) can exert a strong growth-promoting effect on cultured fish. Consequently, a number of research institutions, principally in Israel and the U. S. S. R., have undertaken culture of midge larvae as a food for such fishes as carp, mullet, and sturgeon (Konstantinov, 1952, 1954, 1958; Yashouv, 1970).

Some of the culture methods developed have been highly productive. Konstantinov (1952) produced 400 g/m^2/day in trays with recirculating water and artificial stocking of midge eggs. Yashouv (1970) produced nearly as much (250-375 g/m^2/day) with circulating water but without artificial stocking. Most natural populations of midge larvae which have been studied amount to less than 10 g/m^2 at any given time.

The chief drawback of midge culture systems other than ours is the necessity to sort the larvae from the mud or gravel in which they live. Some of the culture systems (e.g., Konstantinov's) have the further problem of involving fairly high levels of technology.

During the summer of 1971, we hit upon a method to grow midge larvae with a low input of technology in a way that would eliminate the tedium of separating the larvae from the substrate. In an experiment designed to grow freshwater clams, aquaria were fertilized with horse manure suspended in cloth bags. Midge larvae were subsequently found, not only on the bottom of the tanks, but also clinging to the cloth. This suggested the midge culture experiment begun in the summer of 1972 and continued through 1973.

Our method of growing midges consists of constructing a series of small ponds, fertilizing them with animal manure, and suspending sheets of cloth or plastic, hung from poles like clothes on a line, into the ponds (Photo 1). Stocking was not necessary; adults of the midge *Chironomus tentans* were attracted to the ponds to lay their eggs. Periodic counts and weights of larvae were taken to obtain an estimate of production.

While production in our ponds was in no way comparable to that achieved by Yashouv (1970) or Konstantinov (1952), there is every indication that it can be substantially improved. Further, in using the larvae as fish food, the tedium of harvesting has been completely eliminated. All that is necessary is to float the cloth or plastic sheet, attached to the poles, in the fish pond and let the fish do the work. The scheme was tested on a variety of fresh and salt water fishes, including our own cultured tilapia. The larvae were accepted as food by all the species tested.

During both years, the effects on larval production of a number of environmental variables were tested.

Among the variables studied were rate of fertilization, type of fertilizer, materials for the substrate sheets, supplementation of the fertilizer with iron compounds, depth of the ponds, spacing of the substrate sheets, shading and covering of the ponds, use of a greenhouse, circulation of the water, and aeration.

The data from these studies are being analyzed and will be published in scientific journals (McLarney, Henderson and Sherman, in press; McLarney and Sherman, in preparation) and in a forthcoming issue of "The Journal of The New Alchemists." During 1974, we plan to construct a series of midge larvae production ponds, thus fully integrating midge culture into our fish culture system. Based on our findings to date, the optimal combination of conditions for the production ponds would appear to be: fertilization with milorganite at 0.5 kg/m^2/week, burlap substrate sheets, a depth of 1 m, and intermittent water circulation. We anticipate being able to produce a quantity of midge larvae sufficient to effect substantial improvement in the growth rate of our fish.

Acknowledgments

This work was supported by Sea Grant grant no. 22/35252.02, administered through the Woods Hole Oceanographic Institution. Many of the New Alchemists and visitors shared in the joys of midge-picking at one time or another, but I would especially like to thank Shelly Henderson and Marc Sherman for their long hours in designing, constructing and operating the experiments. Dr. Robert Edwards of the National Marine Fisheries Service Biological Laboratory, Woods Hole, was instrumental in obtaining support for the project. Dr. Ivan Valiela of the Marine Biological Laboratory, Woods Hole, assisted in identification of the midge species found in the ponds. We also wish to thank A. Robert Gunning for the use of the land on which the experimental ponds were constructed.

— *William O. McLarney*

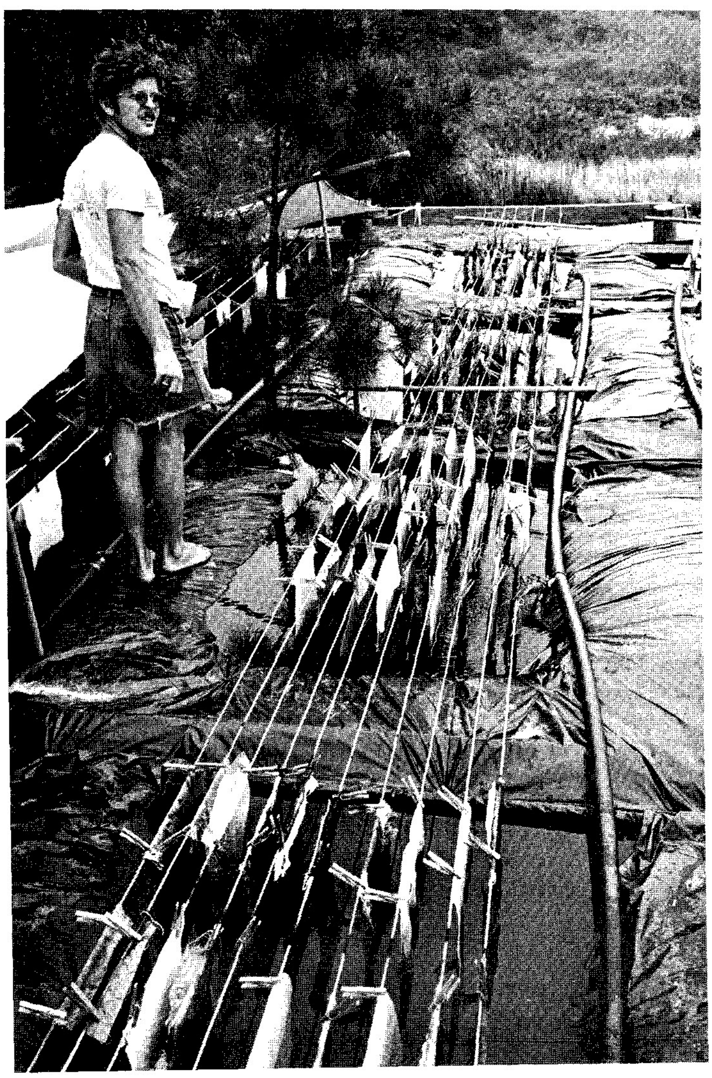


Photo 1

Photo by Peter Sherman

REFERENCES

Konstantinov, A. S. 1952. Semicommercial propagation of Chironomid larvae. Rybnoje Choziajstvo, vol. 1, pp. 31-33 (in Russian). Unedited translation available from Fisheries Research Board of Canada, Fresh Water Institute, Winnipeg, Manitoba.

Konstantinov, A. S. 1954. An experience in semicommercial midge propagation. Rybnoje Choziajstvo, vol. 11, pp. 41-43 (in Russian).

Konstantinov, A. S. 1958. Biology of the Chironomidae and their cultivation (Vniorch), Saratov, U.S.S.R., 359 pp. (in Russian).

