THE BOOK OF THE NEW ALCHEMISTS


Peter Simon

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The Book of the New Alchemists

Edited by Nancy Jack Todd

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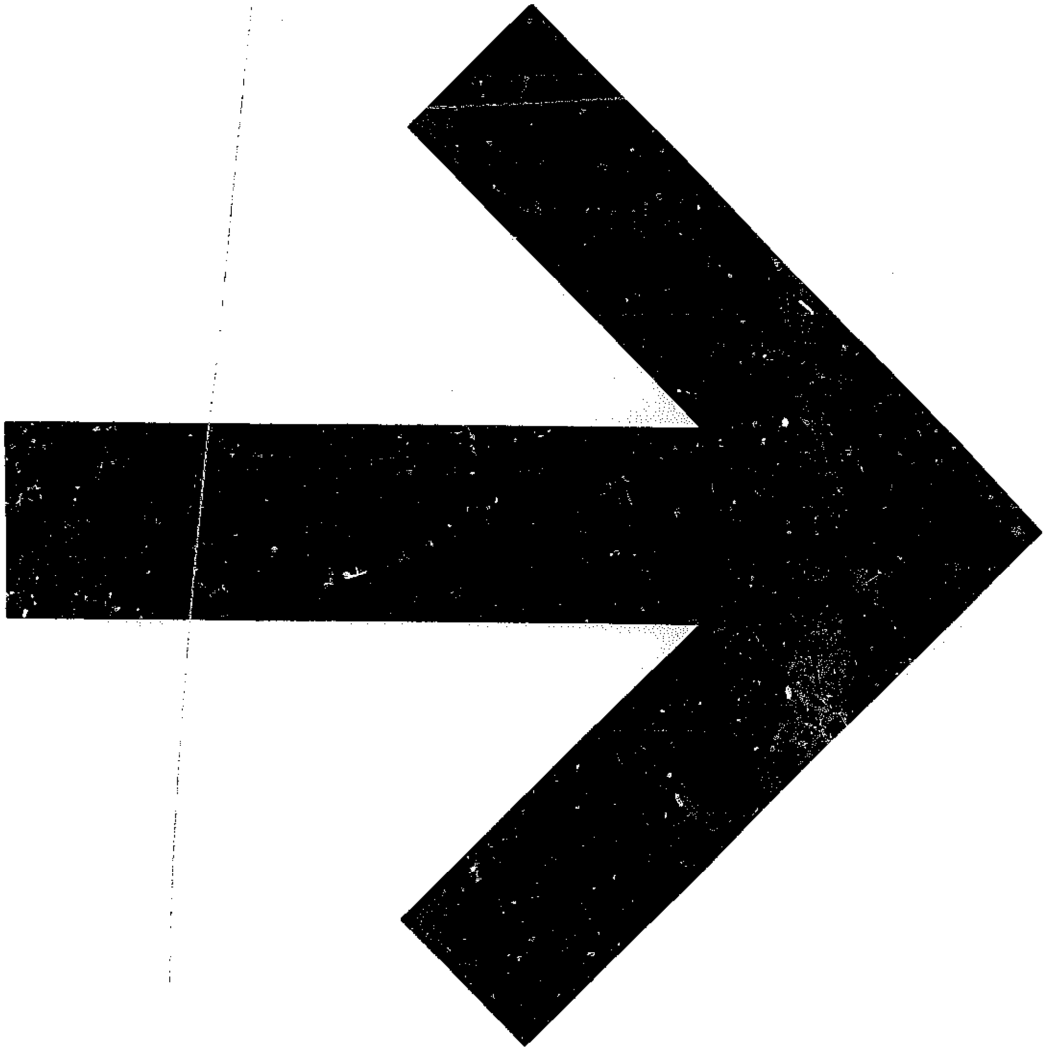

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The light has gone out
and I have been sitting here in the dark
thinking:

Is the power off or is the bulb no good?

Very nice to wander in aimless anonymity
among the metaphysics of astrological signs,
but if I can't see where I am,
how can I see where I don't want to be?

I asked Someone in the room:
did you notice that the light is out?
and Someone said: I cannot see my Self in others
until I can see my own Self.
Then I asked Another: did you notice?
and Another answered: I have to get my head straight first.

Finally I asked Everybody:
DID YOU NOTICE THAT THE LIGHT IS OUT?
but Everybody was too busy
trying to find space in the dark.

Never mind.
I will strike a match
and see.

— my

Photo by Hilde Atema Maingay

Foreword

The Two Worlds of Magic

A few years ago, a small group of artists, scientists, and thinkers concerned about the rapidity of the Earth's destruction and the impending disintegration of social and moral values, joined together to form an organization with a name of peculiar significance for our time—The New Alchemy Institute. The Institute's motto is "To Restore the Lands, Protect the Seas, and Inform the Earth's Stewards." Its members seek a world of "decentralized technology based on ecological principles" and are thus particularly interested in the creation of self-sustaining communities. Their first bulletin states, "The New Alchemists work at the lowest functional level of society on the premise that society, like the planet itself, can be no healthier than the components of which it is constructed." In stating this premise (though still in the mechanistic terms so characteristic of modern thinking), the New Alchemists are the inheritors of an old, now debased, and almost forgotten tradition. But the renewal of human concern for the mother of life, our Earth, is bringing this old tradition to light once more.

The study of ecology, if approached properly, can give the modern student of nature a new awareness of basic phenomena. We have come again to consider that life on earth consists of great and small cycles—from the majestic, rhythmic pulsations of the seasons to the metabolic and reproductive processes of plant and animal—and that all cycles are interrelated, from the huge to the microscopic. The pattern is with us constantly in the most intimate aspects of our existence: in the inhalation and exhalation of breath, the systole and diastole of blood circulation, in the continuing round of generation, birth, death, decay, and renewal of life that governs every cell of each organism. A sign of this awareness is the growing number of international scientific organizations such as the Society for Biological Rhythm Research (in the U.S.) and the Center for the Study of Fluctuating Phenomena (at the University of Florence in Italy), devoted to examining, correlating, and understanding the manifold interactions of cycles, both organic and inorganic.

This belated scientific recognition of the interrelatedness of earthly patterns and cycles is in fact a reformulation for modern times of an ancient idea: that all things on Earth are organically connected in a vast, pulsating network. Further, the Earth is an organic being, itself in turn reflecting the life of the cosmos. "What is below is above; what is inside is outside." So goes the Hermetic formula, the origin of which supposedly lies far back in Egyptian antiquity. But is probably as old as human contemplation of nature itself. This cryptically compressed magical utterance is a motif running through human thought from the preliterate nomadic religions to Taoism, Buddhism, and Jewish, Islamic, and Christian mysticism.

That the small world is the image of the great world had become such a widespread and universal belief in the past that it became a mere formula, often repeated and little understood. Such a phrase as "man, the microcosm" has, in this age of debased meanings, lost its original meaning for us. Perhaps now, in the latter part of the twentieth century when science is seeking the synthesis of life in test tubes and the secret of matter in atomic particles, it is time to remind ourselves of the power this idea has had over the human imagination.

It seems appropriate, then, to return to the past, to try to understand how people viewed the world. One of the clearest statements of the macrocosm-microcosm motif is the following from the *Zohar*, the great thirteenth-century mystical book of Judaism:

For there is not a member in the human body that does not have its counterpart in the world as a whole. For as a man's body consists of members and parts of varying rank, all acting and reacting upon one another so as to form one organism, so is it with the world at large: it consists of a hierarchy of created things, which, when they properly act and react upon each other, together form one organic body.

What holds this vast "hierarchy of created things" together in "one organic body"? Marsilio Ficino, the Renaissance Neoplatonist, drawing on the same tradition, says it is "Love." In his words, "The work of magic is a certain drawing of one thing to another by natural similitude. The parts of this world, like members of one animal, depend all on one Love, and are connected together by natural communion." Like to like—or the system of correspondences, as it was then called—also convinced Leonardo da Vinci in the sixteenth century that:

the earth has a spirit of growth; that its flesh is the soil, its bones are the successive strata of the rocks which form the mountains, its muscles are the tufa stone, its blood the springs of its waters, the lake of blood that lies about the heart is the ocean; its breathing is by the increase and decrease of the blood and its pulses, and even so in the earth is the flow and ebb of the sea. And the heat of the spirit of the world is the fire, which is spread throughout the Earth; and the dwellingplace of its creative spirit is in the fires (which in diverse parts of the earth are breathed out in baths), and sulphur mines, and in volcanoes. . . .

Giordano Bruno, that enigmatic heretic whose heliocentric cosmology fostered the Copernican revolution and caused his own death at the stake, in his obscure and ecstatic writings depicts the Earth as being alive, and the world as a beautiful animal. The underlying order of the cosmos was for him, "one circle that comprises the universe, being without bounds. . . . " And "just as in our body blood and humors run round and back, by virtue of their immanent spirit, so it happens in the world as a whole."

To complete the correspondence, the great world must also be seen in the small. Thus, according to the alchemist of the *Gloria Mundi* (1648):

> *Man is to be esteemed a little world, and in all respects he is to be compared to a world. The bones under his skin are likened to mountains, for by them is the body strengthened, even as the earth is by rocks, and the flesh is taken for earth, and the great blood vessels for great rivers, and the little ones for small streams that pour into the great rivers. . . . Whatever else may be discovered inside and outside a man, all according to its kind is compared to the world.*

"What is below is above." Tradition has it that Thrice-Great Hermes, the original master of alchemy, spoke the phrase in a dream vision later recorded in the so-called Emerald Tablet, a fragment of writing from Hellenistic times. It is this document that contains in highly compact form the whole teaching of alchemy, that abstruse and universal ritual of metallurgic transformation, frequently dismissed as a combination of medieval superstition, avarice, and mumbo jumbo. But are we really to understand this medieval preoccupation with finding the recipe for making gold from base metals as a monumental folly of bemused and befuddled prescientific minds? Or does the Hermetic formula point to a deeper meaning, one related to the present task of the New Alchemists?

The literature of alchemy is filled with extravagant and murky phrases– metaphors for the process of transformation and its ultimate goal: the green lion, the coming of the crow, the dying of the king, the philosopher's stone, *elixir vitae*, the red tincture, the homunculus, the chrysosperm, the quintessence, phoenix, hermaphrodite, white dove, fire in the stone . . . . To the unfamiliar ear and eye, the words, fantastic and colorful though they may be, seem determined to prevent any clear comprehension of the undertaking, as if the alchemists were deliberately obfuscating their endeavors to confound the merely curious. There were doubtless many who called themselves alchemists who practiced a decadent obscurantism and whose motives were corrupted by a search for unlimited wealth. And it has been all too easy for the scientific age that followed to dismiss the "Great Work" as a scheme of vulgar, greedy, half-mad charlatans. But alchemy was then a secret art. The vast number of medieval treatises on the subject did seem to obscure rather than clarify the methods of alchemy, perhaps for that very reason. It was a mystery guild that transcended religious dogmas and sects, and was practiced by Arabs, Jews, and Christians without in any way disturbing their own particular beliefs.

If we consider alchemy as its true adepts practiced it, in the light of the magical correspondences of the great and small worlds, we can understand some of the nature of the serious and ennobling quest it was. We can begin to comprehend (though dimly) the symbolic nature of those dense, highly poetic designations and epithets as a way of participating in cycles of cosmic proportions. The philosopher's stone was the transformation, purification, and redemption of matter, and the consummation of the work was indeed treasure, as the writings constantly assert. Not literal treasure however, but the "spiritual gold"—the outcome of reverent care and deep meditation on the nature of mineral changes. Since each natural object, whether animal, vegetable, or mineral, was considered a little image of the divine cosmos, and would therefore contain within it a spark of the divine spirit, the alchemists sought in their labor to liberate the highest in the lowest form of matter. Their work was the recovery of the inner essence or gold, which corresponded to the divine spirit in metals.

With our analytic and fragmenting modes of thinking today, it is difficult for us to comprehend this magical conception of the work, with its hidden and anagogical relationships of all things. If we would appreciate the quality of alchemical thought, we must understand such declarations as the following by the German alchemist, Michael Maier, as a kind of densely packed poetic utterance:

> *The sun is the image of God, the heart is the sun's image in man. . . . Gold is the sun's image in the Earth. . . . [Thus] God is known in the gold.*

The "fire in the stone" is at once God, sun, heart, gold, and fire. Artists and poets will immediately recognize this way of looking at the world. In artistic creation, debased though much of it has become, we can still see glimmerings of this mode of thought. Paul Klee was certainly imaginatively aware of this when he wrote, "the relation of art to creation is symbolic. Art is an example, just as the earthly is an example of the cosmic." And in the words of a more recent artist and philosopher, Irene Rice-Pereira, it is possible to trace the remarkable continuity of the alchemical mode. "Would it be too conjectural," she wrote in 1956, "to assume that, just as the Earth was part of the sun, and man is part of the Earth, this energy of the sun is an *internal radiating energy* in man?"

We must also seek an explanation of the alchemists' physical methods within the magical world view. Their main piece of equipment was a translucent spherical vessel called the philosopher's egg, hermetic vase, or athanor. This closed system, a microcosm, was to mirror the great world in the transmutation of matter. The vase was heated, cooled, and rotated while the various substances within were seen to undergo physical changes, which were also spiritual transformations. Dissolving, coagulating, and recombining within its sealed world, the "spiritual blood" circulated to reveal the heart of matter. The alchemist watched carefully, meditating upon the inner meaning of each change, carefully noting the ascent and descent of mercury, the volatile substance that was the model of spirit in matter. The interactions of metals in their various forms, the distillations from solid to liquid, from liquid to gas, or gas to crystal, all prayerfully tended by the alchemist, exemplified the process of purification in the soul.

But before the soul's purity could shine out in its true nature, a new synthesis had to take place. From the violent conflict of contending substances there had to come a grand reconciliation. The great theme of alchemical literature was this wedding of opposites, the "alchemical marriage" of conflicting contraries from whose union would be born the hermaphrodite. This mysterious figure, portrayed in a variety of forms and embellished with richly symbolic images, is the epitome of the alchemical art: the coming together of the masculine/feminine polarities that combine into a higher unity, a powerfully creative unity. Within the hermaphrodite the circle is completed. Here is the enigmatic meeting place of left and right, arrival and departure, movement and rest. As the blood flows through the heart and is revivified, so all change flows through this being. Like Hermes, the hermaphrodite becomes the channel between heaven and earth, the messenger between gods and men.

All the alchemist's work, prayer, and efforts were directed toward this goal: to awaken the dormant powers of nature, to reconcile her dynamic conflicts, and to assist at the birth of a new and higher consciousness. Through the hermaphrodite lay the path beyond good and evil toward liberation from contending dualities.

Alchemy at its best was a form of spiritual dialectic whose synthesis would need the separation of matter and spirit. All activity can take on a sacred value if viewed in this way. Even the most lowly and, to us, profane task can have a spiritual meaning if one performs it with such awareness. Work which today has become so despised and meaningless for many, could be transformed as in the appealing Hasidic story of the holy shoemaker whose devotion in stitching the upper leather to the lower sole was so intense that his activity became a ritual of binding the upper and lower worlds. So the profound meditation of the alchemists became a sacred ritual of reconciliation and purification. This was the gold into which base metals were transformed. This was the coming together of earth and heaven, the completion of the circle of perfection.

If there are those like the New Alchemists who can restore this forgotten sacred vision to our impoverished awareness, then there is hope for a renewal of the earth. Without the vision and the love it brings, all such labors remain meaningless.

—Betty Roszak

Berkeley, Calif.

INTRODUCTION

The New Alchemy Institute was born during the 1969-70 academic year. It originated partially in a series of evening seminars held by John Todd and Bill McLarney for their biology students at San Diego State College. Because the seminars were concerned with environmental deterioration and damage to biological systems, they were well attended by students, staff, and often by other interested people. The talk would last long into the night, well after the formal seminars were over and most of the people had gone home—after whatever particular horror story that had been presented that evening had been discussed (or despaired over). A question that arose repeatedly in those late hours, before people drifted off, was: Could anything be done? And if so, what could we—what could anyone—do to alter what seemed to be the almost inevitably tragic fate of a civilization that had violated the biological bounds that bind all life? The evidence we had been hearing was gloomy indeed. There were high levels of air pollution; because the smog in Los Angeles was so bad much of the time, children were sometimes asked not to run. We listened to reports on the omnipresence of DDT and the nitrate contamination of ground water from fertilizer run-off, the dangers of radioactivity, the poisoning of the oceans, and threatened and extinct species of plants and animals. Like themes in a piece of music, the environmental dangers were interwoven against the political, economic, and social matrix of that time, as they are today. The major difference between then and now is that we have advanced in time without a fundamental shift in paradigm, yet the themes continue and, as in a symphony, become louder and more strident as they move toward the crescendo. The time remaining to us to introduce new themes diminishes.

The question we finally came to one night in San Diego was: Is it too late? Did any one of us, or anyone that we respected, have compelling evidence that there would simply be no use in making some effort, however tenuous, to swim against the main current of modern technological society? As none of us had reached such a point of utter hopelessness, we gradually began to formulate a few ideas of what might be done. From this somewhat contradictory construct of intellectual pessimism and glandular optimism, we formed a group and called our quixotic gesture New Alchemy.

The reason for the name has been well explained by Betty Roszak in her foreword. At the time that it first occurred to John Todd, we had little conscious knowledge of its full implications. Our understanding then was that in order to change what to us, and to many wiser people, seemed the disastrous course of modern society, there had to be basic changes in its structure, that merely changing the coefficients or substituting one technological fix or large-scale energy source for another was not the answer. The transformation or alchemy had to be more fundamental. People once again had to be given control over those necessities upon which their lives depend—access to food, shelter, and energy, and to an environment not poisoned by industrial wastes.

We accepted the precepts of a finite biosphere containing finite resources and of a rapidly expanding human population drawing upon it. Insatiable consumption of its nonrenewable resources and destruction of the biological support base seemed senseless. We began to examine the fundamental needs of people, the basics with which they sustain themselves, and to ask if there might be alternatives to the present energy-dependent methods. By that time, the back-to-the-land-movement was well in process and many of the rural communes were already reporting casualties, which were frequently caused by naïveté on the part of many of the idealistic participants about living without the buffer of modern technology between themselves and the harsher realities of the natural world. We knew that answers could not be simplistic as we began to look at questions of human food, shelter, and sources of energy. Gradually, we began to articulate the question that is at the essence of New Alchemy: Are there biological analogues by which human populations might sustain themselves other than the present exploitive, dangerous, and biologically insupportable technologies? Could humanity ever hope to coexist in a mutually supportive and beneficial way within the biosphere, or are we fated to partial or complete self-destruction, taking many other forms of life to extinction with us?

There is another aspect of the story of the beginnings of New Alchemy in San Diego. Even in those days we were mindful of what Stewart Brand has referred to as our talk/do ratio. Concurrent with the seminars, we participated in a series of field trips to a ranch in the dry, hilly country southeast of the city, just above the Mexican border. The field trips had the orthodox purpose of furthering the biological education of the students through immediate involvement with the environment; they were prompted by another, less-official reason as well. The ranch was being rented by friends who were interested in homesteading, and we hoped that some of the information obtained would be of practical use to them.

As the studies proceeded, it became apparent that for all the theoretical and biological education of the group it did not include the knowledge of how to sustain people in such a difficult, arid environment. Unlike the long-banished Indians, these academics did not know what or where to plant, or how to look for food and water. We initiated a more intense study with every student undertaking to examine some part of the environment in detail. Soil and soil animals, insects, plants, shrubs, rocks, trees, and birds were collected, studied, and catalogued. Very slowly some pattern began to emerge. Midway up a small gorge we found a plant, the roots of which are known to seek out moisture, indicating the presence of of a hidden spring. Below, where the gorge began to flatten out, there was a live oak tree with an association of plants that included miner's lettuce, which we knew to require good soil. With the discovery of water and suitable soil, agriculture became a possibility. And if fish ponds were to be made to link the two, then food self-sufficiency and an agricultural ecosystem were within reach.

The story has an abrupt but pointed conclusion. As excitement began to stir over these newly discovered possibilities, the landlady arrived and, in a variation on one of the themes of classic melodrama, announced to our gentle, long-haired friends that she was raising the rent. The increase was more than they could afford and so they were forced off the land. Even before they departed, the bulldozers had appeared on the crest of the hill to begin the leveling for yet another colony of southern California weekend cottages.

What remained with us from this experience as we crossed the continent and resettled on Cape Cod has been fundamental to New Alchemy. We came to realize fully the necessity of the active search for biologically adaptive methods of providing for people. It is this that underlies our aquaculture and our intensive organic agriculture, our work with solar energy, windmills, and bioshelters. And our search has been rewarded with almost unnerving rapidity. Since 1969 when the question of biological analogues was first articulated, the response in our thinking has undergone a slow transition from inquiry to cautious optimism to unqualified affirmation. In the various descriptions throughout this book, culminating with the three articles on bioshelters, it should become clear that, although our work is as yet embryonic (and it must be remembered that not the smallest fraction of what has been allocated to established forms of technology, agriculture, or energy has been spent on biologically sound alternatives), the potentialities for humanity's symbiotic relationship within the natural order scarcely have been glimpsed. During the bitter winter of 1977, when schools and factories were forced to close due to the scarcity of natural gas, our bioshelters absorbed and retained solar heat, regulated their internal climates without recourse to fossil fuel, and fostered the plant, fish, and human life within them. From such early indicators—harbingers, really—we feel that, imaginatively and broadly applied and with the ethic of stewardship always implicit, the options open to us are many and varied. We have so far only scratched the surface.

There is yet another optimistic note. Through the research of Amory Lovins, a brilliant physicist working with Friends of the Earth, we have been made aware of the practical transitional steps that could take this society from here to there—from our present, almost surely fated, industrial society to one in which naturally adaptive support strategies, renewable sources of energy, and nonexploitive, appropriate technologies form the basis for human sustenance. For a clear understanding of these steps, Mr. Lovins's work should be read*; the fundamentals include an end to the profligate waste we practice on every level and the adoption of an ethic of conservation in its highest and broadest sense. Particularly in North America, broadly applied conservation could come close to being an interim panacea for many of our potential shortages and misallocations. With highly discretionary use of remaining limited resources and a serious dedication to research in appropriate and biologically adaptive technologies and life support systems, a path through the almost overwhelmingly bewildering haze of the future becomes discernible. We do not believe we are fated to close this chapter in the history of humanity or the planet with either a bang or a whimper. If we do so it will be because we have chosen, through lack of will or imagination or love, not to act. We have become convinced that humanity does indeed have a future. We are, in fact, to quote Mr. Lovins quoting Pogo, "confronted with insurmountable opportunities."

What we at New Alchemy do not and cannot know is whether such a path will be chosen. We do not know, as Richard Falk once asked, whether there will be a sufficiently widespread change of consciousness soon enough to affect the course of national and world events. This is not an answer that we, as New Alchemists, can bring to our point in history. What we are doing is following a

*Most pertinent to this writing is "Energy Strategy: The Road Not Taken," *Foreign Affairs* 55 (October 1976): 65–96; also available in *Not Man Apart*, the journal of the Friends of the Earth, November 1976. Lovins's books include *World Energy Strategies* (Berkeley: Friends of the Earth, 1975) and *Non-Nuclear Futures* (with John Price) (Berkeley: Friends of the Earth, 1975). *Soft Energy Paths* is forthcoming from Friends of the Earth.

Photo by John Todd

path that is becoming increasingly clear to us. We would entrust our lives and those of our children to it. We can only proffer to people in general as Robert Frost once said, "You come too."

Implicit in the course we have chosen to follow is the hope that, like the karma yogis whose wisdom is extended and actualized through their acts, there may someday be found for humanity a renewed sense of place within the larger workings of the biosphere, and that we may, in Gary Snyder's phrase, learn "to live lightly on the earth." Biology for us has become a metaphor for the rediscovery of harmony between humanity and the Earth. And whether coincidentally or not, such a sense of the earth as an organic entity with its rhythms, systems, cycles, and interactions has lately taken on a new credance and scientific respectability. Lynn Margulis of Boston University and James Lovelock, a British scientist, have recently put forth a theory that they have named the "Gaia hypothesis," after the Greek earth goddess. They are entertaining the possibility of viewing the biosphere as being comparable to a single organism, able to control at least the temperature of the Earth's surface and the composition of the atmosphere. This led to the formulation of the proposition that living matter, the air, the oceans, and land surfaces are part of a giant system, which is able to control temperature, the composition of the air and sea, the pH of the soil, and so on—all in order to create the optimum conditions for the survival of the biosphere. Although it is difficult to assess the result of massive human interference with the ecology of the whole, the future human role may be critical to the stability and even the survival of the biosphere.

We do not as yet know whether this hypothesis will have more than symbolic value but, as the alchemists long ago saw the patterns of the whole mirrored in the particular, perhaps it is the destination of these present generations to seek, on our own planet, a reflection of that universal order evident in the stars.

—Nancy Jack Todd

A Modest Proposal

I HAVE been assured by a very knowing American *of my Acquaintance in* London; *that a young healthy Child, well nursed, is, at a Year old, a most delicious, nourishing, and wholesome Food. . . . I GRANT this Food will be somewhat dear, and therefore very* proper for landlords; *who, as they have already devoured most of the Parents, seem to have the best Title to the Children.*

—Jonathan Swift, 1729

Humanity's Future Is Threatened by a Loss of Biological and Social Diversity. To Counter This, a New Biotechnology Is Proposed.

"A Modest Proposal," by John Todd, was among the first of New Alchemy's writings to be published and distributed. Since 1970, when it was written, it has been translated into almost all the European languages as well as Japanese. It remains, with the exception of the treatise coauthored by Bill McLarney entitled "Aquaculture," the most widely read and frequently republished work by a New Alchemist.

It is included in this book for several reasons. No collection of New Alchemy writings would seem quite complete without it. But more to the point, it is the best expression of the philosophy and purpose of the group at the time of its founding. It should be remembered when reading it that many problems that are commonly acknowledged today were then largely unforeseen—even though much of the handwriting in such areas as environmental degradation and overkill in world armaments was already quite legibly on the wall for those willing to read it. The "green revolution" was still being hailed as the panacea for a hungry world. The lack of diversity in agriculture or in ecosystems had not been seen as threatening. In fact, the danger of a narrowed genetic base in plants to the provision of human food has yet to be recognized. Further, the specter of the energy crises that we have since experienced was not then a part of public consciousness. "A Modest Proposal" provides a philosophical, ecological, and political backdrop against which the other articles in the book may be read.

—Nancy Jack Todd

There is a single overview that is increasingly dominating human affairs, while diversity and indigenous approaches are being set aside with the flourishing of modern science and technology. If the present trend continues, the world community will be shaped into a series of highly planned megalopolises, which are regulated by an advanced technology and fed by a mechanized and chemically sanitized agriculture.[1] This future course is countered largely by the tenacity of many peoples throughout the world, including some of the Indians of North America, marginal and peasant farmers, traditional craftsmen, and many of the young seeking alternatives to the modern industrial state. However, national and international agencies and business enterprises are vigorously attempting to raise the standard of living of most of these peoples and incorporate them into the framework of the dominant societies. The rapid influx of populations into urban areas indicates that these attempts are successful in at least one respect, namely that the numbers and impact of those who live apart from the mainstream of society is constantly being reduced. The world is rapidly becoming more homogeneous and therein may lie one of the most serious problems confronting modern man.

It is my contention that we are in danger of losing an important amount of social variability in the human community at the same time as we are losing the required amount of biological variability in our life-support bases. If we continue on our present path at the present rate, then our chances of maintaining healthy communities and environments will be dramatically reduced before the year 2000, perhaps beyond a point where society as we know it will be incapable of functioning.

Most current solutions to the immense problems facing us utilize the latest techniques of systems engineering and involve resource and social management on a previously unattainable scale.[2] Increasingly, governments and international agencies are coping with the future by planning and acting on a world-wide basis. F.A.O.'s ambitious plan known as the "Indicative World Plan for Agricultural Development" exemplifies this approach and will strongly influence, if not dictate, agricultural development in many of the poorer nations over the next quarter century.[3] There are a number of dangers built into top-down management at national or supranational levels as progressively fewer people are going to be making more and more of the recommendations. This could lead to a lessening of the representation of people and points of view involved in shaping society, particularly if systems specialists take it upon themselves to select the inputs and come up with the answers to future planning. Unfortunately, there is no guarantee that the methods currently in vogue will do any more than identify the crises that are piling up, and if important social or environmental variables are omitted, then these plans may actually aggravate our problems. Equally sobering is the very real possibility that most of the solutions to problems now confronting us will lead to a further loss of social and biological diversity. Since we cannot afford to risk survival in this way, the time has come for science to begin to carve out alternatives, even if they are antithetic to society's dominant emphases.

A few years ago the New Alchemists began their search for ways in which science and the individual could come to the aid of humanity and the stressed planet. We shared the uneasy feeling that modern science and technology have created a false confidence in our techniques and abilities to solve problems. We were also disturbed that most futurology seemed to jeopardize the continued human survival and displayed a real ignorance of biology. It was clear from the outset that social and biological diversity needed to be protected and, if at all possible, extended.

We felt that a plan for the future should create alternatives and help counter the trend toward uniformity. It should provide immediately applicable solutions for small farmers, homesteaders, native peoples everywhere, and the young seeking ecologically sane lives, enabling them to extend their uniqueness and vitality. Our ideas could also have a beneficial impact on a wider scale if some of the concepts were incorporated into society-at-large. Perhaps they could save millions of lives during crisis periods in the highly developed states. This modest and very tentative proposal suggests a direction that society might well consider.

At the foundation of the proposal is the creation of a biotechnology, which by its very nature would:

- function most effectively at the lowest levels of society
- be comprehensible and utilizable by the poorest of peoples
- be based upon ecological rather than economic or efficiency considerations, although this would not negate the development of local eco-economies
- permit the evolution of small decentralist communities, which in turn might act as beacons for a wiser future for many of the world's population
- be created at local levels and require relatively small amounts of financial support (This would enable poorer regions or nations to embark upon the creation of indigenous biotechnologies.)

UNNATURAL SELECTION: LOSS OF DIVERSITY

It is necessary before describing a way of reviving diversity at all levels to evaluate how its loss threatens our future. If an extremely wise ecologist-philosopher from another planet were commissioned to investigate earth he would be dismayed at the outset by our nuclear weaponry and our inability to reach a genuine arms agreement. In fact, he might drop the assignment and leave immediately for fear of his life. If he was daring enough to remain, his confidence in our future would be further shattered by the tendency of the dominant societies, whether "communist" or "capitalist," to be constantly selecting the most efficient or profitable ways of doing things, since the bases for judgment within both political systems are too narrow and short-lived. Our ecologist would ascertain clearly that our narrow approaches are reducing our options. The problem is compounded further by the tendency to condition people to the options that remain. To him it would represent an evolutionary trap and, after his survey of energy use and agriculture was completed, he would confidently predict a major catastrophe. There would be no need to go on to industry, the university, or government, despite the fact that much ecological insanity resides in them.

Examples of unnatural selection are everywhere:

For hundreds of years prior to the industrial revolution a wide variety of energy resources was used. Besides animal power and human toil there was a subtle integration of resources such as the wind and water power and a variety of fuels including peat, wood, coal, dung, vegetable starches, and animal fats.[4] This approach of integration through diversity in providing the energy for society has been replaced by an almost exclusive reliance on fossil fuels and nuclear power. Energy sources are often linked together into huge transmission grids, which provide electric power over large sections of the country. The industrial revolution took place only where there was a large scale shift to fossil fuels as an energy source. The costs to the environment and to the sustained human welfare may yet overshadow its benefits. The production of air pollutants and highly dangerous radioactive wastes continues to increase rapidly, and no downward trend is immediately in sight, despite an increased environmental awareness. Modern society, by reducing the variety of its basic energy sources while increasing its per capita energy needs, is now vulnerable to disruption on an unprecedented scale. It would be foolhardy to disregard the very real possibility of a small group of people destroying our power transmission systems. Tragically there are no widely disseminated backup sources of power available to help the majority of people in a nation hooked on massive amounts of electricity. Society was not as precariously based as this in 1776.

On the country's farmlands, changes have taken place over the last fifty years that have not yet had their full impact on the nation. The majority of the population has been displaced from relatively self-sufficient farms to be replaced by large monoculture industries capable of producing crops efficiently and relatively inexpensively. That many of the displaced farm people are on welfare or adding to the ghettos' problems is not usually considered by agricultural planners. Unfortunately, the trend is world-wide as former colonial regimes and present economic involvement of the powerful industrial nations have created a climate of uncontrolled urbanization in underdeveloped countries. There is a contemporary theory that contends that the industrial powers have contributed directly to the conditions that led to their dangerously high population levels.[5]

Proselytizers on behalf of modern agribusiness rarely consider the key role of numerous small farms as a social buffer during periods of emergency or social breakdown. This oversight could well be the result of a lack of civilian research into the needs of a major industrial nation under the stress of severe crises, despite the fact that a disaster could occur.[2] A depression of the magnitude of the one that befell the country in 1929 could well take place, but if one should happen in the 1970s the social consequences would be much more severe. In 1929, a large percentage of Americans had friends or relatives on farms that could operate on a self-sufficient basis during lean periods. Today the situation is alarmingly different as the rural buffer is largely gone and far fewer people have access to the land. The problem is compounded by the fact that today's farms have little resemblance to those of forty years ago, as the modern farm is in no way independent and like other businesses it requires large amounts of capital, machinery, and chemicals to maintain their operations.

The replacement of large rural populations, their unique social organizations, and the many small farms by agribusinesses operated primarily on the basis of short-term incentives rather than as legacies for future generations, is resulting in a tremendous increase in homogeneity in the countryside. When the land and landscapes become just another commodity, society as a whole suffers. It might not be too serious if the loss of a viable countryside was all that was threatened by modern agriculture, but a close look at present agricultural methods suggests that many of them are damaging to the environment and a loss of biological variability is rapidly taking place.

THE GREEN REVOLUTION: UNNATURAL SELECTION

Over the past several decades the agricultural sciences have created a number of major advances in food raising and the widely acclaimed green revolution has come to symbolize the power of applied science and technology working on behalf of humanity. Our confidence has been renewed that the mushrooming populations can be fed if only western agriculture can be spread rapidly enough throughout the world.[3,6] But the green revolution has not been shaped by an ecological ethic and its keenest enthusiasts are usually manufacturers of chemicals and agricultural implements backed by government officials rather than farmers and agricultural researchers, many of whom are aware of the immense complexity of stable agricultural systems. A cursory examination of the ads in a wide variety of American journals and magazines would lead one to believe that the agricultural revolution is a chemical revolution, and perhaps it basically is.

A number of biologists and agricultural authorities are cautious about the future, since they foresee environmental decimation that will offset the agricultural gains before the turn of the century.[7-9] Among some of them there is a disquieting feeling that we are witnessing the agricultural equivalent of the launching of the *Titanic*, only this time there are several billion passengers.

The modernization of agriculture has resulted in the large scale use of chemical fertilizers upon which many of the new high-yielding strains of grains depend. Coupled with this is a basic emphasis on single cash crops, which are grown on increasingly large tracts of land. The dependency on fertilizers for successful crops has created depressed soil faunas and an alarming increase in nitrates in the ground waters in some areas. The nitrate levels are often above the safety limits set by the U.S. Public Health Service for infants drinking water.[7]

Along with the widespread use of chemical fertilizers has been the rapid increase of biocides to control pests and weeds. These substances, particularly the chlorinated hydrocarbons, but also the shorter-lived organophosphates, are altering ecosystems and have the potential to threaten their stability. The use of weed killers and pesticides has reduced the number of species of soil animals in many farm fields, with subsequent reductions in the quality of humus that is essential to the sustained health of soils.[10] Unfortunately, these changes are occurring just as we are beginning to discover how much the soil fauna, particularly the earthworms, contribute to plant growth and health.[11] The use of biocides has triggered a vicious cycle; soils decline in quality, which in turn makes crops more vulnerable to attack by pests or disease organisms. This creates a need for increasingly large amounts of pesticides and fungicides for agricultural production to be sustained.

The full impact of biocides has yet to come. It is as if ecology and agriculture represent a modern Janus in their antithetic stances. While a team of ecologists has recently announced that the full impact of DDT often does not show up in long-lived birds, predatory animals, and man for 25 years after application,[12] agricultural planners confidently predict a 600 percent increase in the use of pesticides in the underdeveloped world over the next few years.[8,13] By the year 2000 the developing nations, as the beneficiaries of an uncontrolled experiment, will have reason to resent the blessings of modern technology.

The most notable achievement of the green revolution has been the creation of new, high-yield strains of rice, wheat and corn.[14] World agriculture has in the space of a few years been made more efficient, and in the short run, more productive because of these super grains, particularly the Mexican semi-dwarf varieties of wheat. They represent a triumph of the modern plant breeder's art, but they are in no way a panacea to the world food shortage. The grain revolution has an Achilles heel; the new varieties, grown on increasingly vast acreages, are causing the rapid extinction of older varieties and a decline in diversity of the germ plasm in nature. The genetic variability, which initially enabled the new types to be created, is threatened, and the very foundation of the new agriculture is being eroded. In Turkey and Ethiopia thousands of local wheats have become extinct over the last several decades and the phenomenon is widespread.[15] It is possible that the genetic variability of wheats could be irreplaceably lost and Erna Bennett of F.A.O. has stated recently that "the world is beleagured as far as its genetic resources are concerned."[15] Some of the most influential agricultural experts are deeply aware of the problem and are attempting to create the necessary "gene banks" before it is too late. It has been suggested that the race to save our genetic resources may be hampered by another biological fact of life, namely that seed storage may not be enough as "reserves" of the original microclimates, and ecosystems may be required if the viability of the local strains are to be maintained.[16]

The trend away from cultivating local varieties to a few higher yielding forms is placing much of the world's population out on a limb. If the new varieties are attacked by pathogens the consequences could be world-wide, rather than local, and plant breeders may not be able to create new strains before it is too late. Such events are not without precedent. An earlier counterpart of the green revolution occurred in Ireland in the eighteenth century with the introduction of the Irish potato from the western hemisphere.[13] Production of food dramatically increased and by 1835 a population explosion had taken place as a result of the land's increased carrying capacity. During the 1840s a new fungal plant disease appeared, destroying several potato crops, and one-quarter of the Irish people died of starvation. The recent devastation of coffee plants in Brazil is partly the result of their narrow genetic base and their consequent vulnerability to leaf rust disease.[15] The present corn leaf blight in the U.S. is caused by a fungus that attacks plants that carry the T gene for male sterility, and 70–90 percent of the corn hybrids carry this gene.[17] Despite heavy applications of fungicides, corn blight is spreading with heavy crop losses, and blight-resistant varieties may not be available in quantity until 1973 at the earliest.* A modern agriculture, racing one step ahead of the apocalypse, is not ecologically sane, no matter how productive, efficient, or economically sound it may seem.

There are other hidden perils associated with the modernization of agriculture,[18] but the loss of genetic diversity is perhaps the most readily analyzable example of analagous changes taking place at every level of society. Since a scientific or technological advance on one level (e.g., the super grains) may be pushing us closer to disaster on another, it is time to look carefully at the alternatives before these avenues have disappeared behind us.

THE FUTURE: AN ALTERNATIVE

The environmental dilemma is mirrored by comparable changes in the human situation. Unnatural selection is causing a loss of diversity in the human sphere and this loss may be leading toward social instability. Unlike the biosphere, society as a whole may have increased in complexity or remained fairly constant. However, the roles of most contemporary men and women grow ever more simplified as they relinquish the various tasks of living to myriads of machines and specialists. The brilliant anthropologist Levi-Strauss has shown just how far this narrowing of roles has progressed.[19] Unlike our ancestors we have little control over the creation of our power, food, clothing, or shelter and this loss may be harmful to the human psyche. This oversimplification and impoverishment of the lives of most of us could lie close to the roots of much of the chaos, violence, and disintegration that threatens modern society. Erich Fromm has suggested that violence, especially, is related to boredom[20] and it seems probable that ineffectualness and boredom are allied in this case.

Function, particularly in the twentieth century, has been replaced by social dither. The immense popularity of snowmobiles, garden "tractors", motorboats, hunting, and contact sports indicates that we have a strong need to recapture the roles of explorer, farmer, navigator, hunter-provider, and warrior. In part, these are displacement activities, attempts to regain equilibrium with the progressive specialization of most people's lives.

The individual's retreat from function and diminution of roles is a negative trend as it removes him or her from the totality of the world. By restoring and extending a genuine interaction with the life processes upon which people depend, it may be possible to reverse this

*The threat of corn blight has since abated, but the basic problem of lack of genetic diversity remains.

course. This task should begin at the lowest functional levels, at the level of the individual or the small group and their life-spaces.

A real knowledge of microcosms is essential to understanding higher levels. The basic tenant of this proposal is that to build a viable future for humankind we must begin to place emphasis on restoring microcosms in a meaningful way—be they forests, fields, small farms, or communities. If they are healthy, society as a whole will respond, and if they are ill, the human community cannot be well, no matter how much legislation, time, and money are directed toward saving it.

Fraser Darling, in his perceptive studies of remote Scottish peoples, showed how self-sufficiency was a positive force in their lives. The most independent communities were far more diverse and socially alive than the single industry towns and those heavily dependent on a life-line to the outside. He also found that they coped far better in their dealings with the world at large. Equally important, the independent communities cared for their environment and were less prone to despoil it for short term monetary gain.[21]

The first step toward countering homogeneity would be to create a biotechnology based upon an ecological ethic. This biotechnology would function at the lowest levels of society, providing inexpensive life-support bases for individual families, small farmers, or communities who desire more independence and a way of life that restores rather than destroys this fragile planet. It would not be founded upon profit or efficiency considerations but on the philosophical view that all things are interconnected and interdependent, and that the whole cannot be defined in monetary terms. Energy production, agriculture, landscapes, and communities must be tied together within individual research programs and each area should be considered as a unique entity worthy of study. From indigenous research projects would evolve a biotechnology that reflects the needs of each region and peoples. In this way it will be possible to have fantastically varied communities and landscapes, as each develops its own integration with the world around them.

The New Alchemists have begun studies to shape the skills needed to establish modern, relatively self-contained communities that capture their own power, grow their own foods, and utilize their wastes. Smaller systems, which could be adopted by suburban dwellers or any peoples interested in significant personal changes on behalf of the environment, are in the early stages of development.[9] It is our feeling that the adoption of such support systems would increase individual independence and re-establish a much-needed link with the organic world. If such a bond were created, people may begin to relate more realistically with the larger world around them. It should not be overlooked that the findings of this new biotechnology, if widely adapted, would permit a nation to function more normally during periods of hardship.

The first task of this science is to explore the little-used, ancient, nonpolluting forms of energy such as the sun and the wind, and perhaps even the waves and water currents. On a small scale it will be possible to harness and create new potentials for "old-fashioned" forms of energy. Recent technological advances in energy conversion and storage ensure the likelihood of success. It will not be the task of this biotechnology to create energy systems capable of handling the needs of large cities or industries. However, its discoveries might make decentralization or a return to the countryside more appealing.

Research on new uses for the clean energy sources should be closely linked to an ecologically based agriculture and aquaculture. With this orientation there would be no imitation of the present agricultural sciences, which are basically committed to extending the large, unstable, monoculture agricultural enterprises and increasing specialization in food production. This bioscience should focus on the creation of rich soils, and the raising of high quality plants and animals together in sophisticated polyculture schemes. Its goal would be the founding of stable and beautiful agricultural environments. Rather than being geared toward displacing people from the land, it would attempt to reverse the trend by emphasizing intensive forms of culture, more varied diets on a local basis, and nurture a love of food producing and agronomy for its own sake. Noncommercial varieties of nutritious foods would be investigated, such as many of the nuts, weeds, and berries, as each area of the country has its own set of neglected wild crops that would benefit from selective breeding.

Besides borrowing many of the research methods and insights of orthodox agriculture and ecology, food research programs should be tied directly with the community's needs and require little capital for adoption. Planting and tending of ecologically sophisticated agricultural plots will require far more training, knowledge, and labor than is needed on contemporary farms. Yet this fact should prove an asset by raising the status of those involved. Persons highly skilled in the creating of good soils and raising nourishing foods will be highly respected and emulated. To work toward restoring the landscapes should become a major intellectual and physical pursuit of the present generation.

Those who teach, investigate, and adopt the findings of this science will be deeply involved in most phases of raising of foods and the generation of power to meet their needs. Diverse multicrop food projects will add to community life by shaping exquisitely beautiful landscapes, which will be a great pleasure to live and work in. Thsese microcosms may contain within themselves some of the seeds of change for the larger society around them.

It is proposed that throughout the country centers of research and education be established and modestly funded. They should not be controlled by the universities, although affiliation in some instances might add to the variety of inputs into their development. Apart from research funding, these centers should be relatively self-sufficient and the knowledge gained be made available to all through community extension on the part of the centers' residents.

Our experiences in attempting to create a wholistic biotechnology for small communities has convinced us that many outstanding young scientists would gladly commit themselves to its development and success, for no less than our future may be at stake.

—John Todd

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Photo by John Cressey

New Alchemy

INTRODUCTION

In the late summer of 1973, a crew from the National Film Board of Canada spent several riotous weeks at the Cape Cod Center making a film under the directorship of Dorothy Todd Hénaut. The result was a short film entitled "The New Alchemists," which, if now somewhat outdated technologically, captured much of what we like like to think of as the essence of New Alchemy. There are lovely shots of gardens and flowers and children, of feasting and fishing and swimming. The most pertinent part, however, comes when Bill McLarney, who is perhaps the most quotable New Alchemist, comes as close as anything to encapsulating what might be called the New Alchemy philosophy. It happened at a time when we were all sitting in a circle on the grass being interviewed. The sultry August sun was setting, and the children had been carted off for an illicit nonorganic dinner by the assistant sound man. In the unaccustomed leisure, the atmosphere was thoughtful and contented. When questioned on his views of New Alchemy in relation to the larger picture of world events, Bill squinted into the camera and managed in a few words to summarize what all of us felt. He said:

> *Well, I don't suppose any of us is fool enough to think that we can save the world. But if each of us were to look at some of the directions we'd like to see the world go in--and then to put our own little bit of force behind one of them--and to have a hell of a good time while we're doing it, well then, that's what we should do.*

That, succinctly, is what we are trying to do. And there have been glorious times in doing it. There have been hard times, too. This section is intended as a mosaic over time of the people, the day-to-day and seasonal activities, and some of the nonscientific aspects of our work.

The First Summer

A ragged band of children hovers on the crest of the hill
whoops shrilly and is gone.
Dark heads, fair heads, brown legs flashing.

In the field below, their parents and friends
are hunched over tiny plants
transplanting them with infinite care.
They seive manure, compost, and earth for flatboxes
talking intensely with swift-moving hands.

Some are careening unsteadily behind wheelbarrows overflowing with seaweed.
Others squat on the earth between the rows of plants
weeding silently, mingling laughter and work.

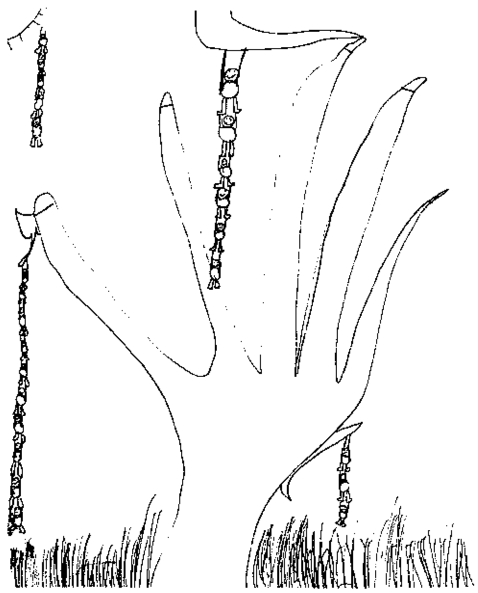
In the upper field an ancient cutter drones through the tall grass.
There is hammering from near the house.
Nearby, sweaty bodies glisten through the translucent sides of a half-finished dome.

The scream of jets overhead can shatter only momentarily
the karmic high that we share.

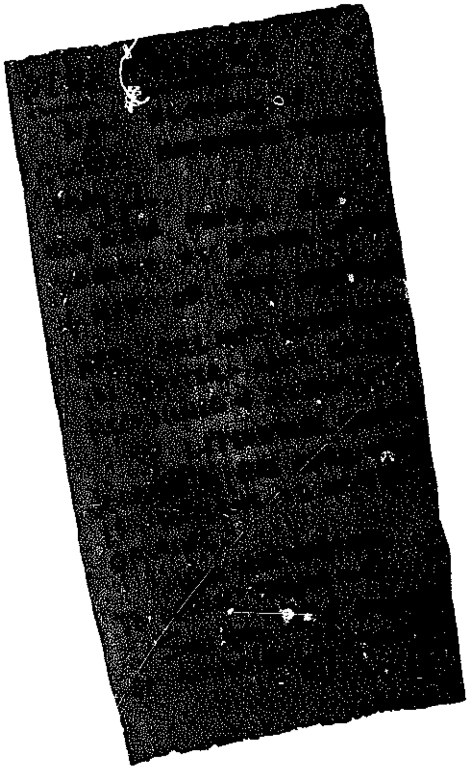
Working Saturdays on the farm
sun-drenched Sundays by the sea

that first summer.

—Nancy Jack Todd



Sven Atema



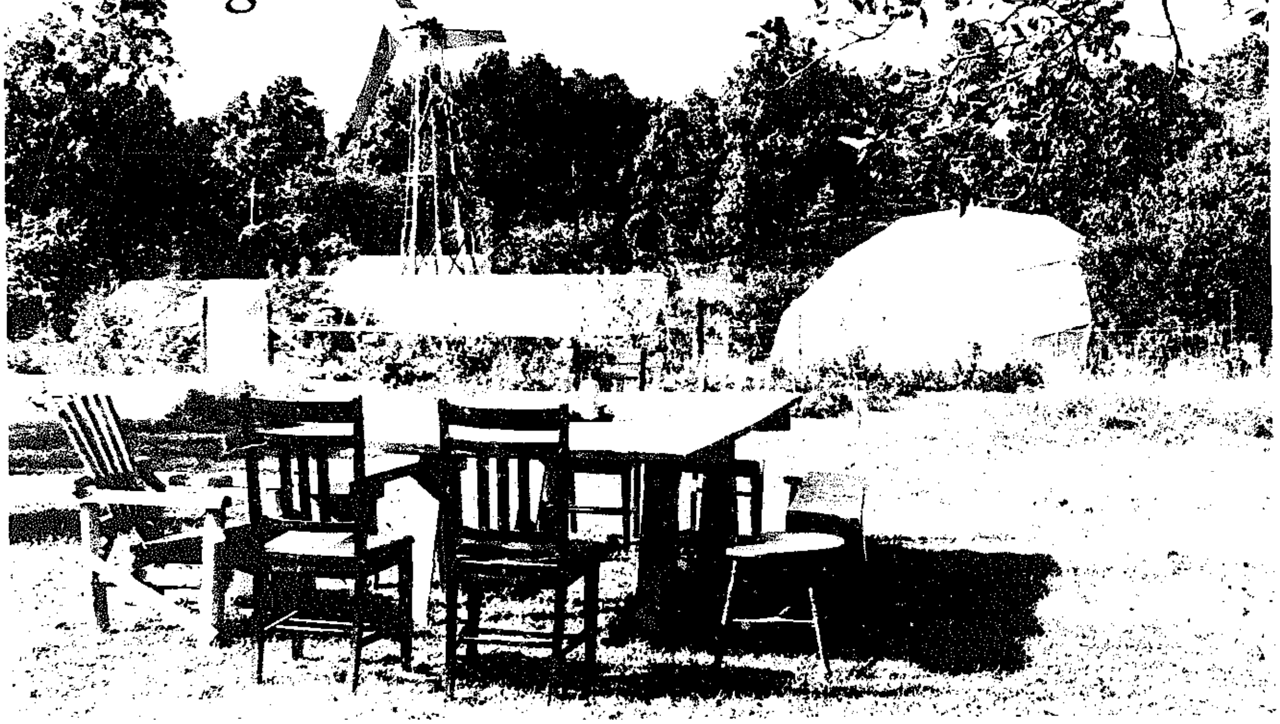
Several years ago when New Alchemy was just beginning or, at least, starting to assume a more substantial form than a small filing cabinet containing a few proposals and some correspondence, there was little in our activities that was predictable from one day to the next. What has emerged gradually, with the passing of time, is a familiar, even rather comfortable, rhythm flowing from day to day and from season to season. We have been occupied with gardens and fish and windmills for long enough to have a feeling for the scope and demands of the work so that, while the unexpected still frequently occurs, the pattern of work and meetings, visitors and Saturdays is within the realm of the known.

It is the same with the seasons. For those of us who stay at home there is the intense bright summer tapering toward the slower, rather mild, gray-brown Cape winter. For the rest of us, the New Alchemy summer is juxtaposed against other countries and cultures and our work there, related but different to that on the Cape.

But, with lengthening days and thawing ground, planting and spring rain, everyone returns and we find ourselves at the edge of another summer.

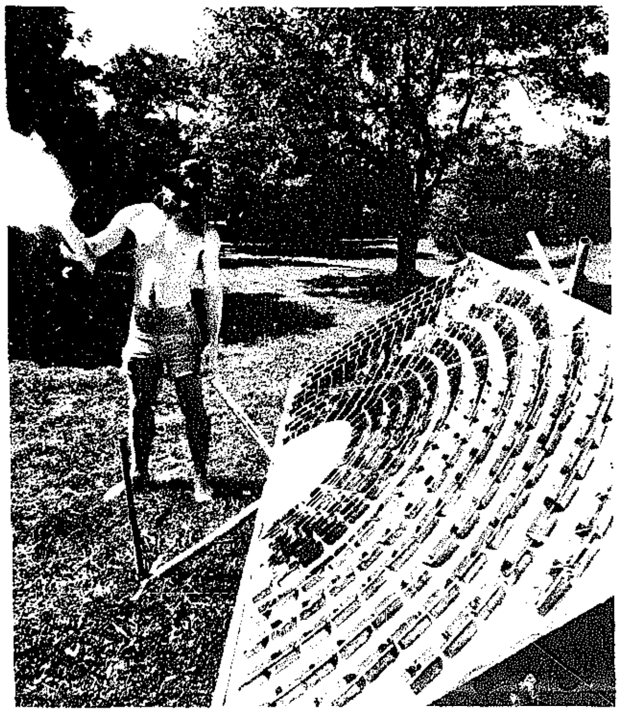
Photos by Hilde Maingay

Looking Back



In looking back over a period which is lengthening into years, enough time has passed and enough seasons changed to find oneself a bit vague as to what it was that distinguished one particular spring or summer from those that came before or after. Yet, there are always differences. The children have grown taller, the garden plots have been rotated, the sunflowers grew in a long soldierly line one year, another in a riotous field, and the apple tree did or did not bear fruit, although the mulberry always does.