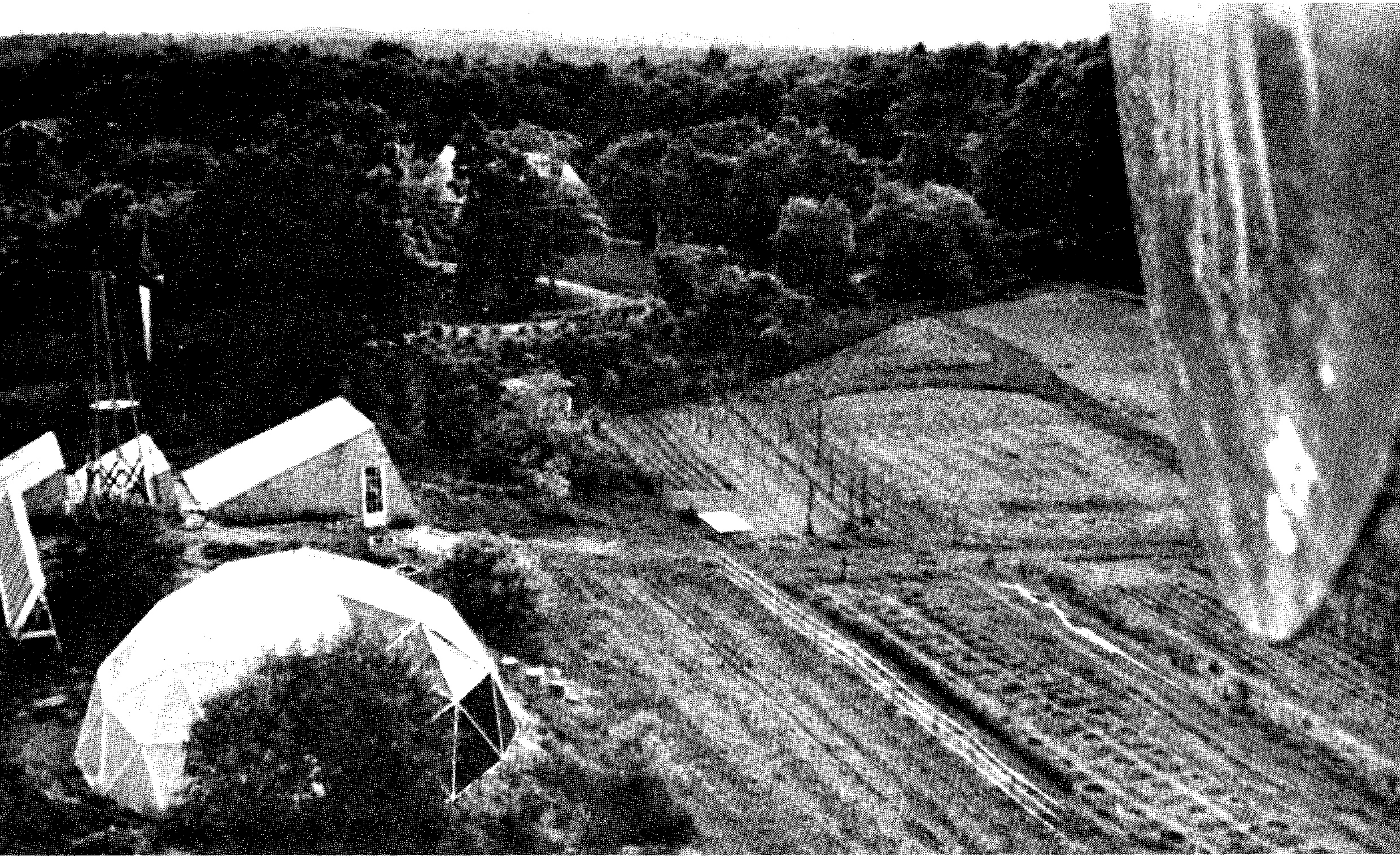
McLarney, W. O., S. Henderson and M. M. Sherman. In press. A new method for culturing *Chironomus tentans* (Fabricius) larvae using burlap substrate in fertilized pools. To be published in Aquaculture.

McLarney, W. O. and M. M. Sherman. In preparation. Further studies on the effects of alteration of environmental parameters on the culture of midge (Chironomidae) larvae on hanging cloth substrates.

Yashouv, A. 1956. Problems in carp nutrition. Bamidgeh, vol. 8, no. 5, pp. 79-87.

Yashouv, A. 1970. Propagation of Chironomid larva as food for fish fry. Bamidgeh, vol. 22, no. 4, pp. 101-105.

Yashouv, A. and R. Ben Shachar. 1967. Breeding and growth of Mugilidae, II. Feeding experiments under laboratory conditions with *Mugil cephalus* L. and *M. capito* (Cuvier), Bamidgeh, vol. 19, nos. 2-3, pp. 50-66.



Explorations

Earlier in the Journal we mentioned briefly the impact that Howard Odum's report to the Royal Swedish Academy had on all of us last fall, both intellectually and emotionally. It could have been said to have had a comparable effect to a doctor's report, pinpointing the progress of a fatal disease. One knows the prognosis is going to be bad and can, of course, only get worse. But, before actually hearing the report, one's fears are still somewhat amorphous and vague, having the tenuous quality of a bad dream. With the report, the specifics take shape. One can no longer be evasive in one's responses. It was so for us with Professor Odum's report, which John Todd discusses here. No longer are the problems ominous but ill-defined. Professor Odum makes only too clear where and how we are endangered, relating this not only to the false concept of energy held by our economic system but also to the living world in which it is based but habitually chooses to ignore. We feel it is a perhaps painful but essential part of Explorations.

A careful reading of this article and that of Richard Merrill, under Land and Its Use, will reveal many parallel, even convergent, themes. It is worth noting that they were written three thousand miles apart and completely without collaboration. What sets them slightly apart from many that have discussed energy in recent months is the fact of both Rich and John's continuing awareness of the inter-relatedness of all economics, energy and agriculture to the finite planet we seem bent on exhausting.

The second article in this section by Eugene and Marya Anderson of the University of California at Riverside is one that is interesting on a variety of levels. As New Alchemy has started working in other countries, we have become all too aware of the fact that "help" in any form is ill-conceived if it is not accompanied by an exhaustive effort to understand the people to whom you would offer your knowledge or skills. While too much pondering could lead to a Hamlet-like paralysis, it is still terribly important, before rushing foward with one's good works, to understand a culture and to know, as the Andersons point out, that there are often taboos and practices which, although often incomprehensible from our frame of reference, can be a deep-rooted part of a people's thought patterns.

Another idea that emerges from the article as thought-provoking is that of the politics of food. Here there is no need to draw on examples from the third world, so successfully have we managed, on this continent, to use food as a means of exploitation. Aisle after aisle of supermarket shelves stacked with highly refined, extravagantly packaged, nutritionally dubious and ever more expensive foods make shopping frustrating, at best, for the comfortable and devastating for the poor. Their exploitation takes another dimension when one considers that it is often the poorest people who find junk foods most irresistible as the only piece of the glittering affluence surrounding them that is in any way attainable.

— NJT

Photo by Peter Sherman

The Dilemma Beyond Tomorrow:

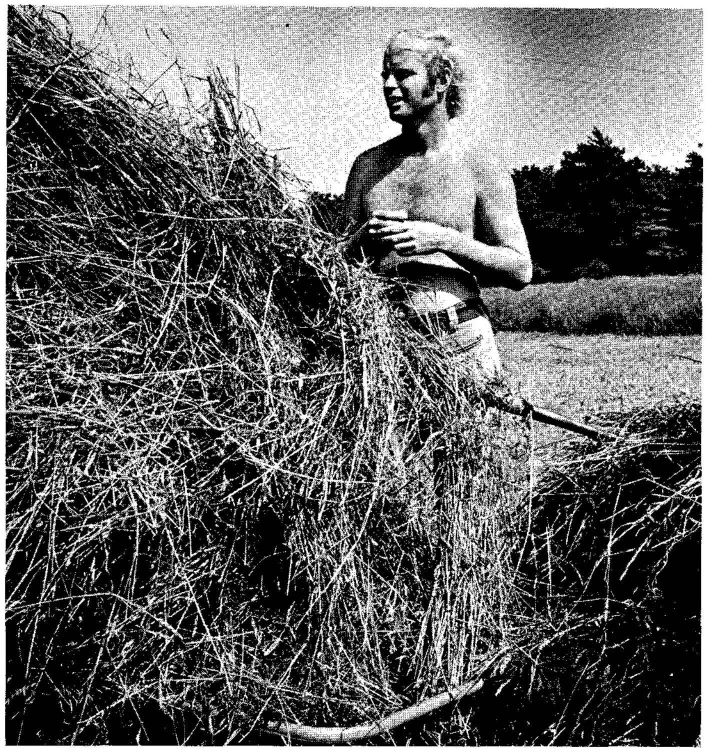


Photo by John Cressey

A Look at How the Fundamental Laws of Nature Have Been Defiled by Modern Industrial Societies Thereby Threatening the Fate of Mankind

Late last fall I attended an ecology conference at Goddard College in Vermont organized by Murray Bookchin, the well-known political ecologist. The Goddard discussions began with a look at the "energy crisis" which was just beginning to flex its muscles, inconvenience and scare people. Several of those present, savvy students of energy and its use in our society, had pretty much concluded that the whole business was a trumped-up affair to benefit the few at the expense of the many. Subsequent events have pretty much borne out their early analysis.

But underneath Oil's dirty underwear there is something critical that needs reading and understanding. Manipulated events can be heraldic in that they provide a model for looking at economic forces in the world by which we can see a bit more clearly into the future. The pseudo-crisis has had educational value with frightening portent.