The landscape, too, has changed. During our first summer, only the domes covering the fish ponds dotted the ridge that rims the gardens. By the next year, three windmills of varying sizes and shapes had taken up their positions. By the following summer, the mini-ark had been added, consisting of three shingled wedge-shaped structures, solar heater and the most elegant windmill yet, with red, wind-like sails that follow the wing. There was also a new fish pond, uncovered this time, for experimenting with white amur and Israeli carp, species of fish adapted to colder climates than the tropical tilapia can withstand. To pump water for this pond, the old oil-drum Savonius rotor was replaced by an updated, more streamlined version of itself. On the lawn behind the house, Earle's solar furnace provided another innovation. After several days of cutting tiny mirrors and mounting them on the wooden surface of the reflector, he had created, in addition to a furnace, a wonderfully psychedelic toy. Peering into it when it lay flat beneath the apple tree gave one a dizzying feeling of hanging suspended in the air, surrounded by leaves and fragmented bits of sky.



Photos by Hilde Atema Maingay

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

Died August 23, 1975.

Photo by Hilde Atema Maingay

There were other changes beyond the physical ones. Far more visitors have been coming to the farm over the past year than ever before and there have been more different kinds of people. In the main, in previous years, most of our visitors could have been loosely described as counter-culture, usually youngish, longish hair, faded jeans, etc. Recently it has become impossible to categorize, for, besides the more predictable types there are families; some with small children, some with teenagers, and some with grandparents. Gardening clubs of older people stop by. Classes of school kids, sometimes entire small schools, come. And there are homesteaders and architecture and every other kind of student, would-be dropouts from business or academe, tinkerers who just like windmills, and fellow travellers in search of a less mechanized approach to life than society at present usually affords.

To share what we do beyond ourselves has been a part of our ethical underpinnings from the beginning. For almost as long as we have had the farm on Cape Cod, farm Saturdays have been felt to be one means toward this end. Farm Saturdays began as an open, community sort of day when we invited interested people in the area to drop by. We would all work for a while, break for a great feast at noon, then stagger, replete, back to work again. But by sometime during the summer of 1974 there were too many people coming to make informal exchanges over lunch or garden labors sufficient explanation for what we were trying to do. It was then that we conceived of and instituted the "tour," which consisted of one or several of us giving a fairly lengthy description of our work, conducting visitors to and through various points of interest as we did so. But within little more than a year it was again becoming clear that there were too many people to be squeezed through the dome without losing several to the tilapia, or to be led through the others without sacrificing the plants. In our deliberation befofe the opening of the '76 season we hit upon the tactic of giving workshops.

We are pleased with this solution to date and plan to continue it because we feel it gives people both a general background and a chance to pursue a special interest in depth with more chance to have questions answered than would be possible in a single extended talk. We ask people to arrive around noon. At this time there is a general introduction on New Alchemy's background, paradigm, ideas, and work. After this we all revive with lunch. We do ask our visitors to bring food with them—something that can be shared like bread or fruit or cheese or a casserole and a bit more than they are likely to eat themselves. This way, in spite of almost perennial anxiety on our part, there is (almost) always enough food and in the general exchange people get a chance to meet each other.

The workshops proper begin after a clean-up at 1:15 to 1:30. There are usually two, sometimes three, taking place at once. The topics cover our basic areas of research and so are on various aspects of agriculture, aquaculture, energy, and bioshelters. The specific subjects in each of these areas vary from week to week. Insect resistance or agricultural forests may be discussed under agriculture, cage culture or semienclosed systems under aquaculture. There is usually an additional workshop on the social and political implications of alternatives, which can range from feminism to the opposition of nuclear power.

It is our intent that these sessions be genuine discussions and not lectures on our part. An exchange for us is a much more real and rewarding form of communication —and education.

The gardens are different each year, of course. I doubt that a garden is ever exactly the same twice. Hilde discusses this in much more detail in her article. Not only have we experienced changes in the numbers and varieties of people who visit the garden. The same applies to the insects. The cabbage butterfly, such a persistent resident in the previous years, chose largely to by-pass us last summer. Not so the squash borer who had not before been a 'regular.' As a result, we had the novel and sad experience of too few zucchini. The scourge of the garden, however, what Zorba called the 'full catastrophe', was the Mexican bean beetle. We spent days and days hand-picking the creatures off the bean plants and yet they came, like the barbarian invasions, in wave after wave. They decimated the lima beans, made pathetic, derelict stumps of the kidney beans, and, although we salvaged a few green beans, they were a mere handful in relation to the number of plants. To contemplate the cost of those beans in terms of work-hours would be unbearable. This year we are experimenting with a biological strategy for control.

This past summer saw a considerable stride forward with regard to composting. Ty Cashman, who was chief of this department, will describe his methods in more detail in his own article. This was the first year that we had someone specifically assigned to overseeing the compost pile, seeing to it that it was properly fed and brewing at all times, and the results have become markedly visible. Several of us, when giving the tour of the gardens, have adopted the tactic of gesturing toward a pile of dirt, consisting largely of sand that has been dug up for the Ark, and pointing out that this was what the soil of the entire garden had been like prior to composting. Although the technique is faintly reminiscent of television commercials, one can then draw attention to the earth in the gardens, which, if not rich black loam, has become fine, dark brown soil. People, if not already converts, are generally favourably impressed with the merits of composting.

* *

Apart from the usual run of activities that take place on the farm, there are a number of other, usually individual, preoccupations. They may be as various and as esoteric as fly-tying and ballet, batiking, compulsive all-night fishing (see the Trash Fish Cook Book) and opera. Each of them affects the common life of all of us to a greater or lesser degree. The fish catch is the main protein base for most of us for the summer. Marsha's voice floating across the grass from the house or gardens as she practises adds immensely to the enjoyment of a day. The same would have to be said of the most recent activity introduced to us by Susan Ervin, the vegetable dyeing and weaving of yarn. Susan arrived in early May and once she had settled in and the summer had begun, she could often be seen in the fields, trailed by one or more of the children, gathering plants and wild flowers for her dyes. Then there would be great steaming pots on the fire near the apple tree as Susan stirred her brew and drew dripping strands of coloured yarn from the kettle. She was working one day with a friend as a storm threatened. As it drew closer, they hovered over their pots, silhouetted with wind-whipped skirts and hair against a menacing sky, racing to finish before the rain could put out their fire. A stranger arriving at that time may well have put a more literal interpretation on our use of alchemy.

* *

One aspect to daily life at New Alchemy which, although heightened in summer is ongoing throughout most of the rest of the year, is the observation and recording of data and phenomena. Every system, biological or technical, is carefully monitored in order that we may have an accurate understanding of the efficacy of our experiments and so that we can obtain some idea as to the conditions under which various ideas may be transplanted to other environments. This puts us in a position to advise people as to the suitability of trying to raise tilapia, for example, in their area, and whether or not they would need an enclosed system to extend their growing season.

Bob Angevine keeps records of the weather, including the amount of rainfall we receive at the farm. Objective accounts of weather seem useful as it is a subject on which almost everyone is strongly opinionated and yet almost never agrees. I have heard an Englishman and a Californian issue absolutely contradictory statements about the state of the day within minutes of each other. Bob collects the data by which our readers and correspondents can judge whether what was a dry summer for us would also be considered as such for them. Actually, he tends to keep a quiet watch on all the systems, particularly with regard to their physical components, often making suggestions that dovetail simplicity of design with availability of materials. Earle watches the internal climates within our biological systems. He records and compares data from the mini-ark and the dome, checking air and water temperatures, humidity, and the turbidity of the water. The information is used for data on energy budgets and provides a basis for extrapolation of our work elsewhere. Being closely involved in the design and construction of the energy systems, he keeps an eye on the windmills, noting such things as pumping rates in relation to wind speed, and generally evaluating performance. He also has to have a realistic idea of the solar heater's capacity which involves measurements of input and output temperatures and flow. The recording and calculations, often painstaking, involved in Bill's experiments with fertile fish pond water and midge production are evident from reading his papers. His aquaculture work also involves a good deal of careful study. He has given a lot of thought to the feeding of fish, observing their preferences, the conversion ratio of various foods to growth, and the resulting yields. He is ingenious and thorough in his quest for plants that, while not commonly considered part of a fishy diet, are acceptable and nutritious to the fish – hence our marigold nibbling tilapia – supplementing, we like to think, their vitamin A requirements. Marcus has long been Bill's deputy in the midge department and gathers productivity information on the midges in the larger systems, particularly with regard to various methods of fertilization and rate of water flow in the ponds.

Knowledge of the biochemistry of the aquaculture systems is vital. John makes regular tests of their chemistry including oxygen, nitrogen, carbon and phosphorus cycles, so that any imbalance in the systems may be detected and corrected. He watches algae production and studies the systems with regard to their ability to purify and regenerate the water in the fish culture ponds. This work enables us to incorporate both microscopic and flowering plants for water purification as well as for food for the fishes, both of which are essential in intensive aquaculture. The invertebrates being cultured are watched for productivity and food needs. He is also experimenting with the ability of the algae to absorb and retain the sun's heat, with the idea of their potentialities as living solar heaters.

As countless photographs will attest, Hilde spends considerable time gathering data on her cabbages.

Arduous as it may seem every worm must be counted, its damage assessed and the health of the individual plant taken into account. Under her surveillance, too, is the state of the garden in general. She must know the chemistry of the soil, in the testing of which she gets some help from Bob, and evaluate companion planting arrangements, seasonal influences and changes, and the value of mulching and composting. With a grant from the Barnstable County Conservation Committee, Susan has launched a study of the feasibility of using Gambusia or mosquito fish in mosquito control and must record the findings of this work.

So, as data must be collected, pondered, and eventually applied, the prerequisite measuring, recording, testing and weighing are woven into our daily rounds.

* *

Bill McLarney and Bryce Butler, our bold fishermen, frequently have been described as fish freaks. This is definitely an understatement. An addiction is the mildest term that could begin to convey the passion with which they discuss, care for, study, pursue, cook, and eat fish. In spite of the fact that summer is an intensely busy time for us, once word is out that the fish are running, they know no rest. However long the work day, with the coming of dusk, they are gone. Sometimes they are not back much before dawn. Whenever they do stumble in, there is the thankless chore, all too often blithely overlooked by the rest of us, of scaling and cleaning the catch. That done, they can fall into bed for a few hours before the daily round begins again. As the summer wears on, they grow increasingly hollow-eyed, but there is little, if any, slackening in their zeal. With the night, we all know that they'll revive, the gleam will return to their eyes and, rods in hand, they'll be off again.

There are eccentricities to be borne with in all of us, however, and if one's friends must succumb to fanaticism in some form, it's preferable when it results in something you can eat. The fish that Bill and Bryce catch for us are one of our summer staples. With vegetables from the garden and the previous night's catch, it's hard not to eat well.

On the cover of the second issue of Lifestyle there appeared a rather angular figure with a shock of dark hair. The figure, outlined against the side of a dome, and leaning over a pool, was that of Bill McLarney. Although Lifestyle explained that he was engaged in feeding the fish, he was actually taking a turbidity reading of the water with a secchi disc. Dr. McLarney at work is unique. He can usually be found by following the freshest trail of beer cans or by tracking the sound of a sustained irritated mutter.

He has established some unique records since the days that he was spelling champion of Cattaraugus county for two years running. He has been photographed netting a butterfly while falling backwards down a cliff. He has been trapped, suspended by his armpits on the rim of an eight-foot fish tank when the sawhorse that he was standing on overbalanced, and he steadfastly refused to abandon the fish he had just captured.

His field work in Costa Rica, the description of which follows, was wonderfully entertaining to watch. Clad in sun hat, fisherman's vest, shorts, and running shoes he pursued his quarry through the water with Chaplinesque élan. In both his science and his writing his standards of excellence are irreproachable but being around the work actually in process is to be part of an on-going comedy.

Photos by Hilde Atema Maingay

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 house-keeping, 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.

Photo by John Cressey

There remains one more change to be related, one which evolved almost imperceptibly. In *Journal Two*, under the heading 'Preservation of Food, Preservation of Self', I described some of the difficulties we were having in distributing the domestic work which seems unhappily inevitable to almost any kind of undertaking, more equitably between the sexes. I said at that time that resentment was high among the women, largely because of the tacit assumption that housekeeping and its attendant chores should be their responsibility. I think that this is often the key to much of the problem of shifting from traditional roles for both sexes. It is less the dreariness of the work in question than the acceptance, often unconscious, on the part of the male that, whatever mess ensues in the wake of his activities, it will sooner or later be dealt with by someone other than himself. And the odds are pretty high that that someone will be female.

It is really very nice to be able to say that this is not much of a problem for us any more. There were virtually no confrontations. What began to turn the tide was our (the women) realizing the necessity for articulating our frustration. The general male reaction was not outraged indignation, but the equivalent of McLarney's "I can dig it." And so they did, for now, although our housekeeping could not be called above reproach, it is done under the rotating leadership of a housekeeper of the week, and it is up to the individual as to whether he chooses to toil alone, or in company, as long as the work is done. It hardly seems necessary to add that most of us prefer the latter.

The goal of balanced sex roles is, however, an elusive one, sometimes laden with unexpected and, for that matter, ill-fated pitfalls. The day is not won when the housework is divided. I mentioned earlier that we have adopted the practice of giving a tour on Saturdays as the best way of offering the maximum amount of information to our visitors. It somehow settled on its own time of right before lunch. This was probably because it seemed that people were ready for a break after working for the morning and that anyone planning on coming that day would have arrived by then. So a few of us would remain in the garden and start talking while the rest of us scurried up to the kitchen to start lunch. One day, as the lunch-preparing bustle was in full swing, one of us, I think it was Nancy Willis, looked around and said "Has anybody noticed-----?" We raised our eyes from our work — and there we were again — all women. By process of elimination the tour was being conducted by -------- not by us. The women's caucus gathered in the kitchen once again. That we, too, should give the tour was self-evident. In the course of the discussion, we discovered that there were some details of the biological systems and the windmill mechanics about which we felt a bit shaky. Fortunately we had among us a post-doctorate student in biology, Susan

Atlas, who was spending Saturdays with us. She would have no trouble with questions along that line. For the rest, we felt that we understood the basics and could manage one way or another. We emerged from the caucus having decided that we would monitor the tour the next week and conduct it ourselves the following one. We announced our intention to the men, who were entirely affable about it. The next Saturday we spent taking note of what was asked and making sure that we would omit none of the standard features.

And so our day came. As luck would have it, the same day brought an influx of visitors that was a galaxy of braininess, complete with a Nobel Prize and countless PhDs., most of them, ironically, biologists. It was not without qualms that we launched into a summary of our view of the world situation and the bearing of New Alchemy's work within the parameters of such a complex picture. Between us we answered most of the questions and managed to give our first tour without either disgracing ourselves or exasperating our guests. What we most need is the practice and the fine public manner that is hard to develop when addressing onself to a stove or to a small child. Still, if a bit haltingly, another hurdle has been cleared.

WHEAT HARVEST

As it had been the previous year, harvesting the wheat was one of the high points of the summer. Although one could never become blasé about the satisfaction of gathering the vegetables one has grown, there is somehow a jubilant quality about the days when we harvest wheat that is hard to account for. It is almost always hot and dusty. The shredder-grinder which we adapt for cutting the heads of the wheat from the stalks makes a horrendous racket, subduing all but the most determined conversationalists. So it is very noisy and dirty and any of us prone to allergies are driven to sniffing and coughing. Yet, for all that, there is an underlying joyous feeling that may be partly attributed to working in a ripe field and perhaps partly to the half unconscious knowledge that in harvesting and storing against the winter we are repeating a timeless act that links us to generations long before and, we hope, to those long after us.

—Nancy Jack 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

Photo by Hilde Atema Maingay

Photo by Fritz Goro

Confessions of a Novice Composter

Susan and I arrived at New Alchemy on a sunny day in May. During our first week we saw that one gap that needed filling was in the area of making more compost for the sandy garden soils. Susan had had considerable gardening experience, but I had spent the last four years closeted in libraries writing about "Nature" in 17th Century French philosophy, but as yet had never turned the soil.

As we set to work, one truth struck my keen philosophic mind at once. The difference between making humus from plants and writing a thesis on "Nature" is that in writing you do the work, in composting nature does the work. My first lesson in stewardship.

From our initial reading, we found that most compost piles take three to six months from building the heap of rough material to spreading humus on the ground. We didn't want to wait that long. Searching around, we came across a method developed at the University of California that claimed to turn out usable compost in 14 days. The recipe called for 100 lbs. manure, 100 lbs. grass clippings and 100 lbs. dried leaves. We had plenty of leaves. The previous fall, a sign had been put up at the dump nearby, directing the town's leaf dumpers to bring them round to us if they wanted to make them useful. That pile had already partly decayed over the winter. Since we have no large animals, we had to search for the manure. Cape Cod, once farming country, is now a vacation area. The only large animals around are riding horses, but there are enough of them to enable us to get the manure we needed by offering to take it away in our pickup truck.

Grass clippings were available from early summer on as lawns began to yield their harvest. We intercepted bags full of clippings at the dump. We often had substitutes for grass clippings: green weeds from the gardens as they began to grow, fish heads and entrails and scraps from Saturday potluck lunches. One day, one of our salt-water fishermen asked me if I would like some fish for the pile — the menhaden were running in vast numbers. He normally didn't fish for them, he said, but he would catch me a couple dozen if I could use them. He said the Indians of Massachusetts taught the first white settlers to bury one of these at the base of each corn stalk for fertilizer. Next morning, there they were in a plastic bag by the doorstep. I left them in the sun for half a day and was rewarded with the realization that the bacteria of decay had started their work whether I was ready or not. The menhaden were about 8 inches long and very bony. I cut them up in

Photo by Hilde Atema Maingay

thirds — head, middle, tail — and spread them throughout a pile that had been started a few days before. Two days later, we got out our pitchforks to turn the pile and were amazed to discover that we could not find the fish. I don't recall the smell as having been bad either. On the other hand, when our fishermen would take the fish guts from a night's catch and dump them on the top of the pile with a light covering of straw, there was a distinctive odor. But when dug in throughout an active pile, they seem to return to their constituent elements so quickly there is little time for offense.

Other sources of green matter were supermarkets, restaurants and a school. We came away from each visit to the supermarket with half a truckload of vegetable trimmings. When we needed it, a couple of restaurants would save their table and kitchen scraps for us. A school cafeteria provided table scraps asking only that we bring the plastic garbage cans (small ones, they get heavy) and put up a sign for the kids explaining that the food scraps should be separated from other refuse.

As the summer progressed, we were turning out a pile 4' x 8' x 8' (about 8 tons) every four weeks. The contents changed as the grasses and weeds from untilled parts of the farm were cut. These were scythed and carried to the piles. Some of the more fibrous weeds we chopped up with a machete.

The "14 day method" takes 14 days in hot California. Allowing for our colder Massachusetts nights and frequent chilly days, we called them finished in about three to four weeks. We always interlayered one-third green vegetation or garbage, one-third dried vegetation (last year's leaves, field grasses, corn stalks, etc.) and a third or less manure. We sometimes interlayered small amounts of granite dust for potassium, and rock phosphate. These we bought. If our weeds had no dirt clinging, we threw in some garden soil every couple of layers to be sure we had all the bacteria we needed.

The final ingredient was water. The pile must be kept moist but not soaking wet. One should be able to squeeze a handful and feel it quite wet, but not be able to squeeze water out of it. A pile of this type generates high heat very quickly, so it is important to be sure it stays wet enough. We usually watered ours each time we turned it.

Besides the above ingredients, the recipe calls for two operations:

For fast composting, all the matter should be shredded before piling. This is essential for quick decay. Shredding multiplies the surface area of the material by many times, giving more working surface for the bacteria. We use a commercial gasoline engine-powered shredder-grinder. You can use a rotary power lawn mower. Lay your material near a wall for a backstop and run over it several times.

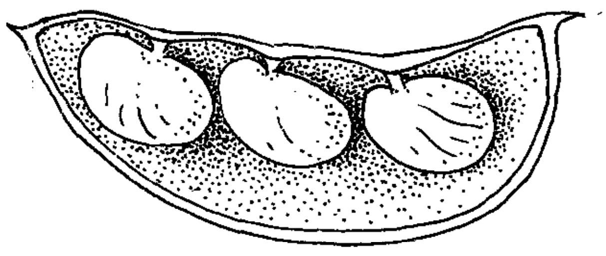
The second operation is turning the pile. The "14 day" pile is aerobic, needing lots of oxygen. When the material is forked from one spot to another all of it is exposed to oxygen. For fastest results, the pile should be turned every other day. Obviously, this method is labor intensive. You put much more muscle into a quick pile than you do into a long-term pile. But the shredded material is easy to fork and even when wet is somewhat light and crumbly. By the middle of the summer, I and those who regularly helped me with the turning were in fine shape. With three forks and two friends, the turning of the pile can be a pleasant half hour. We often did it as the last part of the day's work when the sun was slanting low over the gardens. It left us physically tired and very relaxed — a good feeling at the end of the day.

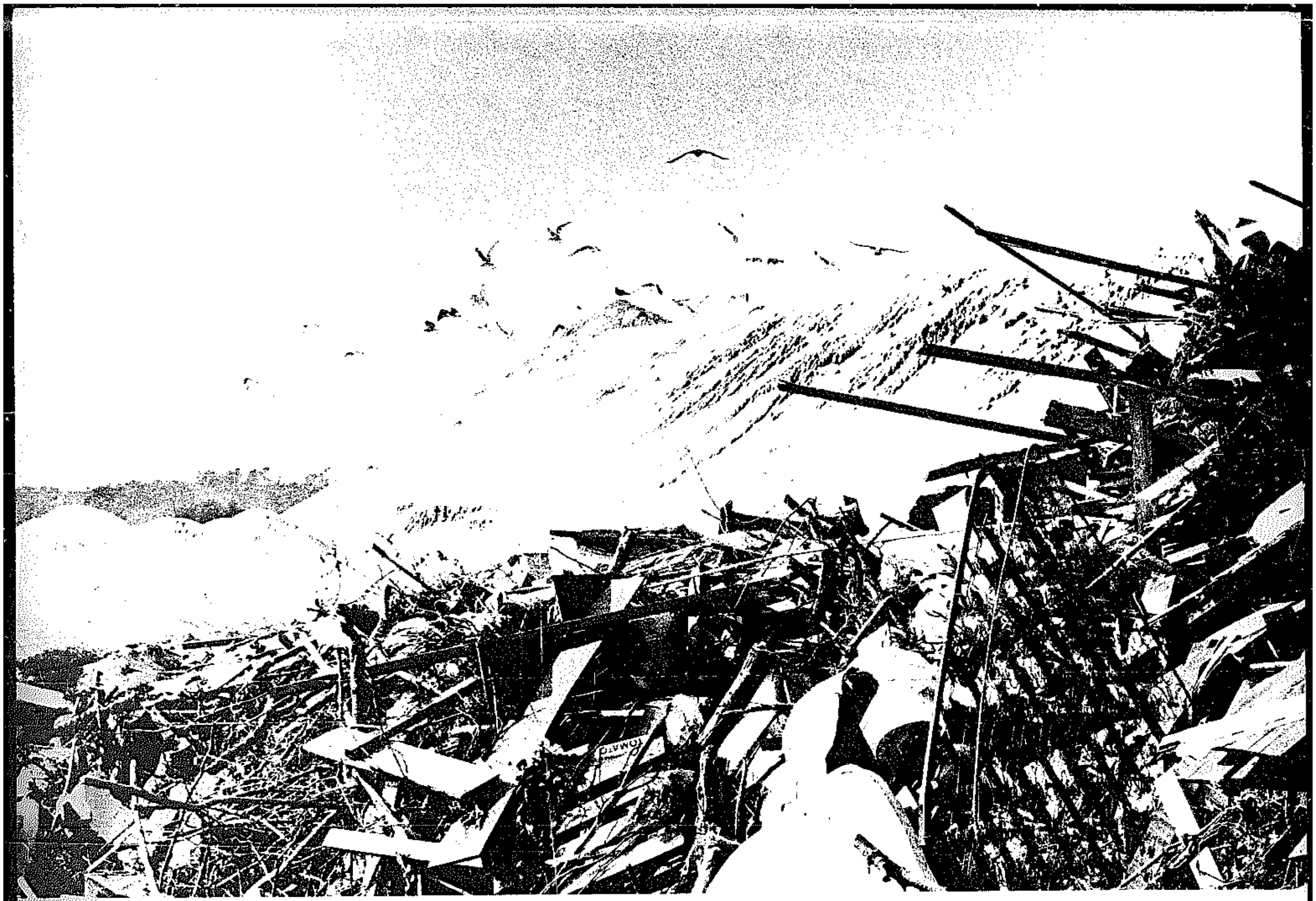
But the crowning reward of this first-time composter was the week I saw a row of beans pushing up out of the ground looking yellowish and limp. We put two or three handfuls of new compost gently around the base of each plant. It rained that night, soaking the roots with the nutrients, and within a couple of days every little bean plant was standing upright and vibrantly green.

From our experience, good compost can be made by anybody. Although no one seems to know exactly what goes on in a compost pile yet, you don't have to know exactly. Susan says that making compost is like making a casserole. You just get a feel for the ingredients. The ground leaves and dried grasses are the filler or bland part — not too active. The soppy ground-up green matter is the sauce — the protein more active. The manure is the spice — you don't need as much but it brings everything together, makes it work.

With a simple recipe, the beginner can get started (I read a total of five pages on composting before getting underway on the first pile). Once he or she has gone through the process, seen it work more or less, then a curiosity will probably develop to know what can be done with different materials in different time spans.

— Tyrone Cashman





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.

—Nancy Jack Todd

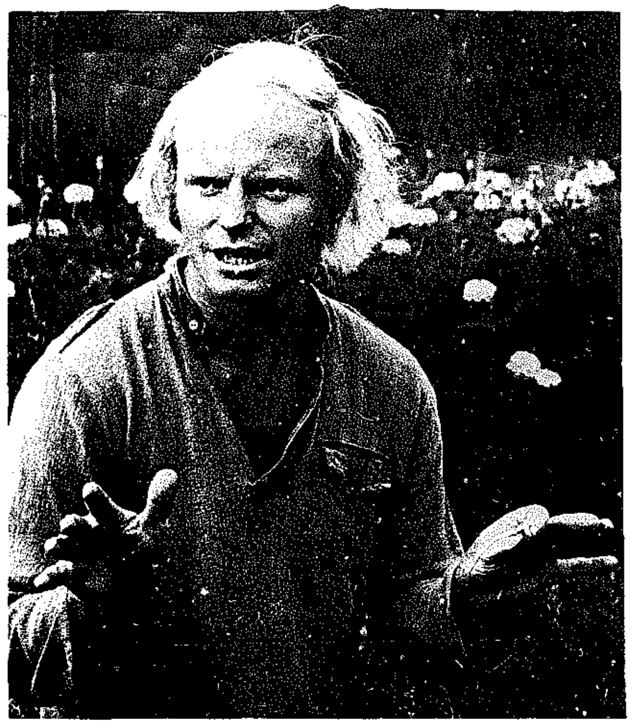


Photo by John Cressey

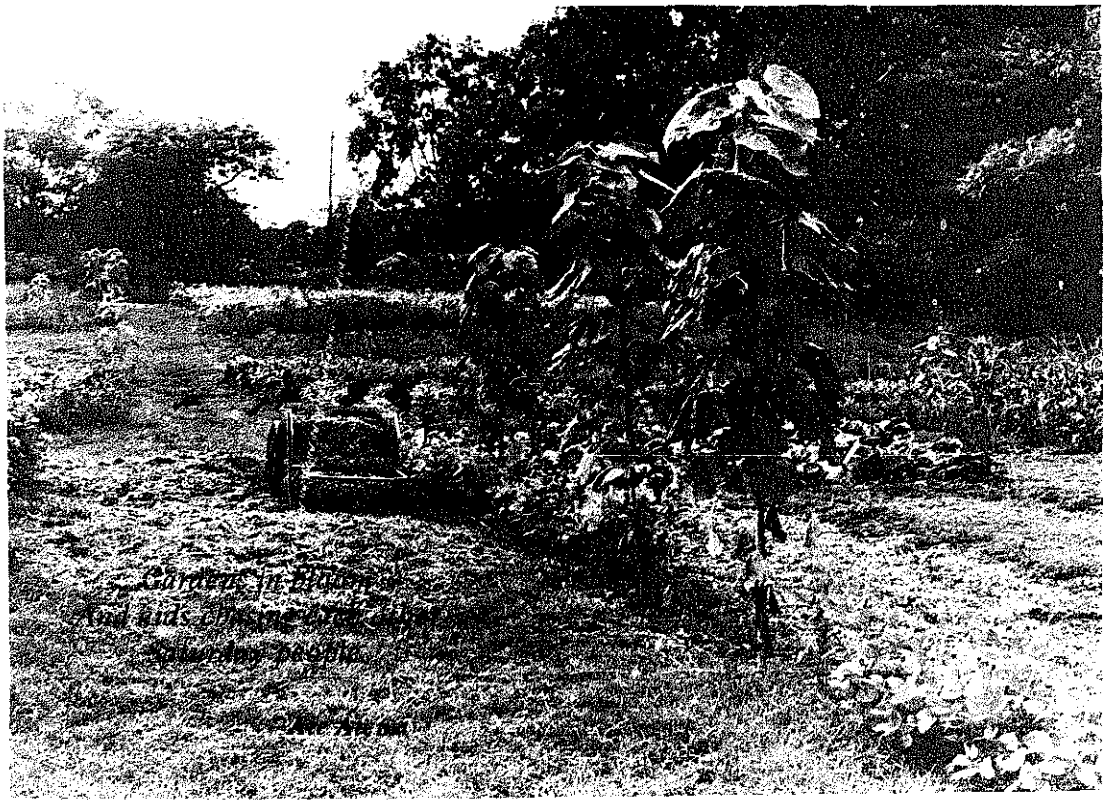


Photo by John Cressey

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

Costa Rica

INTRODUCTION

A New Alchemy farm in Costa Rica has been on our minds since our very earliest days in San Diego—prior to the incorporation of the Institute. In the earliest discussions among Bill McLarney, John and Nancy Todd, and Doug Evans we repeatedly touched on the attractions and problems of the tropical world—how very different they were from those of the temperate zone, but yet how appropriate, to our minds at least, a New Alchemy presence in the tropics would be. Since that time, all of the New Alchemists have thought and talked about the tropics and many of us have worked and traveled in tropical countries—Belize, Mexico, Nicaragua, Colombia, Haiti, Jamaica, India, Thailand, and, of course, Costa Rica.

People often ask: "*Why Costa Rica?*" One can begin by explaining the logistic difficulties of working in tropical Africa or Asia. But still, some people point out that Costa Rica is one of the most fortunate of Latin American countries. If one were really interested in the *problems* of Latin America, they say, one would work in Haiti or El Salvador or Bolivia, countries where ecological, economic, and social crisis is a daily fact of life. It is true that, in terms of such conventional measures as health, literacy, crime rate, educational level, and governmental stability, Costa Rica is ahead of most of its neighbors. So why work there?

For an American there is no Latin American country easier to work in; the generally positive attitude of the people and the lack of legal and political encumbrance permit one to get on with the work. And there *is* work. Most of the negative trends that can be observed in other tropical countries have begun there, too—runaway population growth, massive deforestation, a national emergency (according to President Daniel Oduber), the push toward monoculture crops, unthinking use of agricultural chemicals, replacement of the small farmer by the absentee landholder and the corporation, shortage of basic foods, migration to the cities, etc. It is these trends we are concerned with—wherever they occur. Finally, we are there simply because we feel that it is where we can do the most good. If we succeed, our successes can be passed on to others throughout the tropics.

The pair of articles on Costa Rica included here form an interesting contrast. The first, by John Todd, is written from the vantage point of a naturalist observer, seeing the country with its problems and potential but remaining physically uninvolved. The transition from the theoretical to the actual can be traced through Bill McLarney's account of living and working there among the people and trying to implement some of the ecologically inspired ideas that are decidedly easier to prescribe than to nudge into reality.

Restoration and Reconstruction in Costa Rica

Restoration in Guanacaste Province: *Prospects for Arid Lands*

The great contrast in the climate of Guanacaste in north-western Costa Rica plays havoc on the land once it has been deforested. The climate naturally varies from torrential rains during the wet season to weather that is blisteringly hot and arid during the long dry season.

Since Guanacaste was deforested, flash floods, extremely strong winds and beating sun have resulted in the loss of the basic fertility of the parched soils. In order to restore this region it will be necessary to stabilize some of the impact of the extreme oscillations by tempering the winds, arresting the flash floods near their sources and returning the nutrients to the soils. Much of the area will need to be replanted to trees.

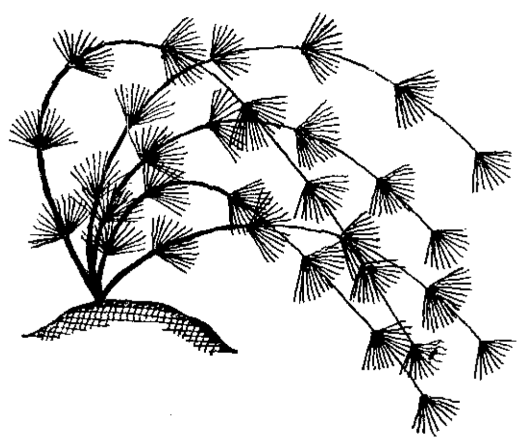
This is not an impossible challenge. A restoration scheme such as I am proposing would work best at the basic social unit, namely the individual farm. Further, a shift to a form of farming derived from ecological strategies could evolve out of existing cattle operations and there would be a place for cattle on the farms of the future. However, they would be one component out of many and they would not dominate the new farms either ecologically or economically as the farms are developed towards a more mature, stable state. The total carrying capacity of the lands would be greatly increased. Despite the diminution of the relative status of the cow on the ecological farms, in the future each individual farm could possibly sustain comparable numbers to those presently found there.

The strategy for restoration I am proposing can be briefly introduced as follows: The extreme oscillations in availability of water and the flooding could be controlled by terraced wadis, small dams and large ponds fitted to the local topography. In this way water and soils normally lost to the area would be retained. Recently discovered biological techniques may make it possible to construct ponds that will hold water even in porous soils. The ponds, enriched by animal manures, could be developed into extremely productive polyculture fish-rearing systems and the highly fertile pond water, in turn, could be released to tree crops and pastures during the dry season either through wind pumps or via ditches and aqueducts. The pond cycle can be very productive and is the key first step in restoring productive regions in arid zones. The ponds might not only permit the growth of large amounts of fishes, but pond water could also act as an important soil improvement technique by fertilizing as well as irrigating the crops. At least in the early stages this might be a critical stage in successful biological farming.

But this is not the whole task. The powerful winds which during the dry season dehydrate and blow away the top soils will need to be ameliorated by reforestation. On each farm the periphery and the hill tops should be permitted to return to wild forests which will break the winds and provide a diverse biological base. Towards the interior of the farm, meadows, pastures, ponds, tree crops and gardens should increasingly predominate. With careful planning to reduce winds in the interior, tree crops, like avocados, which now set fruit badly, or not at all, in Guanacaste because of high winds might be grown successfully. Interestingly, as the complexity of each farm increases the numbers of people needed to care for the land will grow proportionately and many people will probably decide to return from the cities to help tend the crops. Rural communities might be revived throughout the region.

Instead of beating sun and driving, dusty winds, there could be shade and moisture, and cooling breezes under the tree canopies. The rains could be enriched and stored for use during the dry season. New food chains will suggest themselves: Pond systems.... herbivorous, omnivorous and carnivorous fishes, freshwater shrimps, edible aquatic plants and perhaps even in some cases paddy rice could be grown. With water from the ponds, grasses, legumes, grains, fruit orchards, nut groves and high quality timber stands could be irrigated. Gardens, some situated in drained ponds, could be filled with a variety of vegetables, herbs and spices. Ducks, geese and chickens could be fed on the by-products and waste products. Cattle could be provided with shade and maintained on diverse pastures. As each cycle is increasingly linked over time, the productivity and self-sufficiency of each whole farm ecosystem should also climb. At the same time the cost of supporting individual farm residents would be reduced.

None of the tactics for land restoration that I am recommending be tried in Guanacaste are unique in themselves. Rain water runoff and control has been perfected in Israel, the pond cultures have been highly developed in parts of the Orient, and from Russia new information exists which could well permit water to be stored inexpensively. The importance of wild land reserves for a balanced agriculture is indicated from modern ecological studies, and the possible linkages between ponds and food crops from early New Alchemy investigations. The horticultural and forest sciences have a lot to contribute to our understanding of caring for food and timber crops. It is in the assembling of the components from very specialized disciplines into bountiful wholes that will take genius, patience and lots of plain, hard work. Here I can give only the broadest, most introductory outline of how it might be possible to make the land and its peoples flourish in Guanacaste. I intend my comments to be only the most general guides to the future.



RESTORATION BEGINS WITH THE CONTROL OF WATER AND THE BUILDING OF PONDS

The Control of Runoff

Several thousand years ago inhabitants of the Negev desert in Israel farmed using a sophisticated runoff agriculture. Villages, towns and commerce thrived because of their farming skills. How they managed to achieve the impossible and to grow in the desert fruits, wine grapes, grains, nuts and herbs described in the ancient manuscripts has remained a mystery for centuries.

The discovery of the lost desert farming techniques was made by a small group of scientists within the past few decades and their story chronicled in the book "The Negev: The Challenge of the Desert" is as incredible as it is important(10). My ideas for the control and use of runoff water in Guanacaste are primarily derived from them, and I urge those who are working in arid lands everywhere to study their book. Desert isolation forced the small band of scientists to be wholistic and basically ecological in their approaches to the land. The guiding hand of the ancients indicated that the solutions to the mysteries would come from an intimate association of the subtleties of desert ecosystems. For the desert dwellers, the simplest system they devised for capturing and using the brief and infrequent rains was through the terracing of wadis or channels of watercourses which are dry except during periods of rainfall. The low stone terraces slowed the course of the water, permitting it to sink downward into the soil. Equally important, the rich silts were prevented from being washed out of the area. Behind the terraces many of their crops, including grains, were sown.

Besides the wadis, on the more sophisticated farms with larger populations, the hillsides were terraced so that they would act as large catchments during flash floods. The terraces in these instances functioned as conduits and the whole hill provided water for irrigating bottom lands or for storage in cisterns. In the water-poor Negev desert the area of catchment to the area of cultivated fields was about 20:1. The movement of the silt in the runoff water to the crops must have played an important role in sustaining fertility.

Guanacaste is not the Negev by any stretch of imagination, nevertheless, the problems of gathering and directing water in large amounts during the rainy season are very similar. Water must be stored for the dry season and soil fertility must somehow be sustained. In order to do this water management should begin at the top of each microcatchment area just as is the case in the desert. One farm I looked at closely near Santa Cruz had steep upper slopes and the erosion had become so severe that only a few hundred feet from the hill tops the land was gutted with steep ravines. On this farm the only means of restoring it properly would be to build a series of tiny dams near the upper reaches and to lead the excess water into larger catchment areas in the fields below.

The crucial needs for water control are: 1. To avoid losing most of the water to the region; 2. To catch the soils being washed away close to their source; 3. To provide water for ponds which could be the key to restoration and soil enrichment in areas where rain is sparse or nonexistent for a large part of the year. Water storage in large ponds can provide a critical and novel approach to dry land restoration, especially in the tropics.

The Ponds

Rarely have ponds been used for water storage, silt entrapment, irrigation and aquaculture throughout the arid regions of the world for a very basic reason; namely that most desert and despoiled soils do not hold water well. In fact many such regions are characterized by stony and sandy soils. In the main Guanacaste soils appear to be ill-suited for water reservoirs. However, there may be a solution.

Very recently two Russian scientists may have found a possible answer to making porous soils impermeable to water through a study of the biological processes which take place in bogs. Bogs are ideal reservoirs because the stagnant water bottom soil complex called gley is impermeable. On the bog bottom the growth of anaerobic bacteria and the decay of plants without access to oxygen produces changes in the structure of the soil, and the ground becomes less porous. Apparently it turns greenish and blueish-grey and becomes a structureless, water-proof "plastic" mass.

The Russians were able to produce artificially bog conditions in the following way: "A layer of vegetation is spread by bulldozers on the soil surface. The best thing to use is dry vegetable matter rich in cellulose: straw, hay, weeds, potato and beet haulm, hemp waste, reed leaves and spoiled silage. The average is 6 or 8 pounds a square meter. The vegetation layer is then covered with a 6 to 8 inch protective layer of earth. Then the water is let in.

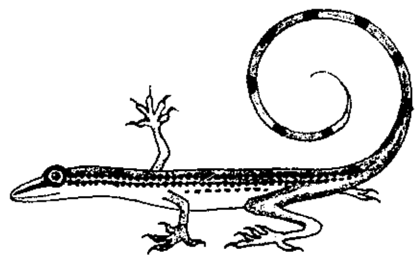
In this laminated screen, the vegetation serves as a source for the development and vital activity of anaerobic bacteria, which create the water-impermeable layer" (11).

Their discoveries, as yet little appreciated, could turn out to be one of the most beneficial findings of modern biology. They may have placed in our hands an incredible new tool that requires little in the way of capital. However, the "universality" of their findings are far from clear and it will be necessary to carry out research in Guanacaste to test if indigenous soils can be made impermeable. As yet there is no assurance that "bogs" can be established that will hold water through the dry season in Guanacaste.

Variations on the Russian experiments should be tried. One possible experiment might be to sow grasses densely on the empty dug ponds at the onset of the rains. About half way through the rainy season, when the grasses are well established, they could be mowed and the grasses be allowed to remain where they fall. Then the earth layer could be added, hopefully leaving enough time for the pond to be filled before the onset of the dry season. Several plantings and new earth layers might be required before the ponds are suitably sealed.

Ponds for the Rearing of Aquatic Animals

There is an incredible potential for the pond culture of fishes and other aquatic animals and plants in tropical climates. To overlook aquaculture would be tantamount to by-passing one of the most effective ways of coping with protein shortages in equatorial lands. In ponds it is possible to take advantage of three-dimensional space and the efficient ability of fishes and other animals to convert algae and microorganisms into edible and nutritionally valuable meat protein.



Oriental polyculturists (those who farm several species within a single pond) are able to raise as much as 8000 kg/ha (which is roughly equivalent in pounds per acre) utilizing relatively simple techniques and requiring only readily available feeds and fertilizers (12).

Certain Malaysian farms provide an interesting, more complex and productive variation on this theme. The pond becomes the key component on small self-sufficient fish-pig-plant farms; Ditches carry the manure from the pigs to the ponds. *Tilapia* and Chinese carp feed on the algae and small invertebrates which thrive in the fertile ponds. Aquatic vegetables (*Ipompoea repens*) are also grown with the fish and are harvested (hundreds of kilos daily) to feed the pigs. On a 4.4 hectare farm (approximately 10.5 acres) 3000 kgs (6600 lbs) of fish and

30,000 (66,000 lbs) of pig meat are produced annually (13). The pond in the Malaysian system provides many of the primary inputs into the farm.

The New Alchemists have begun a search for Latin American analogs to the Chinese and Malaysian systems. In South and Central America there exists a rich diversity of fishes which have been little explored for pond culture. This is particularly unfortunate, as the peoples of Central America enjoy eating fish when it is available.

Bill McLarney has recently embarked upon the lengthy task of studying Costa Rican fishes that might be suited to culturing and his first report is described in the Aquaculture section of this issue. In future issues of the JOURNAL he will continue to explore the ideas and describe the research which may lead to analogs of oriental pond cultures using native fishes in Latin America. Support for this work is being sought.

At this point I am going to propose a hypothetical polyculture scheme for Guanacaste that utilizes several native animals and one exotic already introduced for culture purposes into Costa Rica. A possible line-up is as follows: *Tilapia spp.* is the exotic in the system. Some species of *Tilapia* feed upon microscopic algae while others prefer pond plants, and all species are primarily herbivores feeding low on the food chain. The second genus of fishes that might be adaptable to pond culture is the omnivorous machaca (*Brycon sp.*) described by Bill McLarney.

Also there are catfish of the genus *Rhamdia spp.* which grow to edible size in the slower reaches of Guanacaste streams and they could well occupy a vacant niche in the polyculture ponds. Not to be overlooked is the freshwater shrimp (*Macrobrachium sp.*) which also grows to a considerable size in Guanacaste. At night the lights of shrimp fishermen can be seen as they cruise up and down the streams searching for this much-cherished animal. Shrimp command high prices.

Apart from the *Tilapia*, little is known about the potential of the fishes mentioned above and there may be others far more suitable. The culture of freshwater shrimp is still in the experimental stages, but research on the rearing of *Macrobrachium* is now going on in the Pacific and other parts of the world.

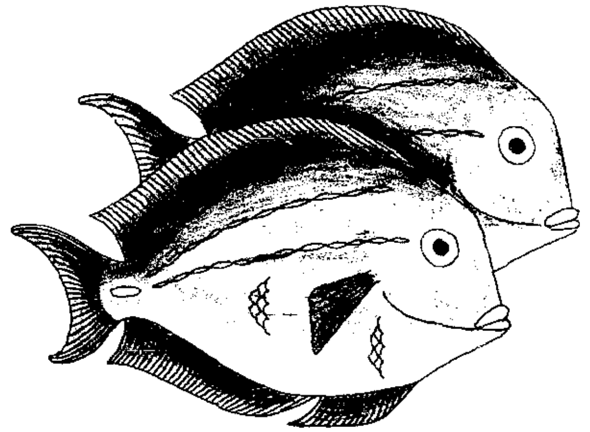
With some support and a few years of dedicated and patient study it is my contention that highly productive aquafarms could become operational in Guanacaste and other regions of Costa Rica. Such farms would provide an essential link in the reconstruction of this beautiful region.

Polyculture Ponds as a Substrate for Intensive Gardens

It should be possible to devise crop rotation schemes to take advantage of the rich pond muck produced from the fish and crustacea waste products and from the remains of algae and zooplankton (microscopic aquatic animals). If the ponds were drained for irrigation purposes after the fish were harvested, then a fertile weed and pest-free bed would be available for the intensive gardening of valuable market crops.

Polyculture Ponds for Irrigation and Fertilization

During the drier periods of the year the ponds could play a primary role in water management on Guanacaste farms. The water would be much needed for livestock and irrigation. Water could be transported by pipes, aqueducts and ditches or pumped by windmills to the pastures, gardens and tree crops. The strong winds of the area during the dry season favor the use of wind-driven systems in the flatter terrain, while along the hillsides the more traditional ditches might prove entirely adequate for the transport of water.



There is good reason to suspect that the pond waters will also add to the fertility and productivity of the soil. The water filled with dense blooms of algae, microscopic animals and their nitrogenous waste products could well act as a liquid fertilizer, especially if the polyculture ponds have been previously enriched by cattle, hog and fowl manures. A few years ago I carried out a small experiment growing parsley and lettuce under the dry conditions found in my laboratory office during the winter. Plants irrigated with water from aquaria with a high density of fishes grew faster and were larger than those grown with tap water. Bill McLarney's field trials with lettuce on Cape Cod are yielding similar results. In arid areas the fertilizing effect of the water from polyculture ponds might prove important for some crops.

Reforestation

The borders and hilltops of the ecologically-derived farms should be allowed to return to natural forests in order to stabilize internal climates and to make the farms more complete ecologically and economically. The advantages of reforestation are many. Forests break the strong winds and provide a diverse variety of plants and animals including insectivorous birds and predatory insects, which in their turn could help to keep pest populations in check. No doubt the wild forests will also house nuisance animals capable of damaging crops; however, their control might best be effected by separating the woods from the fruit and nut groves and vegetable crops by pastures and meadows. The forests might not only add to the biological stability of the farms, but they could within a few decades increasingly provide a new source of income from the selective cutting and sustained management of timber. The farms would have a continuous source of building materials and a cash crop if the woods are managed wisely. Wood as fuel is still important in Costa Rica and with petroleum shortages already a reality there, woodlots could stabilize somewhat self-sufficient farming regions by providing wood for cooking and also for the manufacture of wood alcohol for machinery that could not be run from wind-driven generators.

The forests then can be seen as another vital link in the restoration of regions like Guanacaste. They will act as windbreaks, captors of moisture, holders of the precious soils, sources of biological diversity, havens from the heat for grazing animals, sources of lumber and wood fuel, and as a home for increasingly beleaguered wildlife. Even in the tropics, reforestation, because of the time involved for a woods to become established, requires a prodigious commitment to the future, perhaps even beyond the lifetimes of many of us. But there is no meaningful alternative to this commitment and hopefully it will flourish in Costa Rica.

Stewardship and Land Restoration in the Humid Tropics

The Atlantic slope of Costa Rica, including the Rio Sarapiqui region described previously, is threatened. The agriculture and forestry of the area are primarily exploitive: forests are felled en masse for timber then the exposed areas are planted to grasses for the raising of cattle. The soils, when used as pastures, are exposed to the high temperatures and to an inordinate amount of leaching from the torrential rains, so that within a few brief years the land loses its productivity and sustains only the coarsest grasses and herbacious plants.

The exploiters for their part usually profit well from the stored fertility of the land accumulated over decades or centuries. Having withdrawn the biological capital of the region, they then move on to remaining forested regions to repeat their rapine acts upon the landscapes of the humid tropics. This is the predominant mode of land use and it represents a form of agricultural imperialism which threatens the poorer peoples who settled in these potentially bountiful regions.

But there is an alternative to the misuse of land in the humid tropics. The knowledge and techniques exist that would permit wise modes of farming a diverse array of foods while maintaining soil fertility, perhaps indefinitely. The basis for an alternative tropical agriculture is swiddening, a method of land use which evolved independently many millenia ago throughout the world's tropics. Swiddening, actually a form of gardening, has supported a great variety of human societies until modern times and the principles employed may well hold the key to the future in the wet tropics of the Americas. Modern analogs of swiddening need to be created which also incorporate some of the best findings of ecology and the forestry and agricultural sciences and new tools must be designed for unique conditions created by these analogs. If this came about, there would be a rebirth of societies highly adapted to the wet tropics. An agriculture with its origins in swiddening may perhaps be the only path for the future. It would be deeply rooted in the finest methods of the past but it would not be limited by them. We know that brilliant civilizations once flourished in the lowlands near the equator. The Mayans, for example, wrought elaborate and beautiful monoliths, sculptures and buildings and their triumph was no accident or quirk of nature. For centuries they must have farmed well, carefully heeding the processes of nature herself, and by so doing they had the health and desire to bequeath their mark upon the world.

I have wondered if the decline of the Mayan civilizations was at least in part a result of their societies becoming rigidly stratified. In the end their rulers and priests were no longer close to the soil, so they lost their direct involvement with the forces which sustained them. Decisions were made which were in conflict with nature because they no longer felt her.

SWIDDENING: A PRACTICAL AND CONCEPTUAL GUIDE TO LAND USE

Swiddening is often erroneously considered one of the crudest forms of farming, practiced by the most primitive of peoples. It is equated with cutting and burning of trees for the preparation of the land for crops. This is true but swiddening goes much deeper for in recent times it has been learned that it is one of the most subtle methods of raising foods. Its practitioners have a profound appreciation of the nature of the forest ecosystem to the point where their gardens have a structural similarity to the rainforests which surround them. Swiddening is a form of gardening which uses three-dimensional space and variations in light almost as efficiently as the oriental fish polyculturist does in his ponds.

Traditional swiddening is characterized by the rudimentary nature of the energy involved. Fire, human muscles and the simplest of tools are all that are needed. Despite this, it apparently makes light demands on individual farmers while providing almost all their dietary requirements. Further, swiddening alters the ecosystem less than any other mode of farming of comparable production.

My description of swiddening is primarily based upon the observations and researches of Roy Rappaport who observed its practice in the tropical rainforests of New Guinea by Tsembaga peoples (3).

At least 90% of the lands under a properly managed swiddening regime are allowed to lie fallow and return to secondary growth forest. Despite the fact that a tremendous amount of land is in a "wild" state, the entire Tsembaga territory supports a population density of 97 per square mile and their best lands support a density of approximately 200 persons per square mile; and they do this without degrading or despoiling the environment. (Costa Rica presently has between 95-100 persons per square mile, including San José.)

It is possible to imagine small cultivated plots intensely cropped and dotted throughout the forest. The forest itself contributes by providing its share of wild animals and hundreds of forest plants which are used in the manufacture of tools, house construction, dyes, clothing, drugs and medicines.

Since each garden is tended for at the most a few years, old gardens are frequently abandoned and each family is therefore almost always involved in the preparation and planting of new ones.

The first step in swiddening is the clearing of the underbrush and this task is carried out with machetes. This is hard work involving both sexes and takes up a considerable amount of energy. Several weeks are allowed to pass then the trees are cleared. They are felled then stripped of branches which are piled up on top of the slashed undergrowth. Trees with large trunks are left standing, while the remainder are dragged to the edge of the garden.

The felled trees are split and lashed together with vines to make a pig fence around the garden. The fences keep the domestic and wild pigs out of the garden when it is in use, and after it is abandoned the domestic pigs are often penned on the inside to root out the remaining crops.

After the fences are built the litter is burned as the weather becomes suitable. The burning is a crucial step as it eliminates the underbrush at the same time as it liberates minerals from the forest vegetation for the crops. Some of the lighter unburned logs are used for terracing to hold the soil while other logs mark the various plots.

The next stage in swiddening is the planting of the gardens. The Tsembaga people know and use some 264 varieties of edible plants from some 36 plant species. The starchy foods they commonly plant are several varieties each of taro *(Colocasia esculenta)*, sweet potato *(Ipomoea batatas)*, yams *(Dioscorea)*, cassava *(Manihot dulcis)* and bananas *(Musa sapientum)*. Several of these are fed to the pigs, and in fact each family has two gardens, one for their own consumption and another of comparable size for their pigs.

Other foods are beans (various), peas (various), maize *(Zea mays)*, sugar cane *(Saccharum officinarum)* and a diversity of leafy greens. Hibiscus leaves *(Hibiscus maniot)* are an especially important source of protein. Cucumbers, pumpkins, watercress and breadfruit are also cultured as minor crops and the flowers of the New Guinea asparagus *(Setaria palmaefolia)* and pitpit *(Saccharum edule)*, a relative of sugarcane, are relished. The fruit of one of the screw pines *(Marita)* is used as a sauce on the greens.