I should like, at this point, to make four statements about energy in relation to society and then discuss them a bit more fully, beginning with the last point first.

1. Energy and its use is critical to the fate of society.

2. Our knowledge of energy is primitive and lacking in wisdom.

3. Even if the present crisis is the result of manipulatory activities, the forces which enable Oil and others to be manipulative are growing. Within our lifetimes a terrible scramble for the remaining cheap energy will take place. This almost certainly will mean war and oppression.

4. Contemporary "advanced" societies have built themselves a humpty-dumpty civilization based upon a crude understanding of nature, energetics and society. The scary thing about this is that megatinkerers, oil barons of whatever nationality, could actually collapse the whole industrial world without meaning to, merely by playing their narrow-interest power games. I shall give a brief example of what I mean, but it should not be forgotten that there are at the same time comparable events that could be, and are, occurring in many other sectors of society.

DOWN ON THE FARM, or DO WE EAT TOMORROW?

It is difficult for us to imagine stores empty of food. We have no precedent for such an event. But every time you see a gas station with an "out of gas" sign, remember that the problem is magnified down on the farm. In our mechanized society an empty tank in a tractor can quickly mean an empty shelf in a food store. The lag time can be as short as nine months. Even slight energy shortages have the potential to trigger myriad unexpected events.

As I mention in the article describing New Alchemy's Ark, food production in America, unlike agriculture in many regions of the world, is highly energy-intensive and dependent upon huge oil inputs. The disparity, in energetic terms, between U. S. agriculture and that of peoples with sensitive gardening approaches to farming is as high as 25:1 or even 40:1 in favor of the latter. This is a side of the green revolution its proponents rarely discuss. Some farmers in places like Malaysia and New Guinea are capable of producing twenty calories of food for one calorie of energy expended; we use five calories or more of energy to produce one calorie of food on the American table. We are hooked on high energy modes of food production and because this fact has been ignored, a population has been placed out on a limb.

Energy is used in a variety of ways in the production of food. There is the manufacture of necessary modern machinery and equipment, then transportation, storage, drying, processing and packaging, not to mention a number of other inputs including advertising, all of which require fossil fuels for their sustenance. To make things worse, our agricultural lands have been so badly treated and misunderstood in ecological terms that a whole arsenal of chemicals is required to fend off pests, kill weeds, check diseases and provide plants with nutrients. These chemicals are all ultimately dependent upon fossil fuels in their manufacture and many are petroleum derivatives. Herbicides, pesticides, fungicides and fertilizers can be purchased by farmers only if oil remains cheap and readily available. The manufacture of both nitrate and phosphate for fertilizer requires excessive amounts of energy, surpassed on a per unit output basis by few other industries, such as aluminum.

Industrialized agriculture cannot get along without these inputs, as many alternative paths have been closed behind us. We are increasingly paying the price for treating land as a commodity rather than as something alive and sacred. When the oil tinkers tinker, they could unleash events which will bring real troubles to the farms and the larders of the country.

Already there are ripples as a result of the mini-crisis. In the fall of 1973 a number of farmers were finding it difficult to get enough gas to dry their high-yield corns. The problem is at once ironic and typical; the new corns are harvested "wet", having a higher water content at harvest time than older varieties. Spoilage results if they are not artificially dried.

But the worst problems in the food production chain are in the industrial linkages. Cutbacks in availability of oil to petrochemical industries, as well as increasing prices, could put a squeeze on pesticides, herbicides and fungicides. If these products "short fall" on farm lands, there could be a serious drop in production of foods. Shifts to biological farming methods can and must take place, but they cannot be rapid, as they usually take many years to be effected and require more intensive techniques and planting strategies, not to mention a wholly different attitude toward agriculture. One petrochemical industry spokesman predicted a sixty-five billion dollar drop in his industry and 1.6 million jobs lost in 1974. While he was no doubt exaggerating the magnitude of the problem for ends not yet clear, there is little doubt that shortages and price increases of an unprecedented nature are taking place and that these will inevitably affect farm inputs. One example will suffice to make my point. Within a period of a few weeks, the price of phosphates from Morocco, a major phosphate producer, rose from $14 to $42 a ton.

This whole scenario, it must be remembered, has to be seen against the backdrop of a world without substantial food reserves. Nations with faltering industrialized agricultures cannot be bailed out, short of war or blackmail on their part. If a pseudo-crisis can induce strains into a system, then a genuine reduction in fuel availability could seriously dislocate a modern society.

A real energy crunch is on the way. At this point I should like to bring forth some of the arguments of Howard Odum, one of the fathers of ecology in America. Odum's view of the future is one of the most apt, and we would do well to listen carefully to his message.

For several decades Howard and his brother, Eugene Odum, have been students of Nature, trying to comprehend the primary ecological forces that underlie biological change. They have done much to advance the science of ecology, and a landmark paper by Eugene entitled, "The Strategy of Ecosystem Development", (1) chronicled the characteristics of ecosystems and environments, their use of energy and their changes over time towards more diverse, complex and stable states. Nature changes constantly. The environmental factors and man's impact on these changes are beginning to be understood. Howard Odum, in a small volume, "Environment, Power and Society", (2) attempts to apply the mechanisms of nature and the methods of ecology to an understanding of human societies and their relationships with the living world. The book, with its charts and flow diagrams and its jargon borrowed from the language of systems, has not been widely read outside the discipline of biology, although its message was very clear to those who studied its contents. Professor Odum concludes that highly industrialized societies are so out of tune with nature that their fate will be sealed within the lifetimes of many alive today.

Recently Howard Odum presented a paper to the Royal Swedish Academy of Science entitled, "Energy,

1. E. P. Odum, 1969. *The Strategy of Ecosystem Development.* Science, Vol. 164, 262-270.
2. H. T. Odum, 1971. *Environment, Power and Society.* John Wiley. 336 pp.

Ecology and Economics" (3). Its message was directed both to the public and to world leaders and stated that through our ignorance of energy and nature we have created a world community that is precariously balanced. He predicted a one-hundred-fold drop in the world's population within five to twenty years, a drop closely paralleling a comparable reduction in the amount of energy available to industrial societies.

I should like to précis some of his arguments here, as the paper delivered to the Royal Swedish Academy has yet to appear in print. I apologize to him for any misinterpretations that might enter into my analysis of his ideas.

Odum views energy, whatever its source, be it coal, oil, nuclear fission or the sun and the wind, in terms of its value. By value he means real work after the energy has been extracted, processed and delivered — in a sense paid for. This is energy at its point of ultimate use. He also grades energy in terms of what it takes, energetically speaking, to make it work directly on our behalf. If it takes almost as much energy to mine, process and manufacture the components and substructures of power-producing systems and maintain the support organizations, as can be delivered for ultimate use, then the *net energy* is very slight. He argues convincingly that energy is not seen in this way by economists.

He has modeled inflation through his technique of seeing money as an energy-linked phenomenon in the "ecosystem" of nations. Seen this way, the relationships between energy and money begin to clarify. Inflation, in these terms, is directly related to the diminishing availability of net energy - as the amount of net energy readily available to a society decreases, so does the value of its money. The relationship appears to be a direct one. The quality of energy is also tied to this idea. If more energy is put into the energy-getting process, be it arctic oil, coal, or nuclear plant, than was necessary previously when fuels were more available, then less real work can be bought with the energy produced. At this point, money is worth less, independent of the machinations of high finance or government. To summarize, the value of money is directly tied to the net amount of energy available to the society that prints it.

The available energy reserves will have to be re-evaluated by both modern governments and most of their critics in light of Odum's line of argument. If net energy is the criterion upon which we are to base our planning for the future, then present estimates are much exaggerated as they are based on available reserves or gross energy. Howard Odum states, "Suppose for every 10 units of some quality of oil shale proposed as an energy source there were required 9 units of energy to mine, process, concentrate, transport and meet environmental requirements. Such a reserve would deliver 1/10th as much net energy and last 1/10th as long as was calculated."

Here we are beginning to probe the essence of the quality of energy and the dilemma beyond tomorrow. Nature has her own set of rules and what we can glean from the use of energy in ecosystems seems to apply to ourselves. From this we can see that competitive and cooperative relationships between societies have different meanings at different periods in their development.