Although seeds are used, cuttings are the main source of planting stock and the gathering and planting of the cuttings is a very critical step. Holes are punched in the untilled ground and the cuttings or seeds are placed in the holes and covered.

The growth of the garden must represent an unbelievable sight when really well done. Here the fine art of ecological design stands out clearly. Rappoport's description illustrates applied ecology at its best in the tropics.

"In the garden, as in the forest, species are not segregated by rows or sections but are intricately intermingled, so that as they mature the garden becomes stratified and the plants make maximum use of surface area and of variations in vertical dimensions. For example, taro and sweet potato tubers mature just below the surface; the cassava root lies deeper and the yams are the deepest of all. A mat of sweet potato leaves covers the soil at ground level. The taro leaves project above this mat; the hibiscus, sugarcane and pitpit stand higher still and the fronds of the banana spread out above the rest. This intermingling does more than make the best use of a fixed volume. It also discourages plant-specific insect pests, it allows advantage to be taken of slight variations in garden habitats, it is protective of the thin tropical soils and it achieves high photosynthetic efficiency."

Weeding in the garden becomes a continual and essential task. Successive weedings are even known by specific names and they are carried out in order to uproot herbacious competitors of the crops. A fascinating fact is that tree seedlings are carefully protected and allowed to grow unimpeded, as it is recognized that soils' fertility can only be quickly restored through regenerating trees. Little trees are known to them as "duk mi" which means "mother of gardens". The presence of seedlings prevents grasses from invading and subsequently driving the ecosystem backwards to its simplest, unstable and most infertile state. Young trees capture the nutrients and reach down into the earth so that there will be fertility for future gardens.

What the swidden gardener is doing with an amazing foresight is going beyond caring for the species which feed him. The species of the forest are also cultivated and cared for as he knows that the future of his society depends upon these acts.

With the creation of a new garden every year or two the old garden is visited less frequently and it passes through the various stages on its way to becoming a forest again.

There is another interesting aspect of swiddening worth mentioning here. Professor Rappoport found that swiddening was efficient, despite the fact that it drew upon no elements of modern technology or outside sources of energy such as electricity or fossil fuels. The ratio of yields to input in the gardens is high, varying from 16:1 to 20:1. In light of the non-exploitive techniques involved this represents an efficient and productive form of earth stewardship. We have much to learn from the "primitive" gardeners in the humid tropical forests.

MODERN ANALOGS OF SWIDDENING

Modern man will never return to swiddening in the traditional way. Most people have lost the religious and social rationale for living such autonomous lives and they are far too irresistibly drawn to many of the trappings of the industrial societies to want to return to living without some of the tools and machines developed by "advanced" societies.

In a swiddening society everyone was a farmer and I do not think that farming as a universal occupation is either possible or desirable. Traditional swiddening could not be superimposed onto a contemporary tropical country without changes that would integrate it into the larger economic community. The swiddening farmer had no means of storing or transporting excess produce so cash inflow was unknown to him. His only cash crop might have been pigs, but in the case of the Tsembaga, they were slaughtered for religious festivals rather than for profit.

Nevertheless, if we are to become successful stewards of the humid tropical lowlands, we will have to draw inspiration for our efforts from traditional swiddening. In fact it is absolutely essential that the best methods of the past be emulated in designing the farms of the future. A relatively self-sufficient, modern system of swiddening could be developed which would also produce an excess of transportable foods for sale on the open markets and in my opinion this goal of creating productive and valuable farms could be accomplished without depleting the fertility of the vulnerable lowland soils.

Having been optimistic about the future, I must also introduce a strong note of caution at this juncture. Animals should definitely play an elemental role in the shaping of modern analogs, but the raising of cattle and other grazing animals should be avoided like the plague in the wet lowlands.

I do not think it was an accident that swiddening peoples in the old world raised pigs and avoided husbanding cattle. Cattle survive on grasses and in rainy tropical regions the coarse grasses can arrest the recovery of ecosystems and thereby stop or seriously hinder the regeneration of the soils (14). In fact grasses that are grazed can push ecological succession backwards, increasingly impoverishing the land. The rearing of pigs and fishes need not do any such thing and wisely managed they can play an important role in maintaining and improving the soil.

Alexander Skutch believes that one of the major reasons that civilizations of a high order flourished in the lowlands of the Americas for centuries before the European invasions was simply because the Mayans and others did not combine grazing with agriculture. I think there is genuine merit in Dr. Skutch's ideas. The raising of cattle in Costa Rica should be confined to the mountains and the drier western lands.

Swiddening, forestry and perennial food crops must provide the foundation of agriculture in the wet lowlands. It would be wise to superimpose upon these aquaculture and the rearing of pigs and fowl. These animals can be optimally raised in these regions and will add to the efficiency and profitability of the farms. Only very small pastures should be permitted so that draft animals and the family milk cow can have a place to graze.

A Biologically-Derived Farm for the Wet Tropics

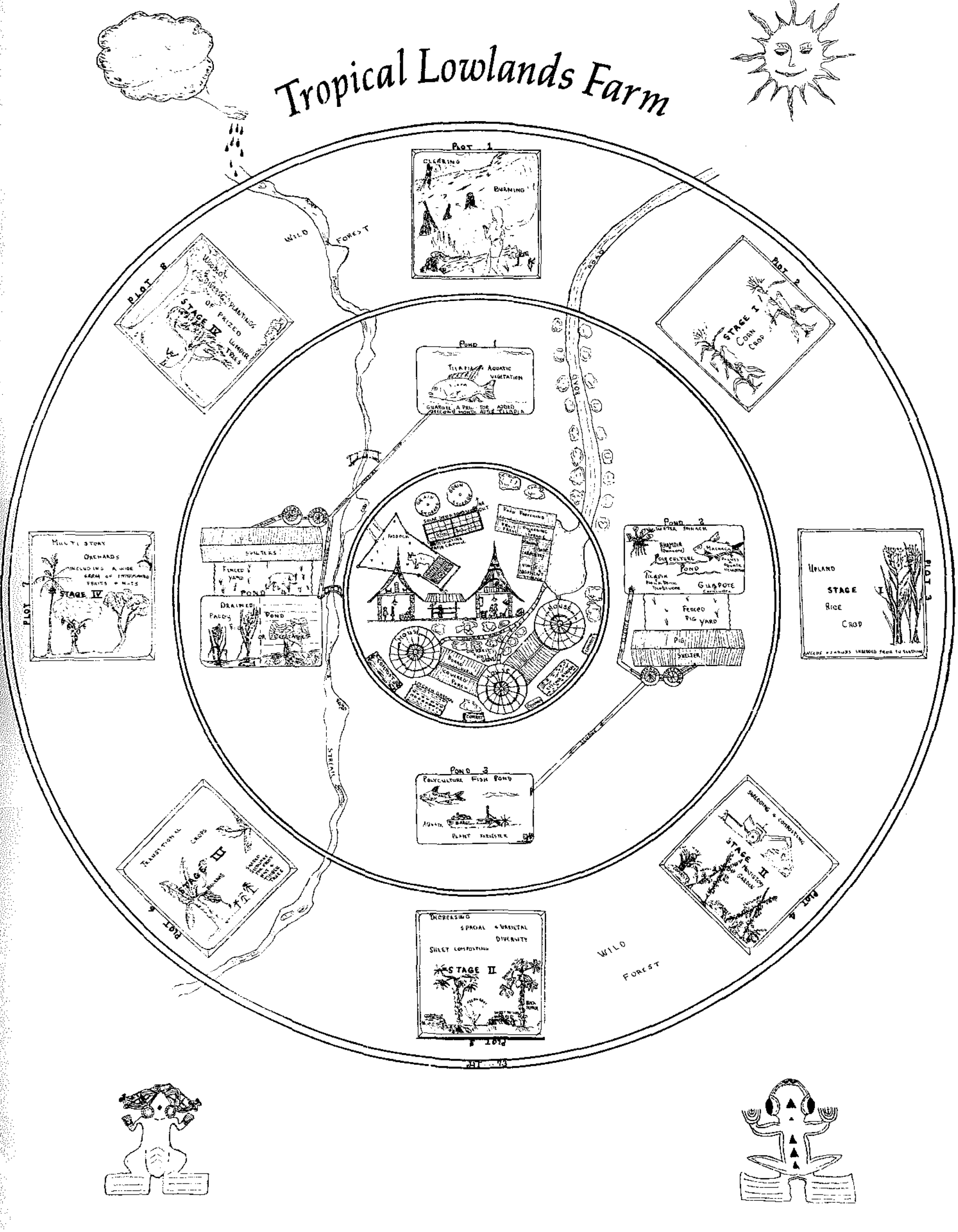
The farms of the future that I envisage would be unique, especially in the tropics of the Americas. They would be diverse and productive and would need a variety of machines to enable the farmer best to mirror the patterns of nature. At no time would the primary biological processes that characterize the ecosystems of each region be violated.

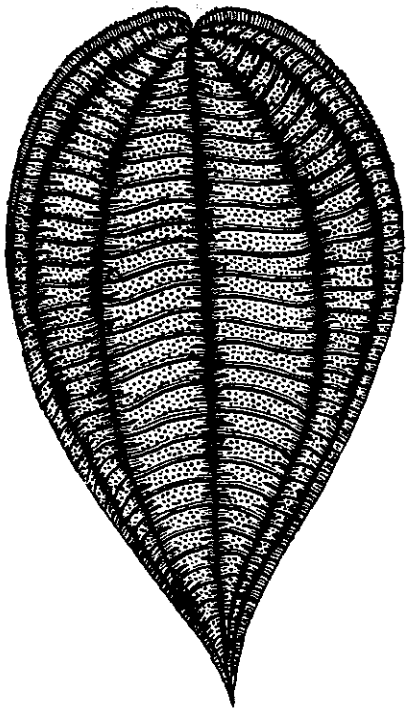
In order to combine ecological strategies with economic efficiency and productivity, each farm should perhaps be small, possibly limited to 50 acres or less. The reasons for the size limitation are straightforward: In a highly complex and productive agricultural system each element requires much more human attention and the orchestration of the farm as a whole necessitates a high degree of familiarity and understanding of each of the components. The size of the farm would best be limited to what the farmer can observe and supervise directly. It may be that this size limit would prove most viable economically, especially if there are cooperative schemes for processing and marketing of the foods on a regional basis. Smaller land units would also make possible a farming life for people with relatively little capital and land.

I want to describe a farm of the future with its roots in the past, which is only an idea and dream of what might be. My inspiration has been derived from many sources and from a number of different cultures. Perhaps not all of them can fit into Latin American cultures although most of them now exist there in one form or other. While some of the components are being tested on farms like the one at Granjas Tropicales, the various elements have yet to be woven together into a fully ecological farm that is reconstructive and profitable. The aquacultural components at this point are still at the exploratory stages.

Some of my suggestions might be off the mark, but hopefully they will stimulate new research and experimentation by many who intend to make the lowlands of Costa Rica their home.

Tropical Lowlands Farm





THE FARM

A model farm of the future should be carved out of the rainforest so that it may begin with the stored fertility of decades of biological activity. The land should not be entirely cleared, but have a series of small clearings of several acres each which would ring the farm. The small clearings, enclosed within the forest, will help ensure some ecological stability around each cultured plot and when the clearings are re-invaded, it will be with plants that are most likely to heal the degraded agricultural sites. These will be the seedlings of the forest itself.

Picture, if you will, a forested farm opened up over a period of years into a series of clearings around the perimeter of the farm. If you were to fly overhead you would see that each clearing is separated from the others by climax forest and since the clearing has taken place over a number of years, each opening would be different. Looking like wide spokes on a large wheel, each plot would be made up of different crops suited to the particular stage of maturity of the clearing. After a number of years the first or earliest opening would be hardly distinguishable from the surrounding forest being comprised of mature trees cultured from fruits, nuts, seeds, and high quality timber. The most recent clearings on the other hand might appear bare or charred from recent cutting and burning.

The houses and outbuildings might best be situated in the hub or center of the farm and outward from these polyculture fish ponds could be dug to create an inner ring which would appear like a sectioned moat from above. The pens and shelters for the pigs and fowl would be between the ponds and the forest, close to the ponds. Within the interior of the farm could be the buildings for food processing, areas for composting and household orchards, and small garden plots.

The symmetry of the model farm has a purpose. It should enable it to develop sequentially and logically from a forested area to a farm that is characterized by its affinities with the forest.

PREPARATION AND MAINTENANCE OF THE FARMING AND FORESTRY PLOTS

As was mentioned, the size of each agricultural clearing should be limited. This would insure that invasions of coarse weeds and grasses would be somewhat restricted and the life of the plot, if properly managed, could be extended for perhaps many years. Paul Harcombe (14) has recently pointed out how small openings in mature forests are filled by climax species by means of vegetative reproduction, release of suppressed saplings, or by the germination of buried seeds. This is significant for the tropical farmer as it means he would have to contend with woody plants in the cultured plots which is easier than controlling grasses and herbs. Also, he would have on hand saplings of wild trees to provide shade and support for his crops.

The first step in clearing would be to cut away undergrowth. This would have to be done with machetes. Then the largest trees would be removed for sale as timber and the intermediate and small trees would be burned within the clearing.

Burning, the next step, would not only help to release the nutrients and eliminate litter (which could also be accomplished by using a shrub chopper followed by mulching), but equally important the burning would destroy the roots and rhizomes of the original vegetation.

TRADITIONAL CROPS

Stage 1:

After clearing and burning the plots would be ready for planting of the stage 1 crops. Traditionally, these have been corn, which requires a lot of available fertility, and dry or upland rice. Plots in their first season might best be planted to these crops and excess production beyond the needs of the human community could be fed to pigs and poultry, or sold.

If the reinvasion of the plot was slow enough, it might be possible to plant the same crops a second time, especially if a mechanical chopper-shredder was used to shred the stalks and the woody plants and vines into a mulch. The mulch might slow down the rate of subsequent reinvasion and somewhat arrest the loss of nutrients from the soil. The type of chopper-shredder I am referring to is the large, gasoline-powered, transportable machine commonly used for disposing of shrubs, branches and small trees in northern U. S. communities. Its role in tomorrow's tropical farming might well be an important one. They could be drawn by oxen or by tractors.

Stage 2: Chopping, Composting and Raising Diverse Food Crops

The strategy through the second stage of the cleared plot would be to restore some of its fertility while growing a wide variety of crops suitable for sale and for consumption by the farm community and animals.

Although the method needs testing and experimentation, it is likely that some fertility could be restored through the chopping and shredding of the plants that have invaded the plots into windrows several feet deep. The windrows, in rows throughout the plot, would be innoculated with some soil and pig manure and allowed to compost. The compost when matured could be spread throughout the plot as a fertilizer.

The stage 2 gardens would be planted between the compost windrows. They would be multistory and diverse, like traditional swiddening gardens. Beans, peas, a variety of vine crops such as pumpkins, squashes, as well as root crops should be tried. Other less well known indigenous food crops could also be planted at this stage. Many of these could be valuable and saleable foods, while others would be solely for consumption by the people and animals on the farm.

Although it has not been demonstrated in the lowlands of the Americas, composting could well build up the soil's fertility. If this is found to be the case, then stage 2 crops might also include plants that produce for several years such as papaya, pepper and other spices. Those crops requiring support could be fastened to saplings that sprout up naturally and are permitted to grow to a particular height then topped and debranched.

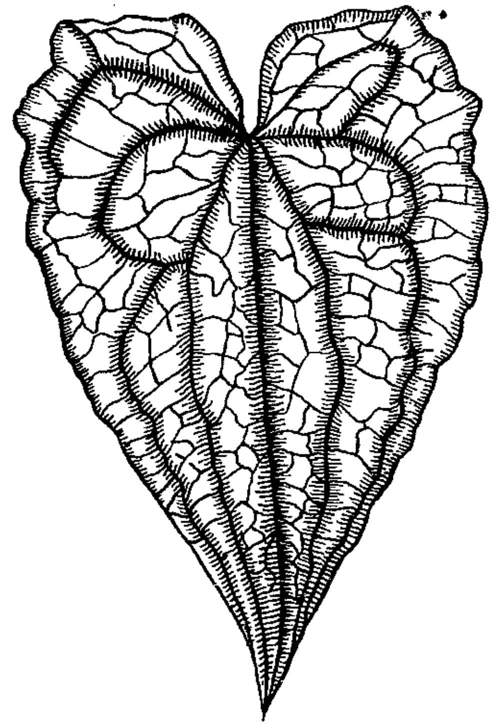
In order to slow the invasion of the site, cutting, shredding and sheet composting would need to be continued along the rows. Sheet composting is labor-saving but slightly less valuable compared with the traditional pile method, and consists of the shredded materials being allowed to decompose in shallow layers on the soil surface. The above techniques might allow the tropical farmer to continue the stage 2 process for five or six years, especially if, through composting, he was able to return to the soil the fertility he was removing with his crops.

Stage 3: Transitional Crops

The next stage is a transitional one in which bananas and plaintains are grown in the aging plots. Some seedlings would be allowed to grow up as well as to act as supplementary shade for the next stage. Shredding and sheet composting of plant materials should continue through this stage although less frequently. The bananas and plaintains have a wide variety of uses. The fruit would be for human and animal consumption and the leaves might be suitable as a food source for some of the cultured fishes.

Stage 4: Multistory Tree Crops

Stage 4 represents the final step of the farm plot to a mature and productive agricultural system. In the shade of the bananas and wild trees, a suitable habitat would



exist for seedlings of a great variety of potentially valuable tree crops.

Some plots could be planted to trees prized for their rare wood. Within a decade or two, with relatively little management after the first year or so, a timber crop of high value could be produced and sold, perhaps directly to brokers who deal in the finest tropical woods. Applied research into the growing of lumber crops of this type would reap rich dividends for any lowland region.

At the end of stage 4, when the trees are cut, the plot would be ready to return to stage 1 and the cycle would be repeated. Different cycles of varying duration could be tested on every farm.

The second approach to the stage 4 plots would be to plant a variety of fruit, seed and nut tree crops. These tropical orchards would begin to produce an income within a decade or less depending upon the crop. Each plot should have a number of different kinds of crops, varying in height and shade and root depth requirements. Many of the fruits could be processed locally or on the farm. Tropical juices, pressed and pasteurized, or sterilized would be very much in demand and could provide the basis for local agricultural industries. Many of the nuts and seeds command respectable prices for the farmer.

I do not have the experience or knowledge of tropical orchards to recommend the most suitable trees for the lowlands. Already cacao and rubber are important tree crops, but their prices are tied to fickle world markets. With many of the improved methods of processing foods, it would seem that the time is ripe to comb the world for suitable tree crops for the lowlands of the Americas. As a biologist I have a bias towards indigenous or native crops, but there may be many trees that would add considerably to Costa Rican tree farming. An effort should be made in the immediate future to involve scientists, agriculturalists, farmers and the Costa Rican government in the establishment of a tree introduction center in the lowlands. The center would evaluate the suitability of promising trees for the culture of foods in Costa Rica. A few farmers are now experimenting on their own but a coordinated effort to test nursery stock and to make it available is urgently needed. Perennials, especially trees, are the plants best adapted to rainy tropical environments.

Stages 1-4 represent a man-made successional farm uniquely suited to the rain forests of Central America. At each stage the diversity and productivity climbs, and if properly conceived, the value of the crop should go up at each stage. Each swidden area has evolved into a highly cultivated, multistory orchard or grove of valued trees and the farm itself is protected by wild forest.

ANIMALS AND ENERGY: A BIOLOGICAL APPROACH

At the heart of the farm I am describing would be a complex for the culturing and raising of animals. The various components of the animal husbandry systems would be linked together. Each element would contribute significantly to the functioning of the whole, resulting in an advanced and profitable farm ecosystem. Pigs would be raised adjacent to the ponds and would be fed farm crops and aquatic plants. The pig wastes would provide the raw material for a methane generating plant capable of producing electricity and heat, the latter to be used for drying some of the crops. The methane plant wastes in turn would be cycled into the ponds to act as the major pond fertilizer. The enriched ponds would be productive of algae which represent the primary food input for polyculture fish farming. The raising of animals, especially pigs and fishes, could be achieved efficiently and optimally on a lowland farm. All the feeds would be grown on the farm, especially in the agricultural plots ringing the farm, and from the ponds themselves. Farms of this type could help meet the increasing demand for high quality pork and fish on a local and national basis. In fact the hot, tropical lowlands represent the very best environment for these activities.

PIGS AND FOWL

The potential for the raising of pigs and ducks in conjunction with the culturing of fishes is great and represents an extremely productive way of bringing together agricultural food chains in a mutually beneficial way. Recall the 4.4 hectare Chinese farm in Malaysia in which pig, fish and aquatic plants were raised together. Some 30,000 kg per year (approximately 66,000 lbs) of pig meat were produced with the primary feed being the aquatic water spinach (*Ipomoea repens*) which grew luxuriantly in the fish ponds fertilized by the pig manure. Besides the pigs, some 3,000 kg (6,600 lbs) of fish were cultured in the small ponds. The fish in turn fed primarily off the algae which proliferated in the enriched ponds.

Ducks could complement a system like this, their wastes being added to the ponds and to the methane generating plant. However, to my knowledge, there is little in the way of markets for ducks in Central America at this time.

In the model Costa Rican farm the pig sties and duck pens should be situated close to the ponds. This would facilitate feeding of aquatic plants to the animals and permit the animal wastes to be treated near their eventual outfall back into the ponds. The sties and pens should have sloped concrete floors so that the manure could be flushed directly into a methane fuel plant, and all feeding of the animals would best be carried out in the pens. Attached to the animal shelters would be yards for the animals to exercise, root about and wallow. The yards would drain directly into the ponds below.

The numbers of pigs and ducks raised on the farm at any given time could vary, depending in part upon market conditions, availability of foods and the need for fuel or electricity from the animal wastes. If a methane plant is not desired, then the number of animals could be reduced. However, a farm scale fuel and electricity plant developed in South Africa by John Fry required the wastes from an average pig population averaging 1000 individuals (15). His was an intensively managed 25 acre farm.

Because of the diverse nature of the farm, a variety of suitable pig feeds would be available including aquatic plants, a number of root crops grown in the successional gardens, fish guts and heads, and if rapid gain was important, some of the farm-grown corn and rice could be used. The catholic tastes of the pig make it an ideally-suited animal for this type of tropical farm.

METHANE AND THE PRODUCTION OF ENERGY

One hundred pigs produce about 400 lbs. wet weight of manure daily and this material could be dumped directly into the ponds as a fertilizer, or used as manure on the crops. On the other hand it might best be cycled through a farm scale displacement digester in which the manure is broken down and methane gas is produced as one of the end products. Methane gas can be used directly as a fuel for machinery on the farm, or it can be used to power a diesel engine which has been converted for methane use. John Fry used his 13 hp converted diesel for generating electricity. A water pump was also driven directly from the engine. The system produced some 8,000 cubic feet of gas daily. At today's U. S. prices this is equivalent to approximately $1,400 a year worth of fuel and the value of the effluent from the system could represent at least a comparable amount in increased productivity in the fish ponds ringing the farm if they were properly managed. A detailed description of the system, including design information, has been given by Richard Merrill and John Fry in New Alchemy Institute Newsletter No. 3 (15). A methane system can be made to function reliably, as the Fry engine and digester combination ran continually with occasional stoppages for 6 years.

In tropical regions without a steady and reliable source of winds, the development of methane plants on a farm scale could help solve indigenous energy needs. The pig-methane-effluent-fish pond cycle takes advantage year round of the potential productivity of the tropics, with the effluent from the digesters becoming a critical factor in fish farming.

POLYCULTURE FISH PONDS

Much of the earlier discussion of pond culture on the hypothetical arid land farm in Guanacaste province applies equally along the humid and rainy Caribbean slope. Even the fish species cultured could be identical or closely related. The major difference between the small farm I am now describing and the Guanacaste model is that the effluent from the methane power plant would create more fertile and productive ponds in the humid lowlands. The ponds possibly could receive close to 1,000 gallons weekly of effluent originating from the pigs. If this energy could be trapped and used as efficiently as the Chinese in Malaysia manage in their ponds, then a major increase in high quality protein production could be achieved in the tropics of the Americas.

The fertilized ponds would be capable of producing prodigious amounts of algae and aquatic plants similar to the water spinach. The latter could be cultured in separate ponds or in combination with fishes, and would represent a substantial portion of the diet of the pigs. Fish culture would have to be designed around the food needs and ecological requirements of each species. A number of years of biological research will be needed to discover the most suitable fishes and to establish their stocking rates for polyculture in the Americas. Except for *Tilapia*, already introduced into Costa Rica, emphasis should be placed on native American species.

A possible roster of fishes to be tested are as follows:

Fish	*Food and Habits*
Tilapia spp.	phytoplankton feeders
Brycon spp. (Machaca)	leaves, fruits and terrestrial and aquatic plants
Rhamdia spp. (pimelodid catfishes)	omnivorous, nocturnal feeders especially on benthic or bottom animals
Cichlasoma spp. (guapote)	predator introduced to prevent overpopulation, especially of *Tilapia*
Joturus pichardi sp. (bobo)	habits not known, but highly prized fish, noted for the quality of its flesh

This is a hypothetical list and except for the *Tilapia* none of them to our knowledge have been cultured as a source of food, although all of them are sought by fishermen as food fish. The goal of New Alchemy fresh-water fish studies in Central America is to create analogs of oriental polyculture systems based upon fishes from the rich and diverse fauna native to the American tropics.

There still may remain the hurdle of marketing of fishes from the polyculture farms. Apart from local markets there is the distinct possibility that some of the species might be suitable for live transport to distant fish markets, while others could be sold freshly processed. In areas without inexpensive refrigeration, it would be necessary to process fishes locally for shelf storage. Some means for drying, smoking and "pickling" of fishes could be devised on a farm or local scale. Recently I had the pleasant experience of eating fish that were cooked and then preserved in olive oil, wine vinegar and garlic. The texture and taste was outstanding. A tropical equivalent might be to cook the fish briefly and then store them in a ceviche "sauce" which includes culanthro, also known as Chinese parsley or coriander. Raw fish in this "sauce" is excellent and much appreciated in Costa Rica and other parts of Central America. Unsaleable fish could be used as feed for the pigs.

PADDY RICE CULTURE

The ponds, drained after the fish are cropped, would be ideal for growing paddy rice. The rich bottom muck would help ensure a bountiful harvest and a rotational scheme could be worked out to take advantage of ponds which occasionally lie fallow. Rice farming would diversify the farm's subsistence base and, if carried out on any scale, it could provide an additional income source.

Tragically, modern rice culture using the high yield strains of rice usually requires a variety of biocides including insecticides to nurse the crop through to its final stages. These poisons would be extremely harmful to the pond ecosystem, so if rice could not be grown organically in the region, then it should not be introduced as a crop on the model farm.

THE TECHNOLOGICAL BASES FOR MODERN TROPICAL FARMS

Space limitations prevent a detailed discussion of the kinds of technology that would be most helpful on the kinds of farms described in this article. Ecologically-derived farms would have unique requirements, which could not be completely met by established agricultural equipment manufacturers. In the long run, this vacuum might turn out to be a boon to tropical societies, as it might induce indigenous inventions or stimulate efforts where possible to substitute biological solutions for the strictly technological ones of orthodox agriculture. For example, there are two basic ways to control serious damage to crops from insect pests. One approach is to spray a monocrop with a powerful insecticide, whereas the alternative is to use ecological strategies against pests which include limiting plot size and proximity and interplanting several crops in the same plot. The latter strategy represents a predominance of biological thinking, which, over the long term, could well prove most suitable against the vicissitudes of hot tropical environments.