If we are to avoid the fate that has afflicted all previous major civilizations, we will have to identify and cope with shifts in energy value. A forest, meadow, village or country will best survive if it uses its energy for the most useful purposes at any given point in time. Energy requirements can and do shift dramatically.

In nature rapid growth seems to be adaptive only during periods when new and cheap resources are available. Ruthless competition exists between plants as well as animals, when a new spacial resource becomes available. For example, when a field is cleared, colonization takes place which involves rapid shifts in species domination and abrupt rising and falling in population densities. The discovery of the fossil fuels locked in the earth's crust and subsequent use of them triggered a process in human societies in some respects analagous to those in the newly exposed field or meadow example. New energy resources became available. The scramble to exploit them was imperialistic and aggressive. Those that succeeded in obtaining these resources have in effect "changed the world."

A second phase may be approaching when readily available energies basically have been tapped. In nature, those energies remaining are used for maintenance and the gradual shift to other modes of interaction. Rapid net growth specialists like the weeds in the fields are replaced by a diversity of organisms, longer-lived, and of higher quality, with more subtle, frequently synergistic relationships which maximize their energy efficiencies. The area that was a field changes into a forest that is more diverse and stable.

Odum feels that we are going to be forced to shift from a rapid growth society to a steady state society and that we will have to begin soon or the crashes that in nature are characteristic of shifts from growth to steady states may be felt by ourselves.

There is a constructive side to his message: should we shift to a steady state system, the quality of life could, in theory, be maximized. Odum speculates that only in such a society could socialistic ideals of equitable distribution be effected.

At this point, I should like to probe the concept of energy quality and its importance in understanding the significance of the present scramble for new energy

3. H. T. Odum, 1973. *Energy, Ecology and Economics.* Paper invited by Royal Swedish Academy of Science. 26 pp.

sources. One of the most difficult and important ideas Odum introduces is the idea that higher quality energy must subsidize lower quality energy if the total energy output is to be maximized. The forest provides a good illustration: leaves at the top of trees transport fuels so that more shaded leaves which have less solar energy available to them get some additional energy. In this way the dim light that reaches the forest floor can be utilized even though it is of lower quality. Energy is maximized because the uppermost leaves provide a support base for lower ones which work less efficiently. High quality coals and oils, when they are inexpensive, keep goods and services cheap. These goods and services, in turn, provide the subsidy for marginal kinds of energy which would not yield much on their own. I shall elaborate on this concept when discussing the role of nuclear power in the field of energy as a whole.

Economists and technocrats are predicting that the marginal energy yielders might one day become economical. Odum claims this to be a fallacy on the grounds that they require the subsidy to exist at all. Present day marginal energy yielders represent lower quality energy sources.

It is at this point in the argument that the technologists like to point out that new technologies with greater efficiencies will be developed to reverse the equation and save us before readily available fossil fuels are exhausted. The story may not turn out so beneficently, as technologies with high end-point efficiences, (for example, engines that develop considerable power with relation to fuel requirements) actually acquire their efficiency through energy-expensive manufacture, maintenance and support structures. To produce more efficient engines requires more energy in the form of extremely complex factories. The percentage of net energy yielded may actually decrease with more efficient engines.

Environmental technologies being developed in the name of pure water and pure air also reduce the amount of net energy available to society for useful work. In relatively small and balanced human communities, pure air and water are provided by a free energy subsidy from nature. Wind, water, sun and soils work together to purify wastes and human by-products. But natural purification works only when human societies are made up of relatively small units surrounded by ecosystems such as lakes, swamps and forests that have the ability to purify and restore. When urban sprawls become too large, nature's aiding capacity is overtaxed and the free subsidy vanishes. At this point we have to maintain livable environments with costly and energy-intensive technologies like sewage plants, which include tertiary treatment facilities, waste extraction, transport systems and others. The cost to society, as a result of overshooting the natural carrying capacity of nature, is great and unhappily, is ignored by almost all.

Societies must be designed using nature as a recycling partner if they are to survive the period when high energy purification technologies can no longer draw on cheap energy sources to sustain them.

There is much discussion of new sources of energy, especially solar energy, these days. The New Alchemists and others are trying to use these energies on a small scale in more delicate and sophisticated ways. Trapping the sun's heat to provide livable climates in greenhouses and housing structures takes advantage of an energy source normally quickly lost to the atmosphere. But to see large-scale utilization of solar energy as a replacement for oils and other fuels may well prove to be an ill-founded fantasy, and to expect solar power to permit our civilization to continue on its present course is nonsense.

Solar scientists see our salvation in the large-scale manufacture of solar cells that translate the sun's energy into electricity. These cells will be mounted on vast solar collectors, some of them in space. But the solar energy striking a given unit of collecting area is very low, some 10^{-16} kilocalories per cubic centimeter. This means a tremendous amount of energy in the form of subsidies from oil and coal economies will be needed to manufacture a very large number of cells and installations for concentrating the energy and transforming it into electricity for its ultimate use. The net energy available to society may not be nearly as high as solar exponents believe.

However, plants which have an incalculable amount of surface area exposed to the sun will remain the best utilizers of the sun's energy. Their end products, food, building materials and wood fuels, represent the most effective use of the sun's energy. Plants have tiny semiconductor photo receptors based upon the same principles as have been adapted for use in solar cells. Unlike manufactured solar cells, they constitute another of nature's subsidies.

It follows, if the above notions are correct, that the whole concept of environmental technology needs re-evaluation and that those technological processes which duplicate nature's work must be seen as economic and energetic handicaps. The contemporary dilemma has been created by the establishment of high technology industrial and urban regions which have long overshot nature's healing capacity. Our attempts at correction and purification of these ecologically unsound areas will actually run down available high quality fuels at a more rapid rate. If we stick with our present system we are trapped, because we will need to use a disproportionate amount of energy to sustain a livable environment which in turn will leave less energy available for primary work. For future societies to thrive, growth limits should be set by ecosystems rather than by economic dictates which span only a few years. It is unlikely that new forms of energy, even nuclear energy, will be able to bail us out if we don't restructure the human landscape of this country.

Nuclear energy is considered by many high technology advocates to be their trump card, but this is a myth the perpetuation of which is in part responsible for continuing on our ill-fated course. Professor Odum, in discussing the energetics of nuclear energy, does not feel the need to go into the dangers inherent within the use of the atom in order to make us rethink what we are presently doing in promoting a large nuclear industry. On the other hand, I think the safety factors, nuclear waste storage and the slow but steady build-up of radioactive materials in the environment are justification enough not to develop nuclear energy as the panacea to all our energy problems. Odum's argument rests on the fact that the net energy from nuclear power plants is low, being presently subsidized by coal and gas economies.

In his talk to the Royal Swedish Academy, he states, "High costs of mining, processing fuels, developing costly plants, storing wastes, operating complex safety systems and operating government agencies make nuclear energy one of the marginal sources which add some energy now, while they are subsidized by a rich economy. A self-contained, isolated nuclear energy does not now exist. Since the present nuclear energy is marginal while it uses the cream of rich fuels accumulated during times of rich fossil fuel excess, and because the present rich reserves of nuclear fuel will last no longer than fossil fuels, there may not be major long-range effect of present nuclear technology on economic survival. High energy cost of nuclear construction may be a factor accelerating the exhaustion of the richer fuels."

The use of breeder reactors is the next link in the efficiency chain. They use less fuel in the production of electricity. However, their net yielding ability is not yet known, in part because of the huge research and development costs involved. Further, contemporary nuclear plants may consume the fuels needed by the breeders before breeder technology comes of age, so we may never know whether or not they could be net yielders, independent of fossil fuel subsidies.

Nuclear enthusiasts are often quick to point out that the ultimate solution to energy in society lies in creating fusion plants; the fusion phenomenon being akin to fabricating small "suns" here on earth. But workable pilot plants have yet to be developed, and there is no concrete knowledge either as to potential net energy or as to how large an energy subsidy will be required. Societies may not be able to afford to shift to the fusion process from their oil and coal bases, even if the concept of fusion should, one day, prove workable.

If the above concepts have a basis in fact, as I believe they do, it is possible to look with fresher eyes into the dynamic of our present society. The picture that emerges is one of instability and unhappy changes unless we begin to create anew human communities within the limits placed upon us by the living world upon which we depend.