Even on an ecologically-inspired farm a variety of machines would be needed as toil-saving devices and for increasing the efficiency of the farm and for processing of the foods for market. Oxen and horses should remain as beasts of burden on the farms of the future, as they require little in the way of capital and perform some tasks more efficiently than tractors or other vehicles, especially during the rainy season. They also do not require increasingly expensive gasoline and oil.

INDIGENOUS TECHNOLOGIES

Local economies and individual tropical farmers could be aided and strengthened by indigenous manufacturing of a variety of equipment and tools. Savonius rotors for pumping water, windmills for pumping or generating electricity (see "Energy" articles in this issue), simple pumps, many of the methane plant components, buildings and a variety of other useful devices could be produced on the farm or in local blacksmith shops. Some food processing equipment could also be built on the spot such as solar driers, fruit presses, solar and wind-powered ice making or freezer units.

As local engineer-crafters begin to develop proficiency, a tendency could evolve to turn to indigenous materials. One example comes immediately to mind, namely fabricating the piping for the water and aquaculture systems from large varieties of bamboo. As ecological farming practices are worked out, there will be a need for new kinds of planters, cultivators and harvesters. If these could be built locally, the diversity and economy of the regions affected would also be strengthened. The stability and social richness would be far greater than in farming areas based on single cash-crop farms or plantations.

IMPORTED TECHNOLOGIES

Some imported technology will be required to make the farms productive, efficient and a pleasure to work. Power saws and chopper-shredders will be needed for clearing and composting; and tractors might help with the turning of the compost, the digging of ponds and the moving of materials. Pasteurizing or sterilizing equipment and some power tools and vehicles for transporting food to markets will need to be brought in from outside.

The success of these farms and the communities associated with them will depend, to a large degree, on there being a healthy balance between the local manufacture of machinery, equipment and structures and the expensive imported aids for farming and living in the tropics. Farms like those I have described will need minimal outside equipment and machinery, but that which is required will play an important role. Unfortunately, we still know very little about the most appropriate technologies for biologically-inspired tropical farms.

CAN IT ALL HAPPEN?

As I reflect upon the future, especially as it pertains to the tropics of Latin America, I am overwhelmed by how much has to be accomplished to reverse the course of land exploitation before the task becomes too difficult and whole regions have to be abandoned. Alternative farms will have to exist by the turn of the century, and they will have to appeal widely to tropical farmers—farms, like beacons upon a wasted sea.

But I am not optimistic about the future. The magnitude of the present dilemma is not clearly recognized, nor is there much chance of finding support to create model farms that represent, in microcosm, the most valuable of nature's processes. Frightening too is the tendency for agencies, organizations and governments to tackle problems on a piecemeal basis, and on too large a scale for individual farmers to relate to. I have observed that people react to new ideas or things very differently, and I suspect the reaction depends on whether the new idea or thing can be actualized by them within their present resources. Small farmers at agricultural fairs are no doubt impressed with the sight of computer consoles that can operate myriads of machines on a mechanized farm, but their reaction is quite different to people who see the small backyard fish farms at our Cape Cod center. These inexpensive little aquafarms are as strange as the consoles, but the immediate reaction is not one of awe, but is more likely to be "I'd like to try that". Anyone with a 25'x25' plot of land can have a small fish farm, but the remote and esoteric console and its array of machines exist in the realm of the "expert" and the large corporate farm. The viewer sees it as an occupant of a world other than his own.

Another variable that dampens my optimism is the tremendous amount of energy, scientific study and plain hard work that will be needed to construct viable alternatives. Our experience at the New Alchemy-East center has shown us how little is known and how much work is required. Not to be overlooked is the vital question of communicating knowledge and perspectives outward so the best approaches and strategies can become widely emulated. People everywhere must become experimenters with the world around them. To give them the necessary confidence is one of the most important but little discussed or understood tasks ahead.

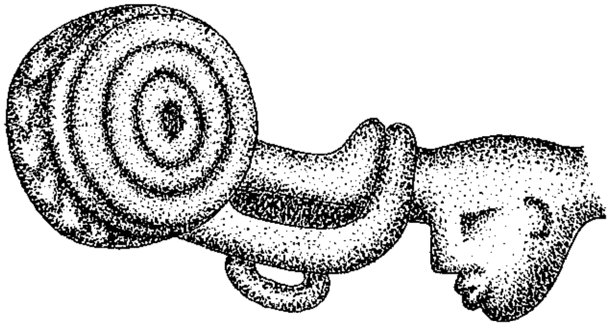
A beginning has to be made, and soon, as the spectre of hardships before us is too great. Armed with what is already known, functional demonstration farms like the ones described should be researched and developed. Financial support will have to be sought as good experimentation will have to include the luxury of testing hunches and ideas that may well fail as well as those that succeed. The search for modern tropical farming methods will not be a direct and straightforward path.

Local or regional governments could play an elemental role in the restoration, either by establishing models themselves or by underwriting some experimentation by farmers. Perhaps they could do both. Another valuable contribution would be the establishment of regional plant introduction groves, nurseries, hatcheries for fish, and pig breeding stations so that the best quality stock would be available inexpensively to farmers adopting ecological methods. Small international research organizations like New Alchemy should play a role too because of their ties with practices in other parts of the world. In specific terms we would like to continue and to expand the studies of Bill McLarney in searching for native fish species suitable for culturing. If the wherewithal can be found, we would also like to collaborate with local people in the establishment of a reconstructive farm in Costa Rica.

Another key step to bring about constructive change might be to establish throughout Costa Rica an independent organization of ecological farmers with the purpose of sharing ideas, stock, research notes and the spreading of bio-social ideas into the larger agricultural community. Cooperative and educational ventures should be emphasized. It should be run by full-time farmers desirous of making their country balanced and productive.

Costa Rica is a beautiful and potentially productive land. If a few people with vision and foresight were to embark upon some of the proposals that have been presented here, then one day a dynamic might be born that would fulfill its promise as a country blessed with restored and productive landscapes and a free and self-reliant people.

—John Todd



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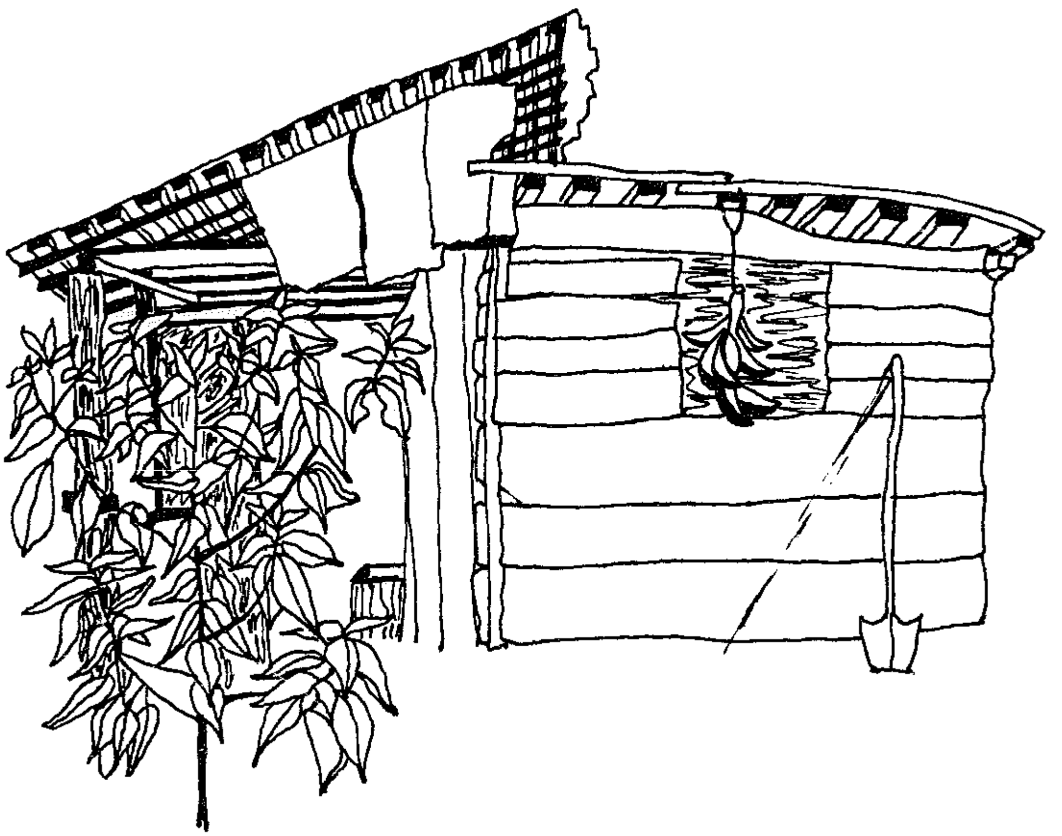


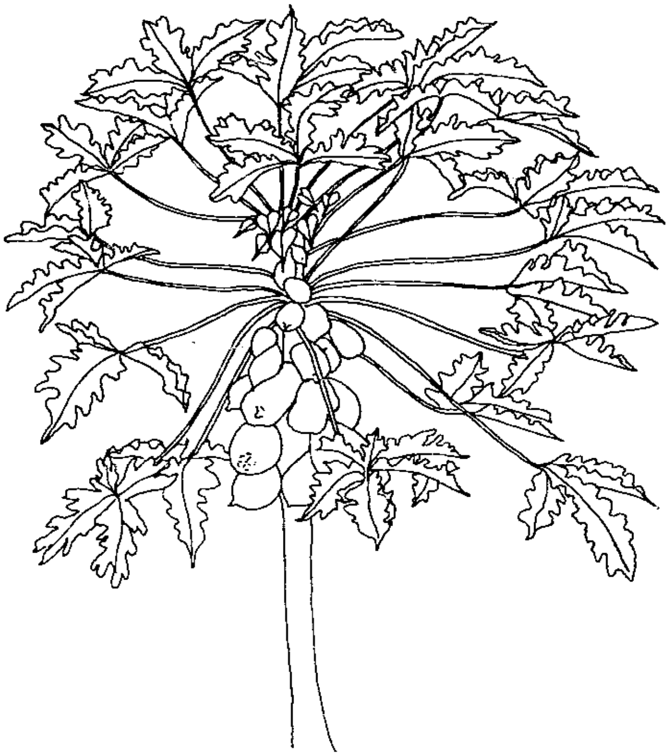
New Alchemy Costa Rica

My first visit to Costa Rica was in 1968, before there was a New Alchemy. In 1970, Doug Evans made an exploratory trip there, and the following year, John Todd and I went down with the goal of locating a site for a New Alchemy center. Since then I have spent three to six months of every year in Costa Rica, and a number of other New Alchemists have spent time there. But the goal of finding a home there proved more difficult than we had originally foreseen. In the years between 1971 and 1975, while we were traveling and talking and counting our pennies and deliberating, some people became impatient with us or lost faith in New Alchemy Costa Rica.

There were a lot of people who helped, too. For several years our home away from home was at Bob Hunter's farm in the Sarapiqui region, and our first small tropical projects were realized there (McLarney, 1973; McLarney and Hunter, 1976). Many other people, in and out of Costa Rica, gave us ideas, inspiration, logistic support, and education, which have been invaluable to our tropical efforts. I would particularly like to mention Eugene Anderson, Don Jose Maria Arias R., Bob and Peggy Brown, Werner Hagnauer, Walter James, Alexander Skutch, Peter Van Dresser, Glodaldo Williams Hall, and Jorge Zamora. Another important step was the incorporation, in 1971, of New Alchemy in Costa Rica, where we are known as NAISA.

Finally, in 1973, Shelly Henderson and I made the trip that eventually resulted in the purchase of our present fifteen-and-one-half-acre farm. The purchase was made possible by generous gifts and loans from Tyrone Cashman, John and Peggy Elter, Richard Etheridge, Stephanie Hancox, Dorothy Todd Henaut, and Mr. and Mrs. Robert McLarney. Subsequently, Bill Haveland and Bob McCullough have made donations specifically earmarked for our tropical work.

The NAISA farm is located in rural Limón province. Limón, the Atlantic coastal province of Costa Rica, is physically and culturally distinct from the rest of the country. The low elevation of much of the province and the moderate-to heavy rainfall make it an emphatically



tropical place. Until 1971, there was no highway, and only one railroad connected Limón with the rest of the country. A majority of the relatively small population was composed of bilingual (English-Spanish) black people of Jamaican and West Indian origin. The substantial Spanish minority and the Chinese shopkeepers were mostly born and raised in Limón. The majority of Costa Rica's tribal Indians lived in the isolated Talamanca mountains, but they were scarcely noticed, and few outsiders ventured into their wilderness.

Today, much has changed. The road has facilitated immigration from the densely populated Central Plateau. The appointment of Hernán Garrón, a Limonense, as Minister of Agriculture in this highly agricultural country, has helped to put Limón on the map, and the government is encouraging all sorts of development in both the coastal and highland regions of the long-neglected province. At the same time, the Limonense are developing a greater awareness of themselves as Costa Ricans, and political consciousness is on the rise. All of these changes have good and bad aspects; the least debatable thing that can be said about them is that they have resulted in greater integration of Limón into the Costa Rican mainstream.

Still, to a gringo, Limón looks and feels very different from the rest of Costa Rica. It is more a Caribbean than a Central American place. Life in Limón is, as the locals often remind a visitor, *muy tranquilo.*

If that is true in the city of Puerto Limón, it is multiply true at the NAISA farm. We are located in one of the more remote coastal areas. There are continued rumors of a road, but for the next few years at the very least, the only access will be by foot or by sea. Every Saturday, weather permitting, a merchant from a nearby town (also without roads) brings goods in his dugout canoe to sell at his little shack on the beach. There we, like everyone else, buy coffee, salt, sugar, and such essential household items as flashlight batteries and razor blades. For the rest of our food supply, we are forced to be self-sufficient or to trade or barter with our neighbors. To mail a letter, visit a medical clinic, or drink a cold beer means a minimum three-hour hike.

Our black neighbors live mostly along the beach while the Spanish live along the single foot road, which leads into the interior. The blacks are the old settlers; the Spanish population is a relatively new phenomenon. Curiously enough, virtually none of our Spanish neighbors are native-born Costa Ricans. They are mainly Nicaraguan and Panamanian, with a sprinkling from other Central and South American countries, trying to provide for their families here in a region where there is still land to be homesteaded.

All of our neighbors are what I would call "hard-core *campesinos*"—people who have chosen not to live in the city, whatever the financial inducements. Their only cash crops are cacao and copra, but our area is not prime cacao land and coconut palms do best along the beach. Any number of salable crops—bananas, citrus, pineapples, yuca, etc.—do well here, but the lack of transport facilities renders it impossible to get perishable crops to market. A few people specialize in turtle hunting. There is a small local trade in meat, fish, eggs, beans, dairy products, and coconut oil but, apart from the sale of cacao, people get by mainly on subsistence agriculture, hunting, fishing, and gathering. They do well at it. Although their diets seem to our tastes high in starch, there is no evidence of nutritional health problems.

Many nonfood needs are also provided locally. Houses are constructed in whole or in part with materials from the local forest. The only boats are dugout canoes. The majority of families cook on wood fires. The blacks make coconut oil for cooking. Forest vines are cut for clotheslines.

Government, too, is a do-it-yourself affair. There are two schoolhouses, with schoolmasters from outside, but virtually no other "official" presence. There may not be much law, but order prevails.

It is this self-sufficiency and capacity for survival that is, in my view, the region's greatest asset. There is something similar to that which drew Peter Van Dresser to northern New Mexico (Van Dresser, 1972): a functioning *local* economy. At this time, there is a danger of its being swallowed up by the national and international economy. But there is also the possibility of intelligent diversification—of reinforcing self-sufficiency while at the same time building appropriate links with the outside world, thus improving the standard of living in an atmosphere of stability. We hope that the latter will happen, and that the NAISA farm will be a center for this sort of development.

Before we could function in the community, it was necessary to render the farm functional. The previous owner had had ambitious plans for raising livestock, but left the property when he got the opportunity to convert a nearby, abandoned airstrip into a pasture. The place had been virtually abandoned at the time we acquired it. About half of it is in virgin forest. We plan to preserve this. The remainder was bush and overgrown pasture. The principal food resources were somewhat less than an acre of neglected plantains and a few producing coconut and banana trees. There was a large stand of wild cane and a magnificent bamboo grove to provide construction materials. The only amenities were a barely habitable shack, semienclosed cooking area, and a marginal well.

In 1975, Susan Ervin and I set out to see what could be made of the place. The first few weeks in the area were devoted to getting rid of a *parasito* ("squatter"). When Susan had to leave, it looked as though I would have to face the prospect of establishing a farm single-handedly. It didn't work out exactly that way. I had some help from three visitors from the States, Mel Baker, Susan Malcolm, and Alvin Stilman. But I especially want to thank the local people.

I was fortunate in that the first person I met in the area was John Holder, one of the most self-sufficient persons I have ever known. He introduced me to the man who sold us the farm, gave us food and lodging during the *parasito* episode, and helped in a thousand small ways. When it came time to build a house, I hired John to direct and assist with the construction, which began with felling a gavilán tree and hauling heavy timbers out of the woods. He recommended another man, Miguelito, to help in clearing land. I was somewhat concerned over spending our meager NAISA funds on labor, but there was no other way; I had neither the time nor the skills. Then one day John refused his pay. Soon after, Miguelito showed up for work with a friend. They settled for a cup of coffee.

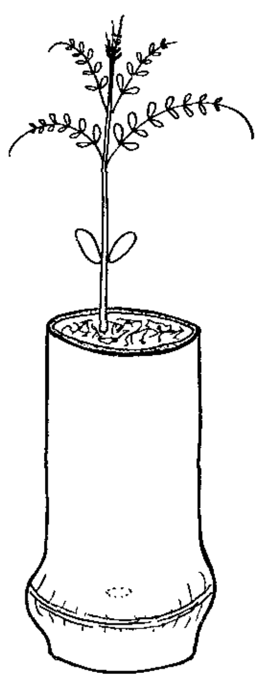
Since that day, we have had any number of helpers. A man may walk five miles in the rain to chop bush. Two children I had never seen before have arrived. Their first question was "How many machetes do you have?" Others may bring gifts—a sack of beans, a pumpkin, seeds, baby fruit trees with neatly balled roots, a jar of guava jam. I haven't been able to pay one of them.

I don't mean to give the impression that all of our neighbors are saints. There have been problems, too: cows in the pineapples because a neighbor refused to fix his fence; coconuts we wanted to eat were spirited away, presumably for sale; a man with phony papers trying to sell us nearby land. But by being in the position of *needing* help, I found out who *would* help. I had little to offer besides "thank you" and an occasional fish, but once the seriousness of our farming venture and my own willingness to work had been established, that was enough.

By late May, when I started back for the States. the farm looked pretty good. The frame and roof of a new house were up. All the plantains and coconuts had been cleaned out and a substantial number of young fruit trees reclaimed in the process. Sizable plantations of pineapple and yuca, a vegetable garden, and a fruit tree nursery had been started.

Unfortunately, there was no one to look after the place during my absence. Various plans involving friends from the States had fallen through, and the best of the local people had their own farms, leaving me only the drifters and drinkers to choose from. The neighbors would be glad to look in on the place occasionally, but it would be out of the question to ask them to do the daily maintenance, which is a must for a tropical farm.

In desperation I hired a young man who passed by, claiming he was from Belize. (I am too fond of that country to want to believe it.) He was a disaster. He wrote New Alchemy regularly, explaining how he was cleaning the yuca, putting walls on the house, planting corn and beans, etc. He signed his letters "Farmer Man."



Farmer Man did none of the things his letters claimed. Worse, he stole from the neighbors; there is not much lower than someone who steals a poor man's boots. Eventually, the local "legal system" worked in the customary manner. After at least one attempt on his life, Farmer Man was driven from the community.

Susan and I returned in February, 1976, to find all of our plantations in yard-high bush, termites in the new house, rats in the yuca, and dead crabs in the well. It was a scene of total desolation. Some of the work could be salvaged. Other parts could only be done over. What worried us more than the cost in labor and money was the harm done to our neighbors and how that would affect our position in the community. To our amazement, not one person has held the Farmer Man fiasco against us. Everyone has a story about him, but to them it is, to use the local phrase, *una cosa de vida,* a mistake anyone could have made.

So we started again. The vegetable garden was almost a total loss, since nothing had been replanted, but there were twelve-foot high gongo beans (a local legume very similar if not identical to pigeon pea) yielding well, and a few scraggly tomato plants. A substantial minority of the baby fruit trees had survived and were transplanted. The yuca and pineapple plants had survived in spite of neglect. The yuca, in particular, buoyed our spirits. Rats notwithstanding, I estimate that there was something close to a ton of edible yuca in our field of less than an acre. Apart from eating the yuca, it is more than a little satisfying to grow a ton of anything single-handedly on your first try. And the yuca has helped in another way; local people are stopping by for yuca, to eat and to plant—our first chance to return substantially the many kindnesses we have received.

One of our first tasks was to dig a new well. Since Farmer Man had sold all the farm tools, we had to borrow a shovel. With the shovel came a neighbor, Geronimo Matute, who started to dig, waving aside my offers to take turns. In half an hour he had dug an almost perfectly circular well about five-and-one-half-feet deep, and in another fifteen minutes of furious bailing, we had clear water to drink. From that point on, our volunteer labor force returned as if nothing had happened.

Up to this point in the story, I have made no mention of specific New Alchemy projects, which reflects the reality of the situation: There weren't any. In 1976, though, we launched our first project and local people are beginning to realize that an Institute is involved. For the entire first season, I had never mentioned this fact; the inference they made was that I was another farmer trying to get started. In the long run, I think this may prove to have been a wiser tack than coming in with institutional banners flying and promises of great projects for the community.

Before discussing present and future projects and problems, there is a little more to be said about the farm in 1976. I was on the farm from late January through mid-May, Susan was there for the first half of that period and Earle Barnhart made his first working visit at the same time. In April, Barbara, Tony, and Michael Lavender came to help and stayed on until mid-July; they will be back in the fall. (Meanwhile John Holder is taking care of the farm.) We all favor different kinds of work, so there has been a nice balance, and things have gotten done.

With the lack of certainty as to who would be on the farm and when, we emphasized perennial vegetables—gongo beans, chayotes, yuca, yampi, malabar spinach, and a beautiful and delicious native perennial sweet pepper. But we also planted native or imported tropical varieties of cucumbers, squash, peanuts, tomatoes, eggplant, melons, onions, okra, green beans, mung beans, and ayote (a sort of native pumpkin) in the hope that someone would be here to eat and replant. We have also planted various local spices, including turmeric, ginger, thyme, Spanish thyme, and coriander.

The ornamental hibiscus I planted last year have bloomed and are forming a hedge by the main entrance. They have been joined by dozens of other flower varieties planted by Susan—mostly native flowers donated by the local ladies.

The plantains, bananas, and coconuts have been chopped out and are bearing well again. Our one-hundred-and-fifty pineapple plants should be bearing by now, as should our largest breadfruit tree. Among the surviving baby fruit trees were oranges, lemons, grapefruits, sweet limes, naranjilla, cas, guava, nispero, nutmeg, tamarindo, stinkin' toe, monkey head, carombola, manzana de agua, avocado, and zapote. A nursery has been re-established for some of these, as well as for others that succumbed to the onmarching bush—breadnut, akee, mango, pejibaye, caimito, and guanabana.

The house, which is what our neighbors call an "Indian house," with walls made of sections of the wild cane that stands between us and the ocean, was 75 percent completed when I left. The first job on the house in 1976 was a prolonged battle against the termites. We should have listened to our neighbors. Their first advice was "smoke." When our first smudge failed to eliminate the pests, we turned to poisons. These were partially effective, but the termites always came back full force within a few days after poisoning. Finally, when we moved into the house, termites and all, the termites left. They couldn't tolerate our twice-daily cooking fire.

We still haul firewood in from the beach, but maybe this year we will be able to afford a small kerosene stove. Our staples are yuca, plantain, coconuts, and gongo beans (from the farm); rice, beans, breadfruit, citrus, sweet peppers, eggs, cheese, malabar spinach, and purslane (from our neighbors); and fish (from the sea and rivers); plus bread, coffee, and a variety of herb teas.

Earle, who is by nature a builder, did a lot of building when he was with us. Thanks to him, we now eat at a table pleasantly situated in the shade of the bamboo, overlooking the surf. He also constructed an elegant well cover, a shower stall made of cane and coconut fronds, an eight-foot-high trellis for chayotes, a wash stand, a special box for growing papayas elevated in loose soil (as they don't like our rather clayey soil), a prototype tea dryer, and scores of handy tools and gadgets (Barnhart, 1977).

Because Barbara's particular interest is aquaculture, I undertook to teach her aquaculture "from the ground down." It turned out to be more of an experience in engineering than aquaculture, but we now have a small pond stocked with fish. It doesn't look like much, but it is a start, and when I recall the spectacle of Barbara or Tony literally covered from head to toe with mud, racing against the rainy season with nothing but a constantly breaking shovel and the most primitive of homemade pumps, it seems like a great deal. Practical fish-raising in the pond was delayed by the invasion of a small crocodile, but we have hopes for this year.

Tony, when he wasn't immersed in the swamp, was researching bat behavior. Perhaps his pilot studies will lead to the first scientific study to be based at the NAISA farm.

No description of the farm would be complete without mention of some of the natural delights which make us glad to be there: the one-hundred-foot-high ceiba tree, which towers over the yuca field; the scores of other giant trees (some of them with twelve-foot-high prop roots) in our forest; the surf, visible from our porch; the incredibly ferocious-sounding howler monkeys; the parrots, carrying on like a yard full of school children; the banana birds (brilliant yellow and black orioles), who light just a few feet away in the bamboo and sing complicated and beautiful duets; the huge electric blue morpho butterflies; the smell of what we have christened the "cotton candy tree"; the little possum who sometimes visits us at night. . . .

A lot of our time is spent on an herb tea project funded by the Arca Foundation. It has involved starting nurseries and experimental plantings of "soril," securing seed, visiting and exchanging ideas with our experimenting neighbors. . . . The project is described in detail in the article entitled "Herb Tea Project" in the fourth *Journal of the New Alchemists.*

Here I should like to emphasize just one point about the project. It originated as much in the minds of the local people as in ours. That is, it was designed with the needs and wants of the local people, as expressed by them, in mind. In our way, we have applied what the Peace Corps and other voluntary service organizations have learned—that the only projects that have a high probability of success are those that people ask for. In the framework of a large institution, the policy of waiting for requests has one drawback—the voices reaching it are usually those of people acquainted with bureaucratic channels of communication.

In our case, communication has been more direct. In my first season on the NAISA farm, I talked with dozens of local people and listened, as one farmer to another, to their desires for the area. Almost invariably we talked of the lack of a road. Everyone allowed that a road would permit them to grow and sell a far greater variety of crops. Most people hoped for the road, but everyone acknowledged the problems it would bring, and a minority was firmly opposed to it. More than anything else, the road is equated with the chance to diversify. The tea project is really only another way of facilitating economic diversification. It is not an "answer" for Latin America. But it is wanted and, to our minds, it fits in this particular community, where nutritional levels are high, but cash income is low (an average full-time worker earns about $50 U.S. per month—Ashe, 1975), and prices of essential goods are only slightly lower than in the United States.