Countries and regions within countries operating upon their own energy resources require less money to function and are in a fortunate position when they export goods and services. Perhaps a corollary of this point is that regional development should be tied more closely to indigenous energies when the future in the long term is seen as being more important than short term wealth and instability. Certainly such an approach would tend to enhance diversity and stability within a region. It might be argued, and quite rightly, that disparities between regions would arise and that the inhabitants of less favorably endowed areas would be poorer. This is partly what I mean by the term, "the limits of nature." Present disparities between regions are sometimes equalized only because of an abundance of cheap energies. This cannot be sustained for long. I have seen communities within a few miles of each other in Haiti, where non-human energy is very expensive and scarce, that are totally different. The root of the differences lies in the local ecosystems themselves. It is when the less fortunate are inextricably dependent on the more fortunate for survival that oppression and injustice reaches its peak.

I would like to suggest that there might be compensations, even though disparities will be generally seen in a negative light. If it were somehow possible to adjust the size of a given community or population to the ability of the surrounding landscape to sustain it, then viable societies might evolve. In these cases, the social goals of equality would have to be worked out within the framework of a region's productive capacity. It may be that sophisticated political theory will one day tell us that an optimal social/political course within a rich and fertile river valley will be different than one for residents of high mountain valleys with inhospitable climates, even given the same goal of maximizing the human experience. In designing adaptive societies, ecological realities need to be placed within the political sphere.

Countries that have high amounts of energy to sell are, in Odum's view, in a strange predicament. If they sell oil (a rich energy source) and don't use it for useful work at home, they too become subordinate nations requiring technical goods and services. Many Arab nations are becoming increasingly aware of this and are shifting more of their energy to manufacturing within their own boundaries. Should they do this on a wide scale they could topple energy-poor manufacturing nations like Japan. Japan's future could provide a barometer of the eventual fate of modern industrial nations.

Those countries or regions that will have the best chance of shifting from their present course closer to steady-state, lower-energy societies will be those that use primarily internal energy sources and relatively high degrees of indigenous technologies in redirecting their path to safer grounds. Those with the richest internal energy sources will, I suspect, retain more of the characteristics found in high growth, cheap energy economies of today.

It is necessary for us to admit to ourselves that there will continue to be differences in relative wealth between regions in the future as there are today, but this fact should not negate the need for political consciousness to strive for social structures which maximize equality within a region. It may be that well-fed, healthy peoples with small amounts of energy available to them will redirect their lives towards stewardship and artistic and philosophic goals. Wealth as understood by materialists may be an enemy rather than an ally. I don't know this........ but I do feel that when we subtly incorporate the living world into our social consciousness, we have a better chance of surviving, and extending the human condition. An enlightened state will depend on a far greater appreciation of the underlying forces of nature.

There have been systems in nature known to have shifted from fast-growing to steady states through a gradual substitution of components from the former state to those of the latter. I suspect that, in these instances, there still existed a fair amount of reserve energy to effect the substitution. But when readily available energy is exhausted, removed, or tied up within a few species, then dramatic crashes can and do take place. Odum's point here is apt when speaking about shifts in human societies:

"Because energies and monies for research, development and thinking are abundant only during growth and not during energy levelling and decline, there is a great danger that means for developing a steady-state will not be ready when they are needed, which may be no more than 5 years away, but more probably more like 20 years."

The urgency induced by this re-evaluation of our present state is amplified by the humanitarian gestures on the part of some wealthy nations in providing food and medical aid to countries suffering from famine and disease. In Odum's opinion, this practice does not stabilize the world as we have been led to believe, but instead depletes existing reserves, ensuring that the world community will suffer en masse, instead of piecemeal. If he is right, we will find ourselves confronted with an agonizing moral crisis. The only consolation may be that, if it were known that a widespread drop in the human population were inevitable under the present modus operandi, perhaps a powerful impetus would be created to develop alternatives. Many of the techniques described in the "Journal of The New Alchemists" are designed as substitutes, utilizing what presently exists within a given region. Indigenous courses of action, to be widely effective, will require significant changes in social and political consciousness and a tremendous amount of hard work and commitment to a future that must be very different from the present.

The place of medicine within the framework of energy reductions is not well understood, but disease as the leveller of populations will again resume its primary role in the fate of humanity. Odum, seeing medicine in energetic terms, concludes that our "medical miracles" are also high energy miracles and that the energy for total medical care is a function of the total energies of a country. As the energies per person fall, energy for medicine declines and chronic disease will again become a population regulator.

Epidemics will also become more prevalent. Epidemic diseases operate under a different principle than chronic diseases. Chronic diseases test the vitality of individuals within a given population, whereas epidemics sweep through a high percentage of a population and the effects are more dramatic and widespread. Nature's systems normally use the principle of diversity to minimize epidemics. The other side of the coin is that an epidemic is a biological mechanism whereby inherently unstable monocultures are eliminated. Man's societies may represent, biologically, a kind of monoculture. Certainly his agriculture is characteristic of unstable systems. We have avoided crashes solely through methods that can exist only as long as there is cheap and universally available fuel. Odum's case is succinct:

"Man is presently allowed the special high yields of various monocultures including his own high density populations, his paper pine trees, and his miracle rice only so long as he has special energies to protect these artificial ways and substitute them for the disease which would restore the high diversity, ultimately the more stable flow of energy."

What is our future going to be like if we continue? Professor Odum's view of tomorrow is an unhappy one:

"The terrible possibility that is before us is that there will be the continued existence on growth with our last energies by the economic advisors that don't understand so that there are no reserves to make change with, to hold order, and to cushion a period when populations must drop a hundred-fold. Disease reduction of man and of his plant production systems could be planetary and sudden if the ratio of population to food and medical systems is pushed to the maximum at a time of falling net energy."

We are, whether we like it or not, confronted with the awesome and unprecedented task of reconstructing human societies so that they come into line with the laws of nature. Hopefully we can do it in a way that extends rather than constricts the human experience. In short, to change the world we are going to have to change ourselves. The beginnings are tangible and concrete, and there are guides including ecological concepts.

We find that there are resources, often in the strangest places, as we become less concerned with high energy and more concerned with diverse wholes. If we are willing to change the way we live, then we can begin to restore and reconstruct. By passing through the portals of nature, we can begin to work with or through her so that the scars begin to heal. The path will involve the three strands of practicality, science on a small and human scale, and a wisdom that is philosophical, even mystical. Separately change cannot come about, but perhaps...... and this is only perhaps, together the world will begin to sing.

It is easy to begin. The Ark and the Backyard Fish Farms reflect wholistic and small-scale thinking, and although they are early explorations into man in nature, they will help give confidence and directions.

Time is not on our side. Hence the urgency and tone of the "Journal." To some, like Odum, our survival is at stake; should they be proved wrong, we still stand to gain. If they are right, there can be virtually no alternative that is not hell, until the living order of the earth's mantle is restored.

— John Todd

* * * * *

This Ant

It stormed all night, thunderous, raining
wind-syncopated on leaves which thrashed
against the sky or, torn away, struggled

on the air like bats until beaten down
and plastered to sidewalks and roads.
Now light, and a calmer wind. The rain's

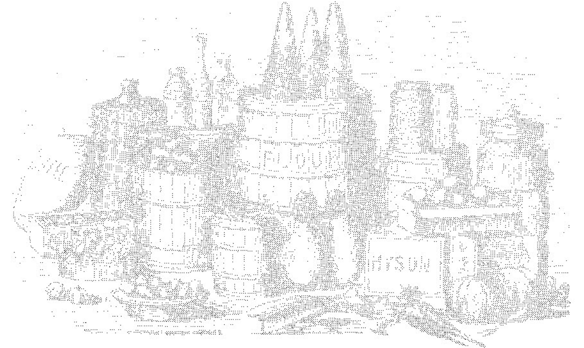
pounding lessens to a second-thought
tap on a drumhead. A long grass stem
dips as a black ant climbs the green stalk

past boulders of water to stand finally
at the tip, feet braced against the sway,
and wave antennae at the sun.

— Don Esty

* * * * *

On the Need for Studies of Food Consumption Ideas



1. The Problem

For some years we have focused our research on fishing communities. Fishing is, of course, a distinctive mode of food production. It is the last stronghold of hunting, as opposed to agricultural and factory production, in the modern world, and as such an anachronism — one which the New Alchemists are trying to eliminate, by developing fish farming. Study of fishing societies led us to a general interest in the change and modernization of food production, and this in turn has taken us on to problems of food consumption.

In the social sciences, as elsewhere, there is little attention paid to the origin and change of food habits. As everyone concerned with the world food problem knows, every culture has an enormously complex and intricate pattern of beliefs, practices, attitudes, taboos, principles and strategies relating to the preparation and consumption of food; and these beliefs are often a major hindrance to the introduction of new, nutritionally desirable foods. Moreover, even with the best of nutritional education, such changes as do occur are often in the wrong direction. Thus in spite of the best nutrition research and education in the world, the United States as a whole has been changing its collective dietary patterns for the worse; more fat and sugar is consumed, fewer fruits and vegetables, and the sugar is increasingly sucrose, which feeds tooth decay bacteria and is suspect of other sins, instead of the less dangerous sugars in fruit, honey, etc. (U. S. Dept. of Agriculture, 1969). Similar deterioration occurs elsewhere; thus in Chile, mothers decided that nursing was old-fashioned, and greatly shortened the nursing period, with disastrous effect (György and Kline, 1970). In our recent research in Malaysia, we found a shift from fruit and vegetables to fat and sucrose, similar to the changes taking place in America.

Nutritionists, agricultural developers and other concerned parties have repeatedly noted such changes, but rarely try to explain them. Rejection of new foods is laid to "tradition" or "superstition", while deteriorative changes in diet are passed off as "ignorance" or, with somewhat more sophistication, explained as prestige-seeking imitation of the west. These are obviously inadequate. Who are the Americans imitating? Their inadequacy is often cloaked behind a body of incorrect beliefs about food habits, some of which beliefs are even stranger than any taboos of the developing societies. Thus the ancient Jews are credited with a fantastic prescience about the vectoring of trichinosis, and their ban on pork thus explained. It is obvious from the taboos listed in Deuteronomy that 1) ideas of sanitation and disease vectoring were exceedingly rudimentary in those days; 2) the pork taboo is part of a long list of taboos, which cover organisms as diverse as vultures and oysters, none of them particularly noted as disease vectors; 3) these taboos fall in a pattern – they all involve animals that are strange, unusual, or anomalous, e. g., in cleaving the hoof yet not chewing the cud. Clearly pork was banned for reasons other than its possible role as a trichinosis vector. Similarly, the Hindu rule against eating beef is explained simply in terms of religion, but is actually a more involved problem (Harris, 1966). The cow is protected because it is more useful alive – for traction, milk and manure. The beef *is* eaten, by lower-caste and some upper-caste individuals. Perhaps the taboo is explained in part by a need to make sure that these individuals get some protein. But, more generally, it is clear that one gets far more protein per acre by saving cows for milk, and having bullocks for plowing the fields for lentils and beans and chickpeas, than by ranching beef. Religion has thus apparently served in great measure as a sanction for hardheaded, practical economic behavior. (On these subjects, cf. Simoons, 1961, for expansion and further viewpoints.)

Anthropology has devoted some attention to these things; not surprisingly, the French are well ahead in this field (Levi-Strauss, 1964- ; Verdier, 1969, with comment by Anderson, 1970[a]). Partly in response to French activity, the British have begun work on the subject, e. g., Leach, who writes mostly on taboo rather than food per se (1964). Yet even the best recent popular books on food contain numerous errors and misinterpretations, and the amount of concrete analysis of food consumption remains exceedingly small. Sociology and psychology, in spite of their interest in man's other physical needs, pay essentially no attention to the subject.

2. Some Actual Cases

Herewith we will briefly note three cases that point up certain facets of the situation.

The Cantonese Cuisine. We have elsewhere analyzed Cantonese cooking, which we studied in Hong Kong, in some detail (Anderson and Anderson, 1969; Anderson, 1970[b]; Anderson and Anderson, ms). This is a highly traditional cuisine, the rules of which are definite and long-established. As Cantonese cooking has reached a high degree of efficiency in resource use, it provides an interesting case.

The cuisine can be analyzed as a minimax game: minimizing such factor inputs as fuel, time, effort and cooking ware, while maximizing nutrition, taste quality and the production of food; minimizing fertilizer and biocides while maximizing the yield of nutrients per acre. A few examples of the process: rice, the staple, produces more calories per acre than any other grain or indeed any other starch crop in the Cantonese climate. It is also rather high in protein and B vitamins as starch crops go, especially if it is not milled overmuch. Eaten with the rice are soybean products, the highest protein-per-acre yield of any crop in the traditional world, and a fairly complete protein at that, i. e., supplying reasonable amounts of all the amino-acids that humans cannot synthesize. Also consumed are large amounts of cabbage-related greens (high in vitamin C and other vitamins in the otherwise vitamin-poor cold season), chili peppers (high C and A), carrots and orange sweet potatoes (very high vitamin A), and fish (cheap, easily available protein). The animals raised – pigs, chickens and ducks – produce maximal protein on minimal feed. They have high conversion ratios and can be fed on scraps, or turned loose to eat the pests and weeds from the fields, saving money and time on control. The cooking process typically consists of stir-frying or steaming for brief periods on very high heat, making efficient use of time and fuel while not destroying heat-labile nutrients. Even salt is used with maximal efficiency, to pickle or preserve foods, which are added to the meal to season it to taste – salt is almost never applied separately.

Thus we find a traditional regime in equilibrium with the environment, making about the most efficient use of resources that a traditional, unmechanized peasant society can achieve.

Penang Hokkien Diet. During somewhat over seven months of research in Penang Island, Malaysia, we studied the dietary beliefs and attitudes of the Hokkien-speaking Chinese who form the largest single group in the island's population. Here we observed, among other things, the deteriorative modernization so commonly remarked on by writers elsewhere. This was most marked in child diets, but was found throughout the system. Nursing of children, formerly carried on for some years, was being limited to a year or so, depending on how "modern" the family was. The children were weaned onto rice gruel, soft sweets and sweetened condensed milk or other milk products. This diet was exceedingly high in starch and sugar, and very low in all other nutrients – even the commercial milk products being highly diluted, in practice, with sugar and water. Formerly the pattern had been to nurse the children for a longer period, gradually introducing rice gruel and other foods. Commercial, sucrose-rich sweets had not been available and fruit had been the snack food of choice. The result of this dietary change was a spectacularly high incidence of tooth decay, especially of the front teeth (incisors, spreading to canines). Such decay is rare in the U. S., where soft foods and sweets are less prevalent in the child diet, at least after the child is old enough to eat solid food. We did not observe clinical malnutrition – partly because we were studying fishing settlements, where even the youngest child gets at least some fish – but the growth rate of the children was lower than that of American or modern Japanese children. The adults in the modern Hokkien population consumed large amounts of fat, as cooking involved much deep-frying in lard. A family of six would use one-half to one pound of lard a day, and sugar, commercial sweets being very popular. A standard snack was flour-and-water noodles in soup, the soup involving much lard or very fat bacon. While not causing malnutrition, as a lot of meat and vegetables were eaten, this diet led to gross overweight and to continued tooth decay. This diet is in part traditional, the noodles especially being a famous Hokkien dish for hundreds or thousands of years, but has been changed for the worse by a combination of factors. Increased wealth of the community and increased production of meat and sugar has allowed the purchase of much more lard and sweets than could have been bought in traditional days. Why was the extra money not spent on lean meat, fruits and the like? The result is a complex social-structural problem. Lack of nutritional education is part of it, but the main part is the felt need of the community to rise in status by westernizing. This need is created by certain tensions and problems affecting the Penang Hokkien community. Long-established in Malaysia and with weakened ties to traditional Chinese culture, this group is still subject to anti-Chinese sanctions by the Malaysian government, which has in recent years been trying to raise the economic level of the Malays which form about half the population of Malaysia to that of the Chinese which constitute approximately one-third. The remaining one-sixth consists of Indians, aboriginals and Europeans. The economic and political measures taken by the government – in effect, positive discrimination toward Malays in education, government jobs, etc. – has affected the poorer segment of the Chinese community. The Hokkien of Penang have been also hard hit, by the decline of Penang as a port area. Most of the poor Chinese of Penang are members of the old, long-established, somewhat de-Sinicized Hokkien community, and most of these Hokkien are poor where other groups, notably the Cantonese, have been more successful and have remained closer to Chinese culture. The Hokkien see their position as worsening. Left with increasingly vague ties with China, no possibility of being accepted as Malays, and a sense of hopelessness over the economic situation, they have developed feelings of alienation. These have often caused, among other things, a shift in the direction of westernization – other doors to a stable cultural pattern being seen as closed. And the leading edge of westernization in the third world has been white flour, white sugar, soft drinks, candy, cookies and fat. These foods are easy to manufacture; the largest number of factories in any one industry in Malaysia is involved in food-processing, most of them in the production of these foods. In addition there is a large home industry of sweet and noodle-making. These foods are easy to store and to sell in the tiny shops so characteristic of Malayan towns and villages. On the other hand, the excellent, varied, cheap and nutritionally superior fruits that Malaysia produces are seen as both "backward", as they are produced by the more traditional rural districts, and identified with the Malays. Meanwhile, fat has been accepted as a sign of health, indeed of security; a very fat man is thought to be healthy and well-to-do, even psychologically well-off; fat children are desired. This is a considerable exaggeration of a pattern well established in Chinese culture; in old China, some flesh was desired, but not gross overweight. We feel this exaggeration of the traditional pattern is a sign of increased, even perhaps "exaggerated", need for security and reassurance.