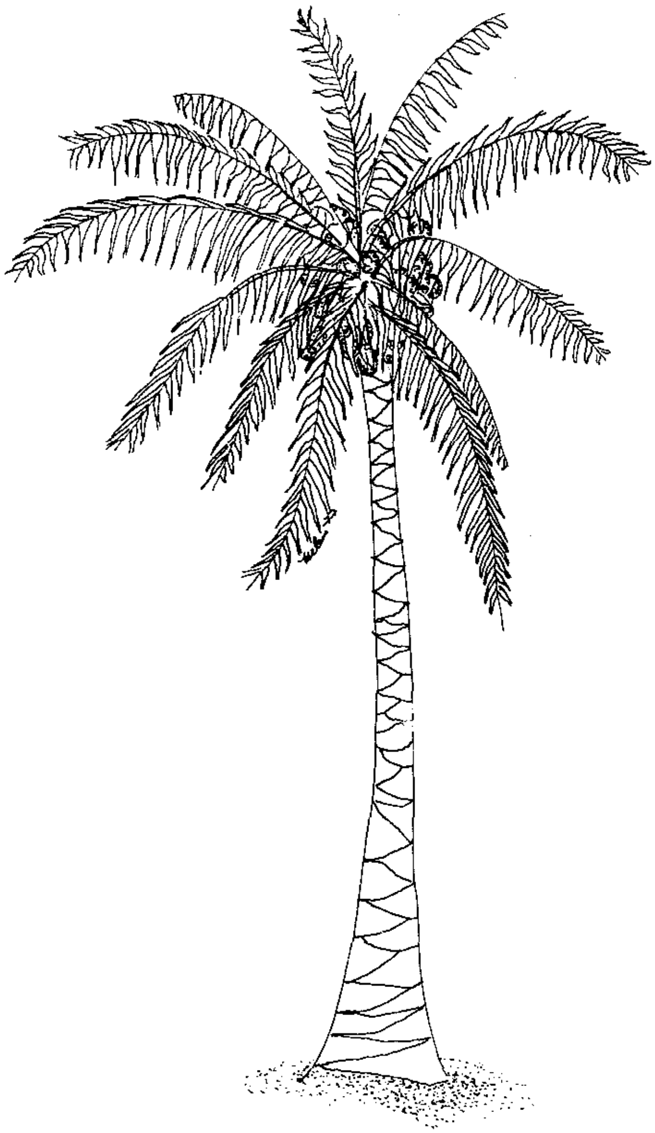
Other possible projects (pending funding) which have arisen from our contacts with the people here:

1. Our tea dryers are based on the cacao and copra dryers ("barbecues"), which are a fixture on most local farms. Their use could be expanded to drying food products. For example, pineapple, which grows splendidly in the area, is excellent dried. As with the teas, all that is needed is the knowledge that it is salable in quantity.

2. We would like the farm to become a source of seeds and planting materials for the community. In a small way this has already happened. I have mentioned the visitors who ask for yuca sticks. Another example is malabar spinach. This little-known plant, available from Burpee, is to my mind, the best pot green to grow in the lowland tropics or during hot summer months in the States. It produces well, withstands the hottest weather, and, unlike native tropical greens such as calalu and jaboncillo, there is no need to throw off the cooking water. We introduced malabar spinach to the region in 1975, and already a number of people are planting and enjoying it.

Having established a minor reputation as a source of seed, we should like to expand into distributing many types of vegetable and fruit seeds. There is in Costa Rica a national shortage of almost all types of seed. It is a cliché that the people of Latin America are not very interested in vegetables, but we have received many requests for such seeds as squash, peanuts, watermelon, cantaloupe, green beans, cucumbers, tomatoes, eggplants, and okra. People ranging from ten-year-old children to old men have planted the few seeds we were able to spare.

This year we plan to expand our gardening activities.



One of our neighbors, Casimiro Dosman, has given us a substantial piece of his farm to use for this purpose. There, Susan and John Holder, who have experience in small-scale commercial vegetable growing, will be trying to put together a combination of the best of native food-growing methods and applicable North American techniques, such as composting. In addition to providing a needed source of vegetables for the community, we want to be able to give seed to others in the area, and to offer informal instruction in vegetable gardening. If you have seed of varieties you believe would be well suited for this project, or know of sources of such seed, we would love to hear from you.

There is even more demand for good fruit-tree seed, largely due to the commercial potential of some types of trees. As one local man put it: "I want to plant fruit trees now, because some day we will have a road, and when it comes, my trees will be bearing already." But perhaps more important is the nutritional role of fruits. A common sight in Costa Rica is that of children throwing sticks at a guava or mango or stinkin' toe tree. It is my impression that, in the areas of Latin America that are above par nutritionally, this sort of casual fruit consumption is a critical factor. At present, most of Limón province is well supplied with fruit. But most of the trees the children harvest were planted by their grandparents, and there is a tendency to take them for granted.

We would undertake to secure stock of local or superior new varieties of whatever fruits are in demand, plant them, and distribute seedlings free, for yard and garden planting, and at a nominal cost for small commercial-scale plantations. There is a local man with skills in fruit tree propagation who could be hired to tend such an operation, if funds permitted.

3. A world-wide agricultural problem receiving increasing recognition is the loss of local varieties of food plants. Our region is not without outstanding local varieties and we would like to secure stocks of these varieties adequate to preserve them. We are just beginning to learn the local cultivated plants. Among those that seem significant are the perennial sweet pepper mentioned earlier, a small, round, and incredibly delicious avocado, and a hardy local cucumber.

4. An alternative to the possibility of the road would be a launch, which could pick up produce at points along the coast. Prior to World War II, such a launch existed, but it was owned by a German company and at the start of the War it was nationalized and moved to the Pacific coast. We have not defined what role NAISA could play in the re-establishment of a launch service, but it would certainly be a valuable service and we are ready to cooperate.

5. A long-term goal for the area would be the establishment of forest farming as described by Smith (1929) and Douglas and de J. Hart (1976) as a dominant agricultural mode. Should we be able to expand the farm or work out a cooperative arrangement with one or more of the local farmers, we would be ready to begin.

6. Although the farm is in a coastal area, there is not an overabundance of fish, and the supply is very dependent on the seasons and the weather. The small fish pond constructed on the farm is a start, but we would like to see a larger aquaculture system, designed to supply the community. We have been circulating a proposal to build a system similar to the one set up by Professor Anibal Patiño in Colombia and described in the article on pages 108–112 (Patiño, 1976). Such a system would be set up on one of our neighbor's farms, and some member of the family could be trained to operate it.

There are three functions we hope the NAISA farm would serve. The first two have already been mentioned —a center for community oriented programs and a functional subsistence farm, organized along the lines of a Samaka farm (Hoskins, 1973) for the use and enjoyment of whoever is living here. Interwoven with these is an educational function. Certainly the farm has already contributed to the education of the gringos who have worked there. We would like to extend this; we think that the farm could accommodate a few students without creating too large a foreign presence. Students in biology or ecology would find a great diversity of habitats in the vicinity—virgin forest, second growth, agricultural land, swamps, rivers, beaches, and the ocean. We believe that, in the long run, tropical countries will benefit as much from basic understanding of tropical ecology as from grandiose "development" and "aid" projects. The potential of the farm for students in Latin American studies is obvious, and there is also much to offer students of agriculture, economics, sociology, and other disciplines.

It is possible that a student program of some sort could contribute to the solution of our caretaker problem, as at present none of us is able to be here all of the time, nor does this seem possible in the near future. A six-month or one-year stint taking care of the farm could be a tremendous educational experience, and having at least one nonlocal person there throughout the year would strengthen our position in the local community.

We should also like to be in a position to pay salaries. In the last two years, New Alchemy personnel from the States have received air fare only, with no pay whatever for the time spent in Costa Rica. As mentioned, in 1975 a small amount of local day labor was hired. In 1976, the Arca grant paid stipends to seven Costa Rican farmers participating in the tea growing experiment. We should like to be able to pay a subsistence wage to New Alchemy personnel who travel to Costa Rica to work, but it is more important to be able to continue being a local employer. It is our policy always to give preference to a Costa Rican for any job there. If the idea of a student caretaker works out, it will be necessary to hire a local person to train, advise, and oversee the student. If it does not work, we shall need to hire a caretaker. If the fruit and vegetable nursery becomes a reality, we will need additional labor to maintain it.

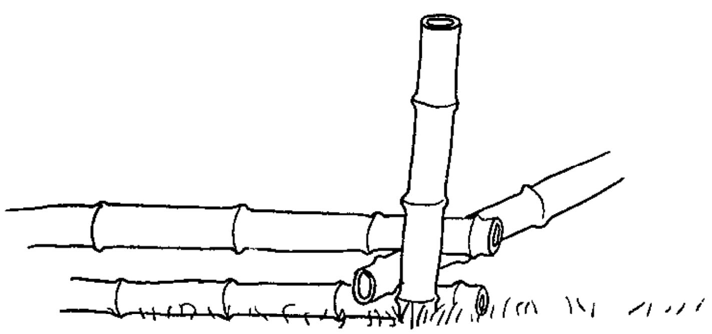
Expansion of the farm is a virtual necessity, especially if we are to preserve our small piece of virgin forest. Currently there is land available, some of it not in use, in the vicinity of the farm, which we might be able to buy if we had sufficient funds.

There are, of course, a number of pieces of equipment we would purchase or construct if funds permitted. I have already mentioned a kerosene stove. There are definite limits, though, to the accumulation of equipment; it is our policy never to exceed the limits of what one of the more prosperous *campesino* families might own. A kerosene stove or an outboard motor would be permissible; a gas refrigerator or an electrical generator would not. (Exceptions could be made for equipment specifically related to our institutional function, for example, a typewriter, but not for items primarily for home or farm use.)

If the latter part of this essay has had the tone of "what we could do if we had money," it is because that is the reality of our present situation. While I was writing the first draft of this piece in Costa Rica, we received our copy of the third *Journal of the New Alchemists.* It stated that our Cape Cod center was operating "on a shoestring." Today, in the late fall of 1976, as I sit on Cape Cod revising my work, New Alchemy East is back on the shoestring. If New Alchemy East is on a shoestring, New Alchemy Costa Rica is running on blisters and hoping for calluses. But that is no worse than the situation of many of our neighbors.

More money would help us, but as long as we can manage a couple of round-trip tickets to Costa Rica annually and somehow arrange for a caretaker, we will be there. We are there because we want to be, and we think our presence will continue to be a valuable one.

—William O. McLarney



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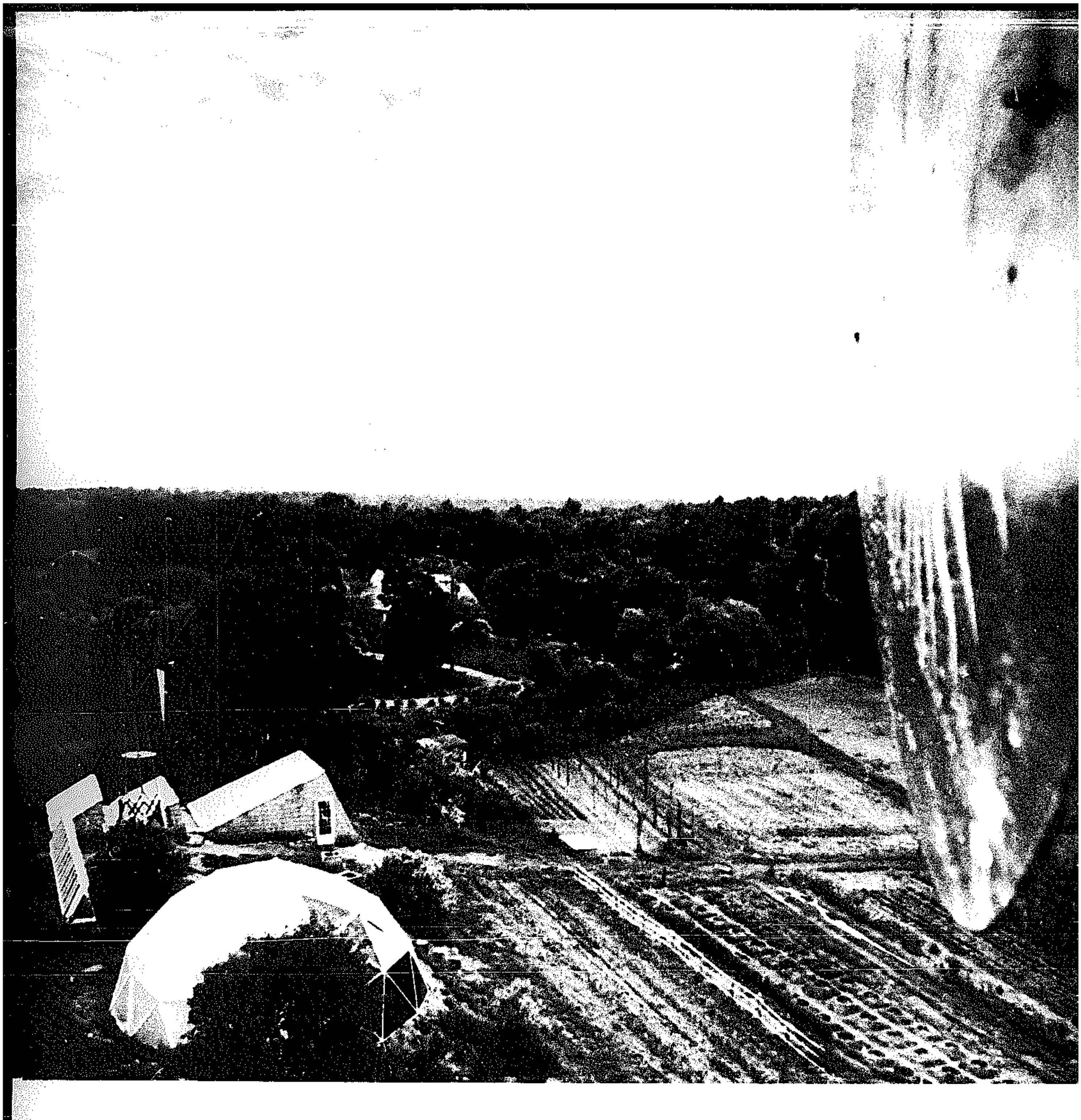


Agriculture and Energy

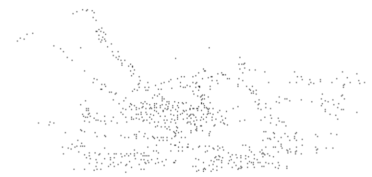
INTRODUCTION

For several generations we have lived in a society alienated from an involvement in its basic functions of support. Not until the flow of supplies, which we have come to think of as our right, is interrupted do we begin to question the sources upon which we depend. The gas crisis of 1973 seems to have been largely forgotten, with the demand for larger cars again on the rise, and although it was a contrived event, it should be seen for what it is—an indication that the resources we take so much for granted are not unlimited. The natural gas shortages of 1977 may well lead to a more serious examination of fuel sources. But as yet there seems to be little broad-based recognition of the fact that our agriculture, our industry, our transport, and much of our electricity are dependent on fossil fuels, and that although exactly how much we have and how long they will last are hotly debated, the amounts are finite. Sooner or later substitutes must be found. It is most facile for many of us to think in terms of a technological fix. "They'll think of something." But the technological fix is almost invariably at further expense to our already damaged environment. The most dramatic example of this is the ultimate technological horror, nuclear power.

Although we feel it to be our work as New Alchemists to devote ourselves to finding ecological alternatives to questions of basic life support systems, a New Alchemy publication would not be entirely honest without a statement of our unalterable opposition to nuclear power. It is compelling evidence of the manipulation of information when there is still so little public knowledge of the dangers to which it exposes not only ourselves and our children, but countless succeeding generations. Possibilities of accidents (and there have been several unnerving near-misses), sabotage, leakage, and the lethal threat posed by the use of plutonium, not to mention the problems of the storage of wastes, are not widely known. The immorality of a legacy that will contaminate the Earth for two-hundred-and-fifty-thousand years, which is the half-life of plutonium, conveys a strange, almost surreal lack of concern in a society that professes a belief in equality of opportunity in life and a love for its children. Perhaps the most succinct summary of the terrifyingly rational insanity is that nuclear nergy is predicated upon both technological and human infallibility.

Meanwhile the sun and wind appear to be with us for as close to eternity as need concern us. With these, human energy needs could adequately be met, given even modest encouragement in developing the necessary technology—which would be integrated in decentralized, smaller-scale energy patterns and used in combination with other sources such as biofuels, geothermal and tidal power.

The articles in this section describe much of what is wrong with present agricultural and energy practices. They are intended to be read as critiques, as indeed they are, but not to be interpreted as endpoints in our thinking. We have tried, at New Alchemy, to shift our intellectual paradigm until these problems no longer loom as insuperable, but rather become a touchstone for biological approaches to agriculture and energy.



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

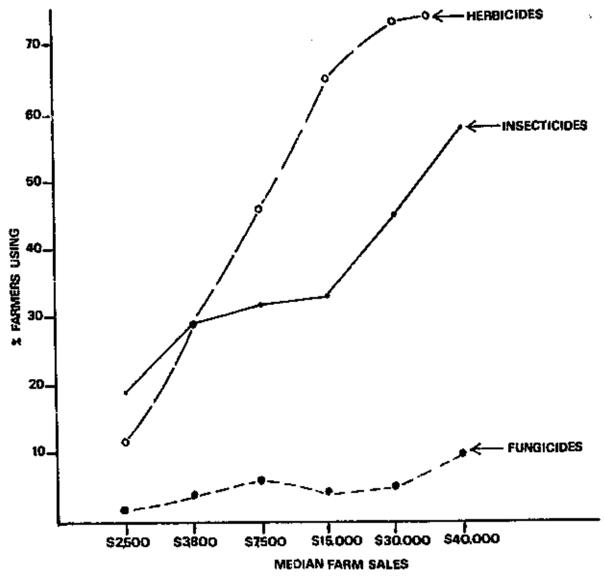


Fig. 1 Proportion of U. S. farmers using pesticides in 1966 according to size of farm operation. From USDA Agricultural Research Service.[9]

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 bee-keeping 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 simp', 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.

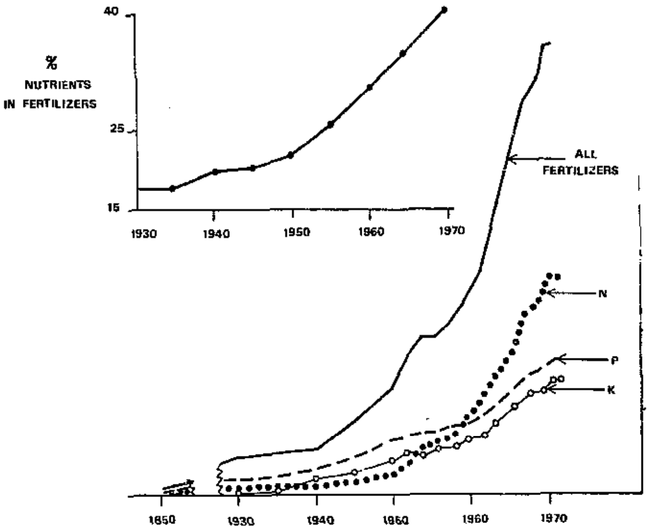


Fig. 2 Trends in the use of chemical fertilizers in the United States. Top graph shows the increasing concentration of primary nutrients (NPK) used in fertilizers. Bottom graph shows the total use of all fertilizers and primary nutrients. Adapted from USDA, Economic Research Service.[33]

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 have been:

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

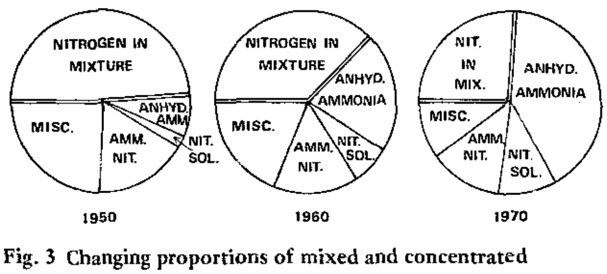


Fig. 3 Changing proportions of mixed and concentrated nitrogen fertilizer being used in U. S. agriculture. Concentrated forms include anhydrous ammonia, nitrogen solutions, ammonium nitrate and other miscellaneous types (aqua ammonia, urea, ammonium sulfate). Adapted from Tennessee Valley Authority, 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.	MAJOR VARIETIES % 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)

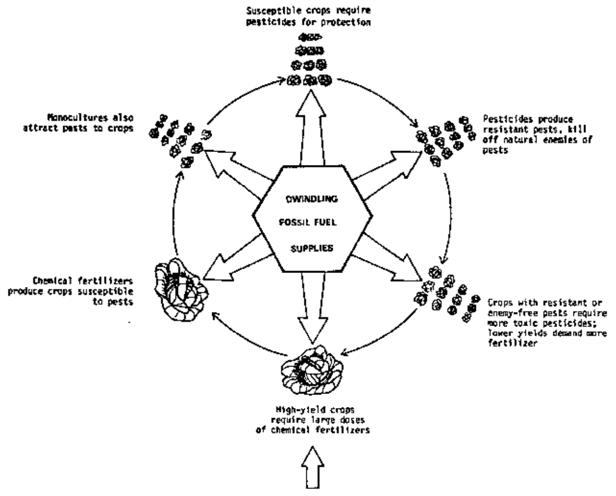


Fig. 4 The treadmill of chemical dependence fostered by the high-energy technologies of modern agriculture and nurtured by a series of ecological backlashes.

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

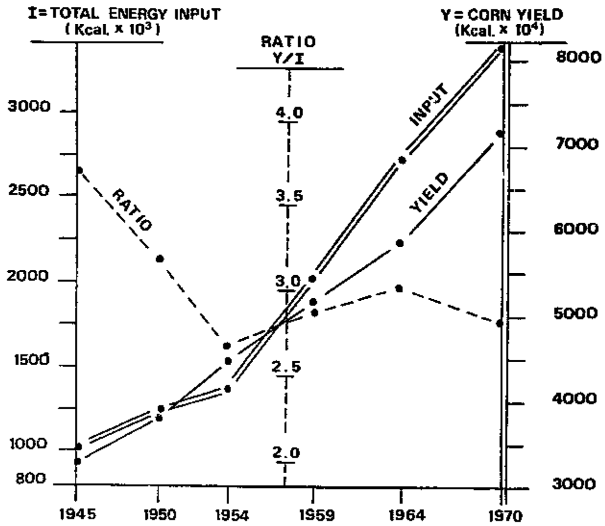


Fig. 5 Trends in the energy efficiency of U. S. corn production (1 Kcal = 3.97 BTU). Energy inputs include: labor, machinery, gasoline, NPK fertilizer production, seeds, irrigation, pesticides, crop drying, electricity and transportation. Note that,on scale, figures for yields are ten times greater than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

COMMODITY	CROP ENERGY VALUE GAL GASOLINE/TON	PRIMARY ENERGY INPUTS* GAL GASOLINE/TON	RATIO: CROP ENERGY/ INPUT ENERGY
Field Crops			
Barley	[illegible]	15.4	6.6
Corn	107.[illegible]	46.5	2.3
Rice	106.0	41.5	2.6
Sorghum	97.[illegible]	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	
Range	(93.6 - 170.9)	(133.4 - 322.4)	.63
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.

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,

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. Adopted 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.

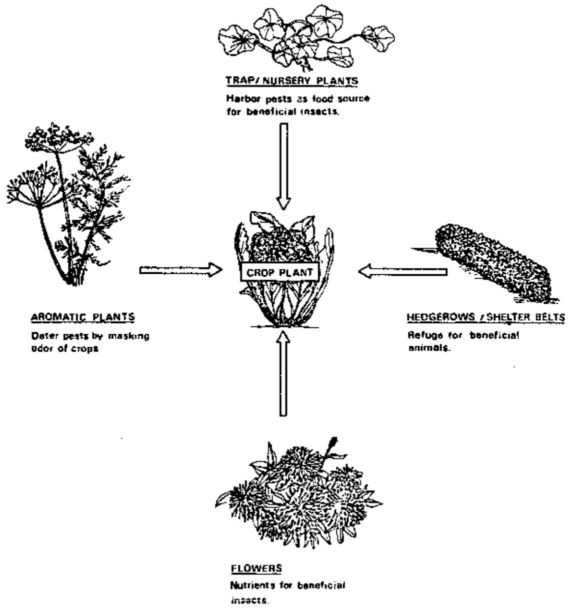


Fig. 6 Some possible components and plant interactions of a diverse cropping system, based on a garden model of "companion planting" arrangements.

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.

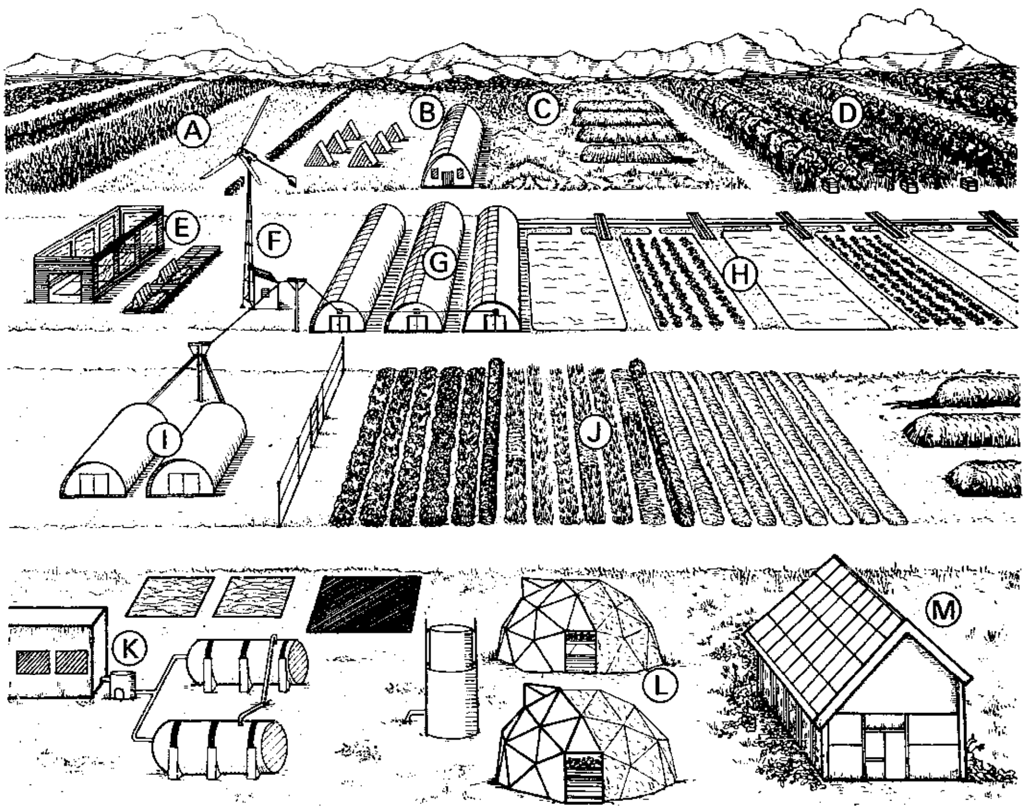


Fig. 7 An idealized polyculture farm and research center. A=Grains, green manure and forage crops. B=Solar grain-drying structures. C=Windrow compost piles on fallow section. D=Diverse, multi-storied orchards with undergrowth of refuge plants and green manure crops. E=Fish=food stocks; aquaculture insectary 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

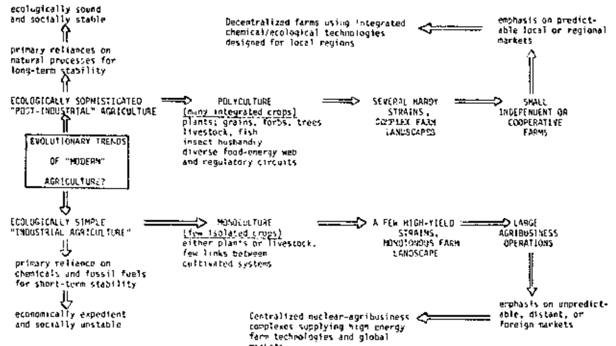
And so I believe that the Back to the Land idea is a long-term goal; no one now living will live to see it fully developed. It will be a long, slow movement... not, I hope, toward an Earthly paradise, urban or rural, but toward a new nativity of our people in the real world and in the scheme of things.