The Health Food Syndrome in the United States. With a student, Janet Farley (ms. and pers. comm.) we have done some very preliminary investigating of the rapid shift to health foods and organic foods in the United States. These foods are exceedingly well-established in certain U. S. communities, notably the Seventh-Day Adventists, and have become essentially a part of the traditional folkways of these communities. They have recently been discovered by the young, and are now – as *Time* magazine well puts it – "the Kosher of the counter-culture." This we see as part of a pattern. Along with astrology, magic and so on, the health-food movement is a counter-science; a pseudo-scientific movement, traditional and well elaborated, with its own "authorities" and body of data, and a long heritage, much of it one of identification with the underdog or at least with the dissenter. Disillusioned with the science that has given us the nuclear bomb, the jet plane, biochemical warfare and the Nazi gas oven, the young seek an alternative science. This is in itself interesting; obviously the demons of war are not produced by science per se, but by politicians' use of it. However, American youth has been brought up to think that "Science" has given us these blessings, along with others such as cars and factories, and the idea that technology is an independent force, rather than a tool that can be used or misused, has become firmly rooted. Thus, logically, rejection of war and materialism means rejection of the science that produced it. Specifically, in regard to food, such things as store-bought bread and white sugar, tasteless and overused as they are, are identified with orthodox food science, and thus good food must be sought in the alternative stream. The tasteless, textureless character of much modern food has greatly helped, since whole grain homemade bread, for example, is clearly more interesting to taste as well as theoretically more nourishing. But considerations of aesthetic quality are at best secondary.

Further work on this matter is needed, specifically to correlate involvement in the organic food movement with degree of rejection of orthodox science and other aspects of life that are felt to be in opposition to the counter-culture. (Cf. Deutsch, 1967, for the history of the organic movement and its identification with protest; Deutsch is very unfairly biased against organic foods and the book is far from the objective appraisal needed, but it is the nearest thing we have . All the literature on the subject, as far as we can ascertain, is partisan on one side or the other).

3. Directions for Future Research

Our concern is to relate food habits and patterns to other social concerns, and to explain both, or at least to understand them enough to allow us to make verifiable or disprovable statements about them – in short, to predict changes in food habits as related to other patterns of behavior. This involves understanding of the ecology of agriculture and diet, to prevent the gross mistakes of some developers who have tried to modernize agriculture by making peasants give up food they needed for balanced diets, or introduced changes that upset traditional production of such necessities. It also involves some understanding of the history of the society in question, specifically its economic organization and the distribution of political power within it and between neighbors and contacts.

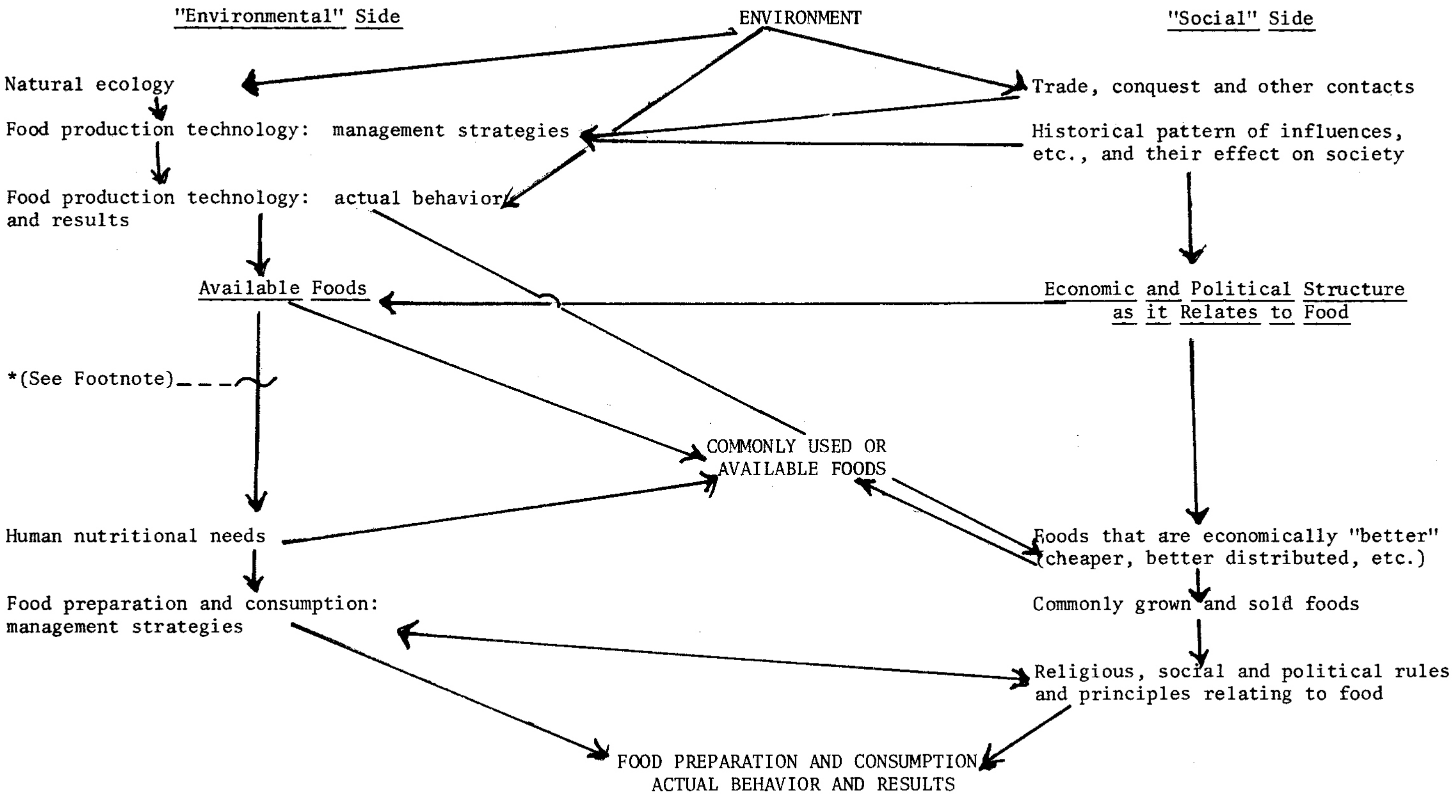
We hope, further, that nutritionists will devote more effort to establishing dietary needs and the effects of various foods and food chemicals. The current acrimonious argument over the merits of vitamin C as a cold-preventer (cf., notably, Pauling, 1970) indicates that even this long-studied and well-known chemical is poorly investigated. To us, as relatively unbiased observers, it seems that both sides are far more dogmatic than the evidence permits; statistically-significantly large samples and adequately controlled experiments are not overly abundant in the reported literature. Similar controversies, less well-publicized but none the less important, are being waged over the minimum calorie requirements of the human organism; requirements for trace minerals; toxicity of a whole range of additives and food chemicals, including naturally-occurring ones like oxalic acid; and many other things. The ratio of dogmatic statements to hard, well-controlled experimental evidence is consistently too high, and the social scientist is somewhat at a loss in evaluating needs. We are also not helped by the lack of field studies of the nutritional status and food consumption patterns of both traditional and non-traditional societies. It seems that the nutritional requirements of the rat and other laboratory rodents are far better known than those of *Homo sapiens.*

4. Very Crude Steps toward a Model

The following schematic diagram has been developed as an extremely rough beginning of a model for guiding research. It is based on a number of models (e. g., those found in the cited works by Levi-Strauss, Harris, et al.) combined and modified in light of our research. We are currently trying to refine it.

And the model concludes with the actual nutritional status of the population as well as its food habits.

It should be noted that change introduced at any point changes everything in the model. However, for convenience we have not drawn in the reverse arrows, for, for example, introducing a new crop often changes everything else as, most spectacularly, when New World food crops like maize and chili peppers were introduced to Asia. Population rose very rapidly, in part through these dietary changes, putting a strain on traditional political systems which had trouble turning out administrative personnel fast enough to govern the population. Ecosystems were stressed, for example, by the shifting -cultivation system, overloaded by increased pressure brought about by population growth. And, of course, food preparation and production were stretched.



*Many investigators believe that adaptation to available foods changes nutritional needs.

Refinement of the model is needed, especially on the "social" side, which is at present hard to quantify and in places debatable. We think we are right in relegating ideology and religion to a very minor position, but this may not be so; other workers disagree. We have also left any "instinctive" or "inborn" factors out, but they may just possibly be relevant.

5. Exhortation

This whole field of concern has grown in our minds because our research has made us more and more aware that food consumption patterns and beliefs must be understood if the world is to be fed. While food production technology is more important, and raising the incomes of the poor is certainly more important, in giving the human race an adequate diet, food consumption cannot be ignored. Some Asian countries, for example, have concentrated on rice production increase because of the belief among both public and leaders that rice is the perfect food. Since protein and certain vitamins and minerals are more generally inadequate than starch and B vitamins in the Asian diet, though starch and the B's are far from sufficient either, this has had a dubious effect – especially when growing more rice means growing less protein, as when insecticides on the rice kill stream fish, or when mechanizing rice agriculture means growing few buffaloes in an area dependent on retired plow-buffaloes for meat. Another unexpected problem was found in analysis of fishing development; we found that many tropical fishermen make their real profits from sales of high-priced "luxury" fish, and thus fishing development is hindered, through lack of capital, in areas where meat is the prestige food. We assume, contrariwise, that the livestock industry has more potential in these areas than it does where a feast means gorging on high-price seafood. Such things can affect the entire economy and are more complicated and, therefore, more interesting even than such changes in taste as the worldwide Sucrose Revolution with its legacy of carious teeth.

– E. N. Anderson, Jr.
Marja L. Anderson
University of California, Riverside

BIBLIOGRAPHY

Anderson, E. N., Jr.
1970a *"Réflexions sur la Cuisine."* L'Homme, X:122-124.
1970b *"Feed the World: A Food Tract (Part I)."* Ecology, the Journal of Cultural Transformation, no. 3:5-18.

Anderson, E. N., Jr., and Anderson, Marja L.
1969 *"Cantonese Ethnohoptology."* Ethnos, 1-4: 107-117

Gyorgy, P., and Kline, O. L. (eds.)
1970 *Malnutrition is a Problem of Ecology.* Basel: S. Karger

Harris, Marvin
1966 *"The Cultural Ecology of India's Sacred Cattle."* Current Anthropology, 7:51-66.

Leach, Edmund
1964 *"Anthropological Aspects of Language: Animal Categories and Verbal Abuse."* in New Directions in the Study of Language, ed. by Eric H. Lenneberg, Cambridge, Mass., MIT, pp. 23-63.

Lévi-Strauss, Claude
1964 *Mythologiques.* Paris: Plon. 4 vols. the last not yet published.

Pauling, Linus
1970 *Vitamin C. and the Common Cold.* San Francisco: W. H. Freeman & Co.

Simoons, Frederick J.
1961 *Eat Not This Flesh.* Madison: University of Wisconsin

United States Department of Agriculture
1969 *Food for Us All: Yearbook of Agriculture, 1969.* Washington, D. C. : Government Printing Office.

Verdier, Yvonne
1969 *"Pour une Ethnologie Culinaire."* L'Homme, IX:49-57

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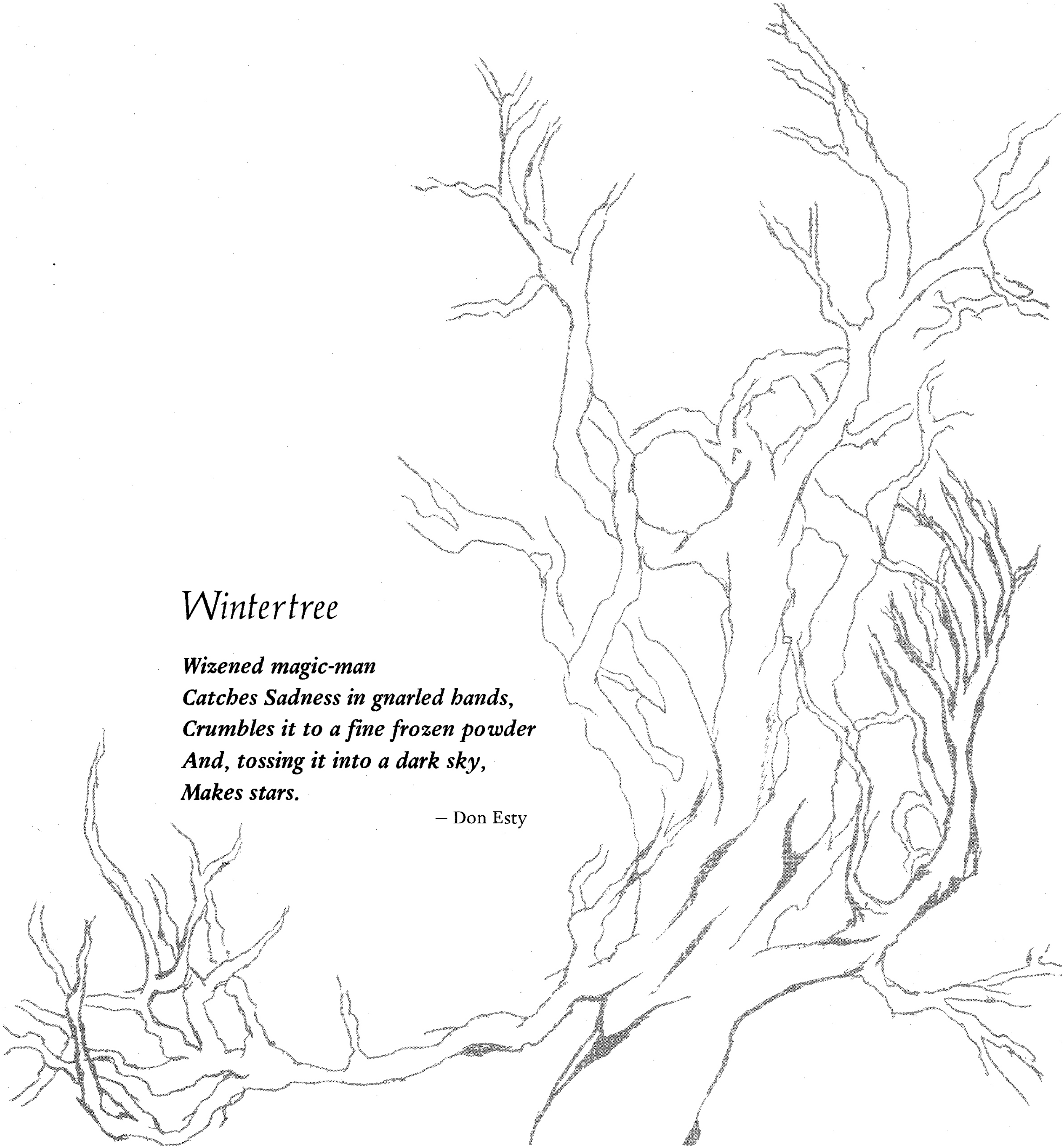

Wintertree

Wizened magic-man
Catches Sadness in gnarled hands,
Crumbles it to a fine frozen powder
And, tossing it into a dark sky,
Makes stars.

— Don Esty

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