— 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

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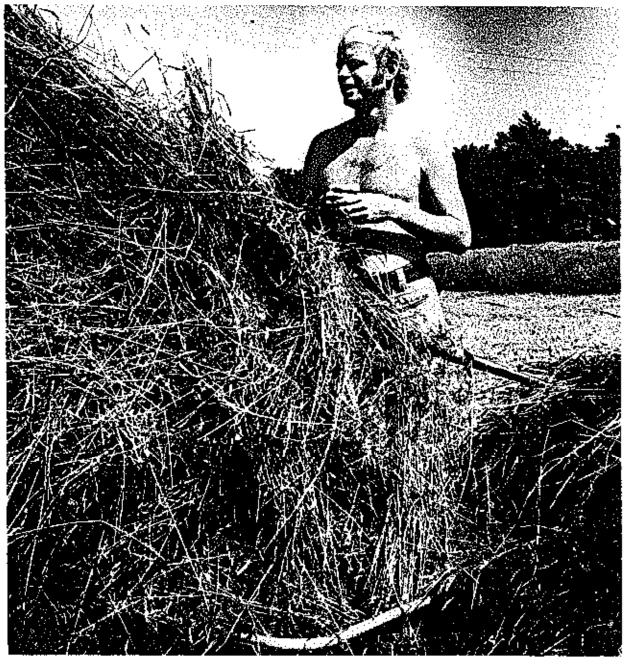


Photo by John Cressey

The Dilemma Beyond Tomorrow:

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

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 reevaluated 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. Human societies may represent, biologically, a kind of monoculture. Certainly 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.

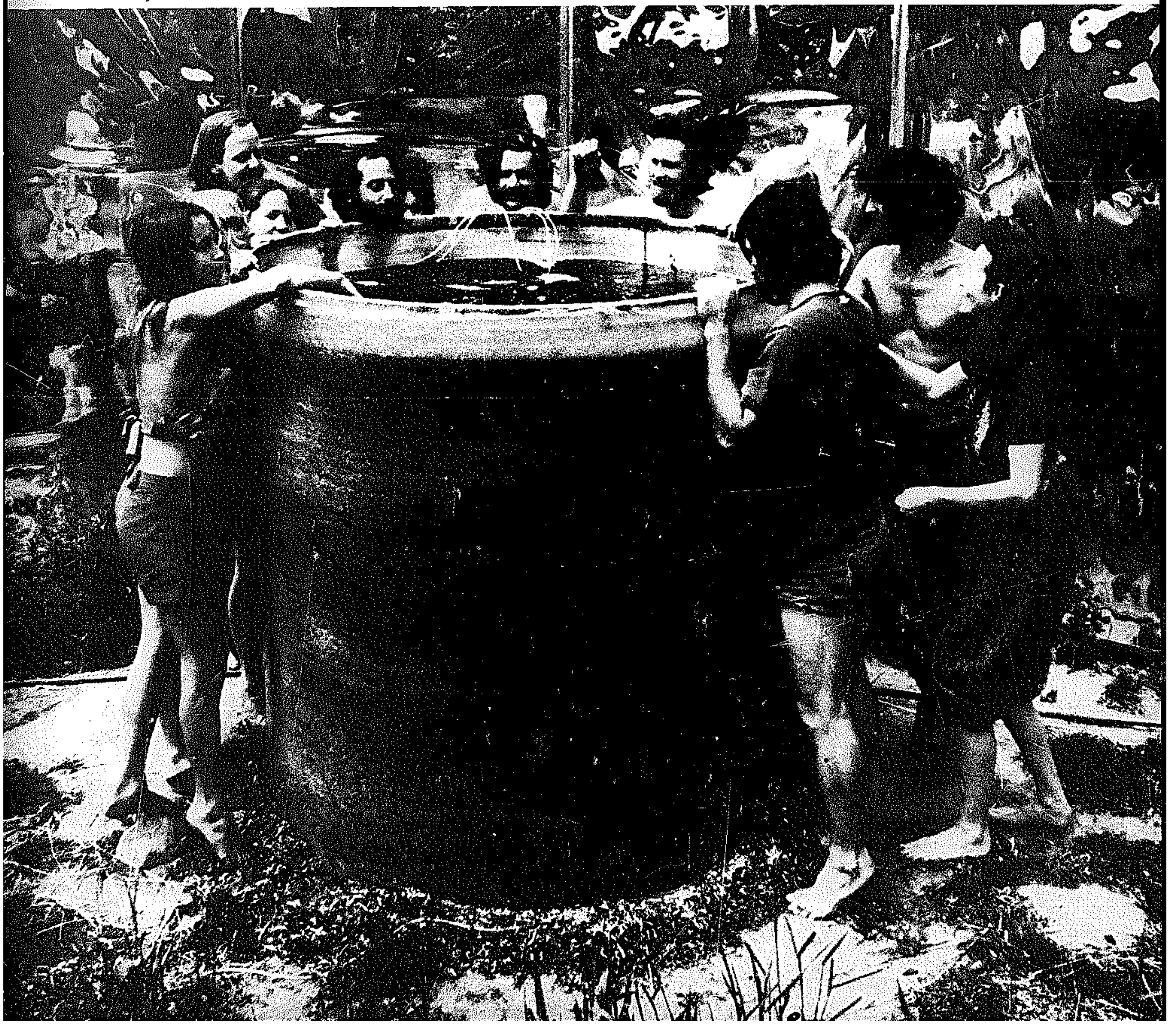
We find that there are resources, often in the strangest places, as we become less concerned with high energy and more concerned with diverse wholes. If we are willing to change the way we live, then we can begin to restore and reconstruct. By passing through the portals of nature, we can begin to work 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.

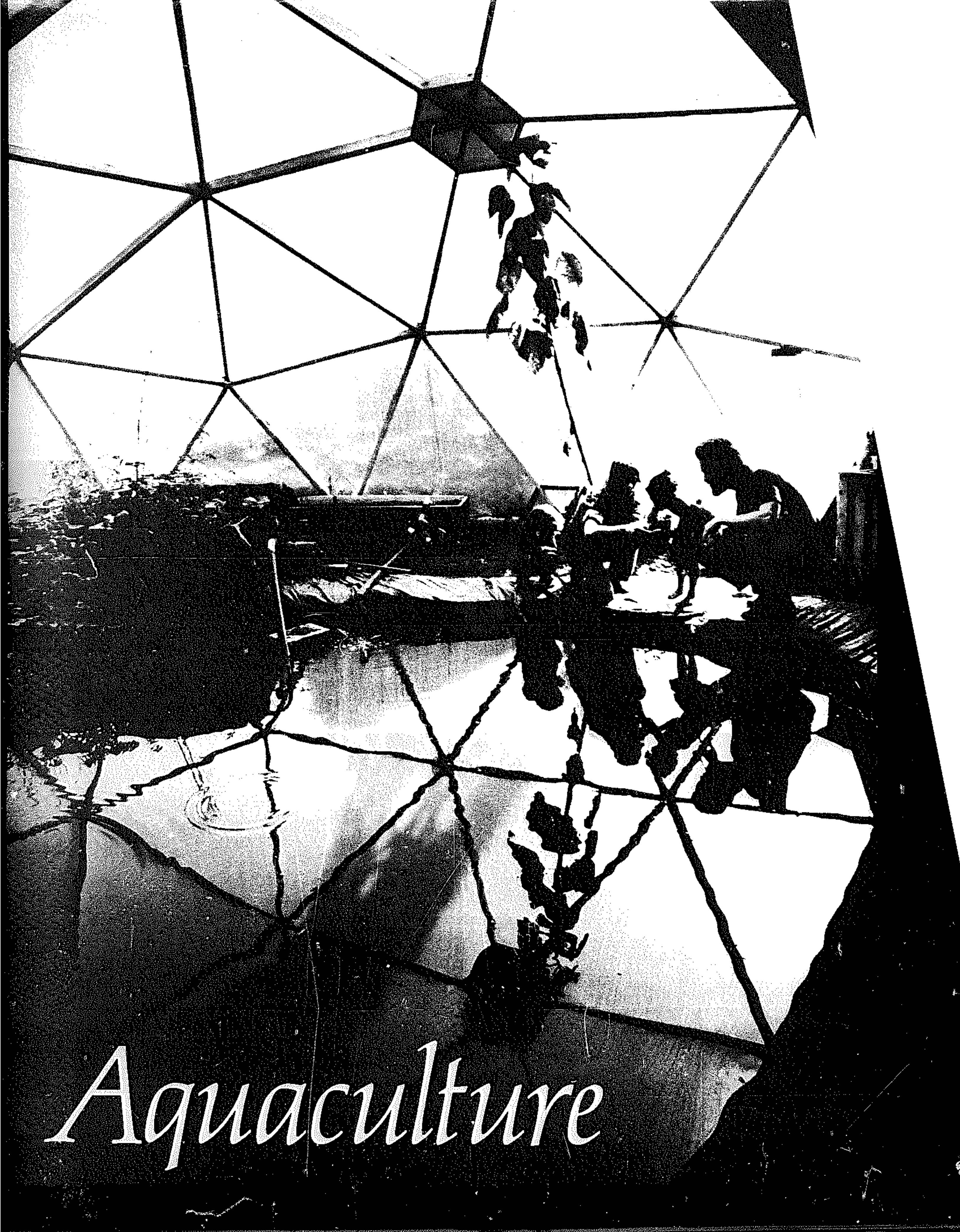
It is easy to begin. The Ark and the Backyard Fish Farms reflect wholistic and small-scale thinking, and although they are early explorations into man in nature, they will help give confidence and directions.

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*

Photo by Peter Simon




Aquaculture

INTRODUCTION

Aquaculture has been a part of New Alchemy from the beginning. The reason for this is the fact that both John Todd and Bill McLarney are marine biologists and, in Bill's case, his interest in fish is extreme to the point of fanaticism. It is more than fortunate that they brought to the group their biological knowledge, with its aquatic specialization, for it has resulted in a much broader scope for looking at intensive food production than had we confined ourselves to landcrops.

Although raising fish and other aquatic animals for human food has been widely practiced in other parts of the world, particularly in the Orient, in North America fish are not frequently a major component of the average diet partly because, as yet, many of us can still afford to rely on other sources of protein. But it is a hungry world, and although people like Francis Moore Lappe are doing extremely significant pioneering work in balancing protein in a vegetarian diet, raising fish for food still has many advantages.

The first and most obvious of these is that of maximum utilization of space, as a body of water is three-dimensional and often can satisfactorily occupy space ill-suited to other use. Most aquaculture, especially in the U.S., centers on feeding to fish such foods as grains that might otherwise go directly to people and it is therefore ecologically comparable to cattle raising. We strive, whenever possible, to feed fish food that neither competes as human food nor despoils the environment to provide it. The tilapia, which have been our major crop and are almost universally acknowledged to be delicious (a heading for an article that appeared in the *New York Times* about them reads: "Farm-Raised Fish. A Triumph for the Sensualist and the Ecologist"), subsist on a diet that is approximately 80 percent green algae inoculated into our own ponds from natural ones in the area. The remaining 20 percent is composed partly of garden scraps like carrot tops, purslane, kale, and chard. For their protein needs, particularly as fry, they are fed insects, worms, and insect larvae, which we either trap or raise ourselves, as is the case with midge larvae.

This is an oversimplified explanation of what is one of our greatest areas of concentration and interest at New Alchemy. We have found increasingly that polyculture, which involves the growing of several species of animals together, is more effective than monoculture. We have experimented with different methods of aeration, with a variety of feeding ideas and with different combinations of aquatic plants and animals.

Within the past two years we have begun a series of experiments that indicate a truly exciting potential. We have been raising fish in what we are calling solar-algae ponds. These are cylinders that are placed on the ground and stand about five feet high, with a variety of diameters. They are made of a translucent fiberglass material. As with our work in bioshelters, the opening of structures to maximum interaction with light has made a vast difference. Because light can enter the pond not only at the surface but on all sides, photosynthesis by the algae is greatly increased, resulting in much enhanced productivity. After our second summer's work with these ponds, in one ninety-eight-day experiment, our yields, on a volumetric basis of comparison, exceeded those of Chinese polyculture fish farms (known as the world's most productive pond culture) by fifteen to twenty times. This is equivalent to 36,500 pounds per acre in ninety-eight days. We expect further major increases in productivity within the next few years.

Although it has been necessary to have trained biologists to create these aquaculture systems, as is explained in the article "Walton Two," we hope to research methods to make them approachable by anyone. We feel ourselves to be like chefs, concocting and devising our recipes that we shall then publish for people to try and adapt for themselves.

"Walton Two," a handbook on fish raising as we work with it on Cape Cod, is our first attempt in this direction. The second article, "Cultivo Experimental de Peces en Estanques" comes to us from a very highly respected Colombian biologist, Professor Anibal Patiño R. We are proud to include an example from another climate and culture as an illustration of a successful application of ideas comparable to our own.

The brief piece on gley is a little-recognized but very significant item of real news. In many areas of the world, porous soils cause ponds to drain. Cement or plastic liners are often expensive or inaccessible. A biologically created liner makes sealing possible and opens up the scope for aquaculture, polyculture, water retention, and irrigation and is therefore an important component in land restoration. Since the publication of this article in our third *Journal,* further corroboration of gleization has been received from areas as diverse as Saskatchewan and Florida.

A New Low-Cost Method of Sealing Fish Pond Bottoms

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

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

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

1. The pond bottom was completely cleared of debris, rocks, etc.

2. The bottom and sides were covered completely with wastes from nearby hog pens. Care was taken to apply the material to the vertical sides of the pond as well as to the bottom. This layer and each subsequent layer of material was added in quantities sufficient to just cover the previous layer.

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

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

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

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

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

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

– *William O. McLarney*
J. Robert Hunter

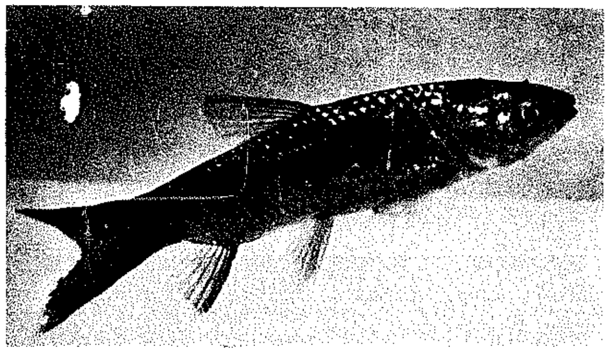


Photo by Fritz Goro

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

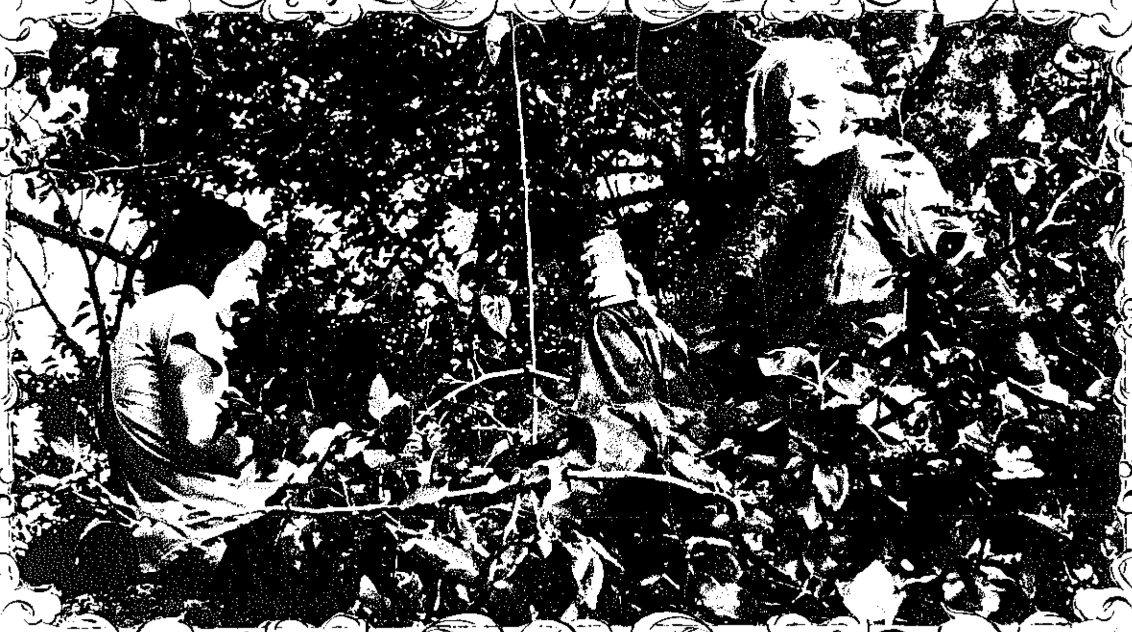


Photo by John Cressey

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 humanity's folly; the spectre of the peaceful atom is as frightening in the long run as the existence of the nuclear military establishments.

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

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

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 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

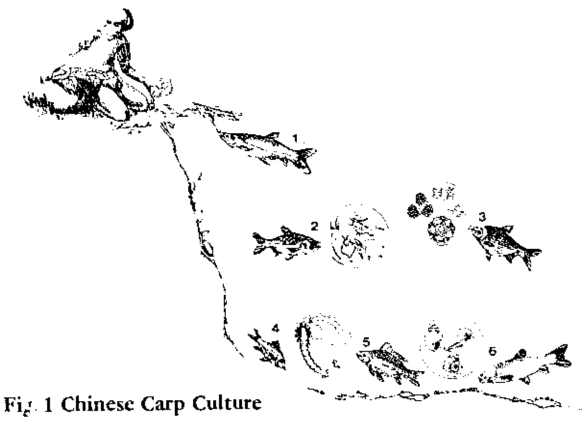


Fig. 1 Chinese Carp Culture

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

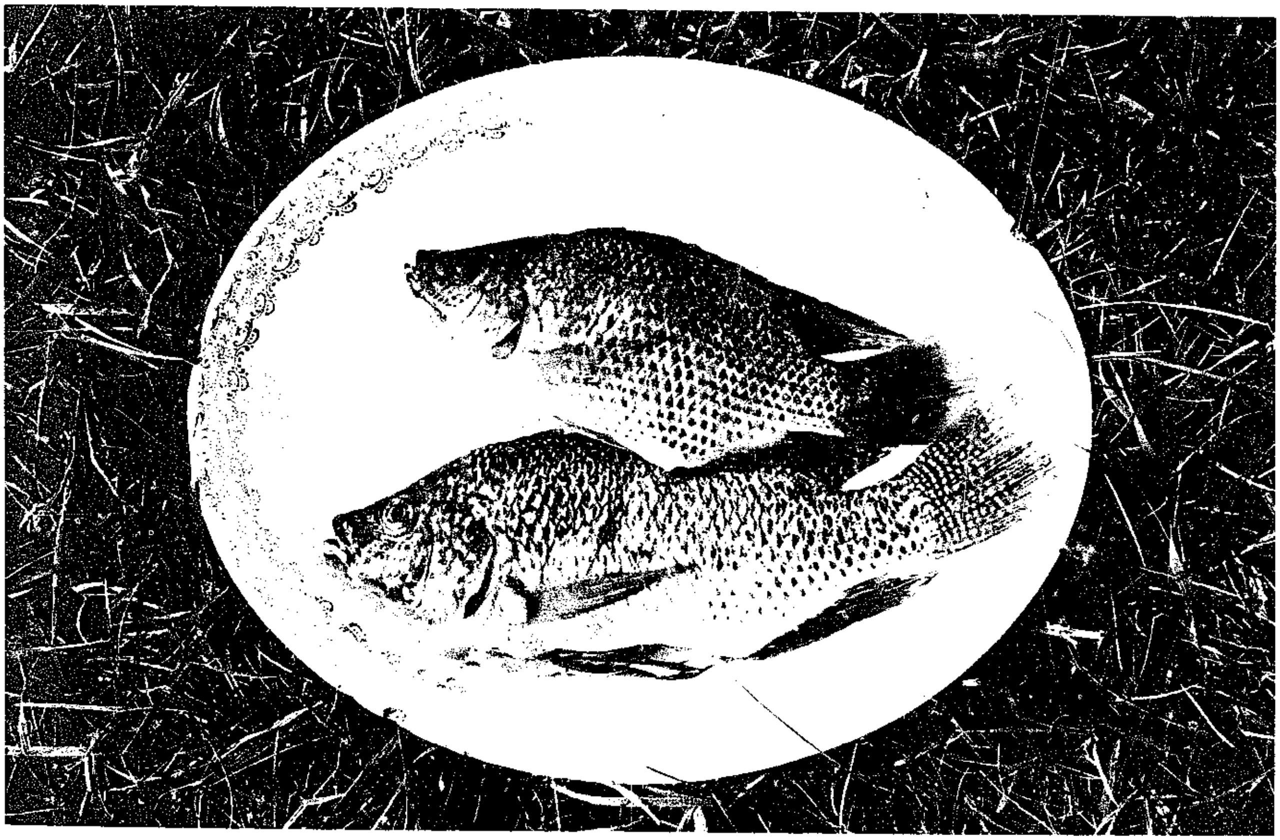


Photo 1 - *Tilapia* *Photo by John Cressey*

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

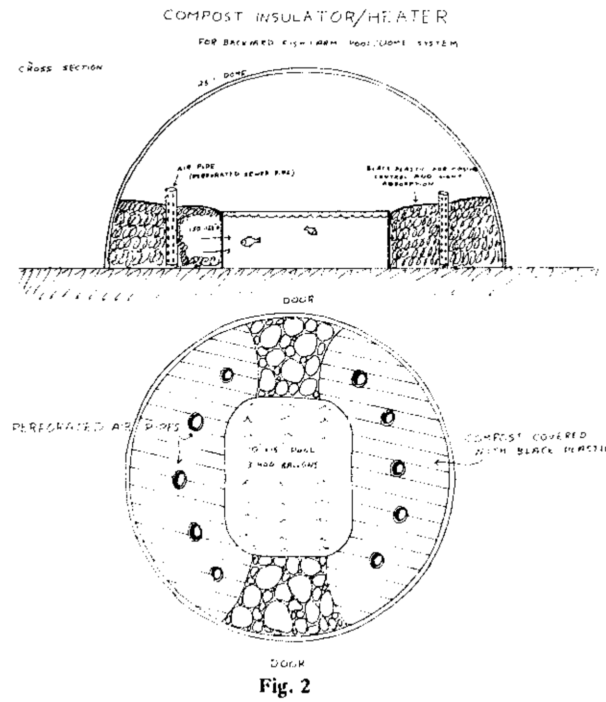


Fig. 2
Compost – Dome System

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

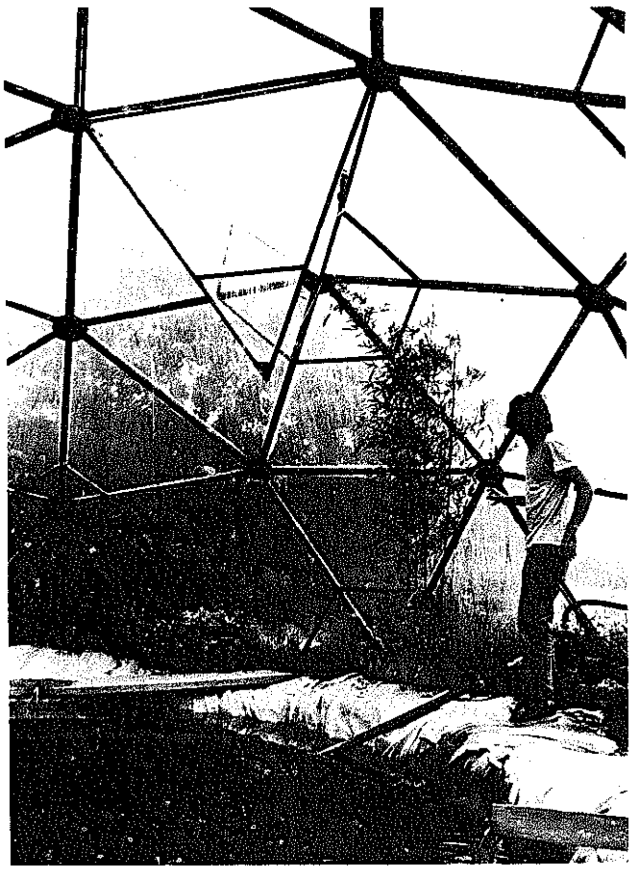


Photo 2 *Photo by Alan L. Pearlman*

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.

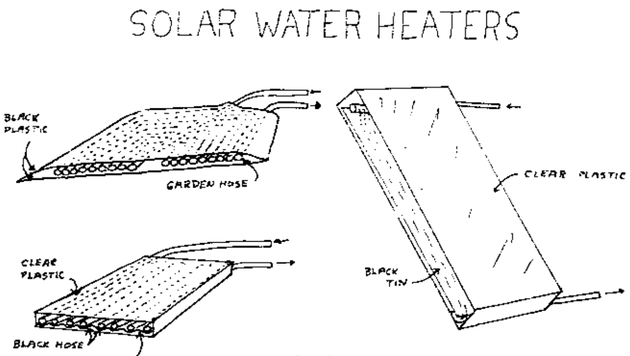


Fig. 3

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.

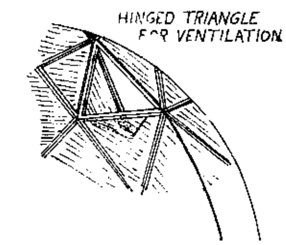


Fig. 4 – Ventilation

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.

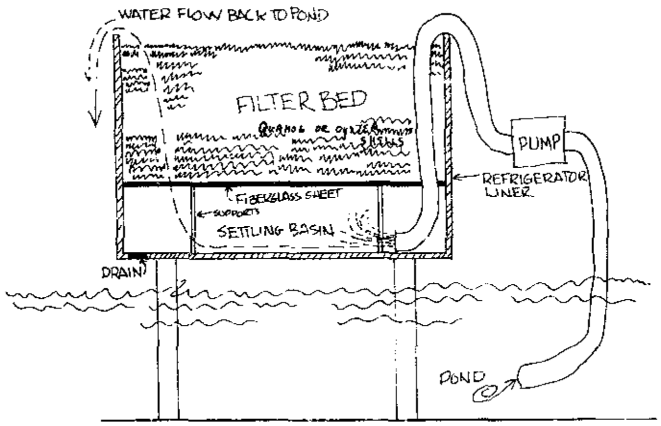


Fig. 5 — Filter

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-

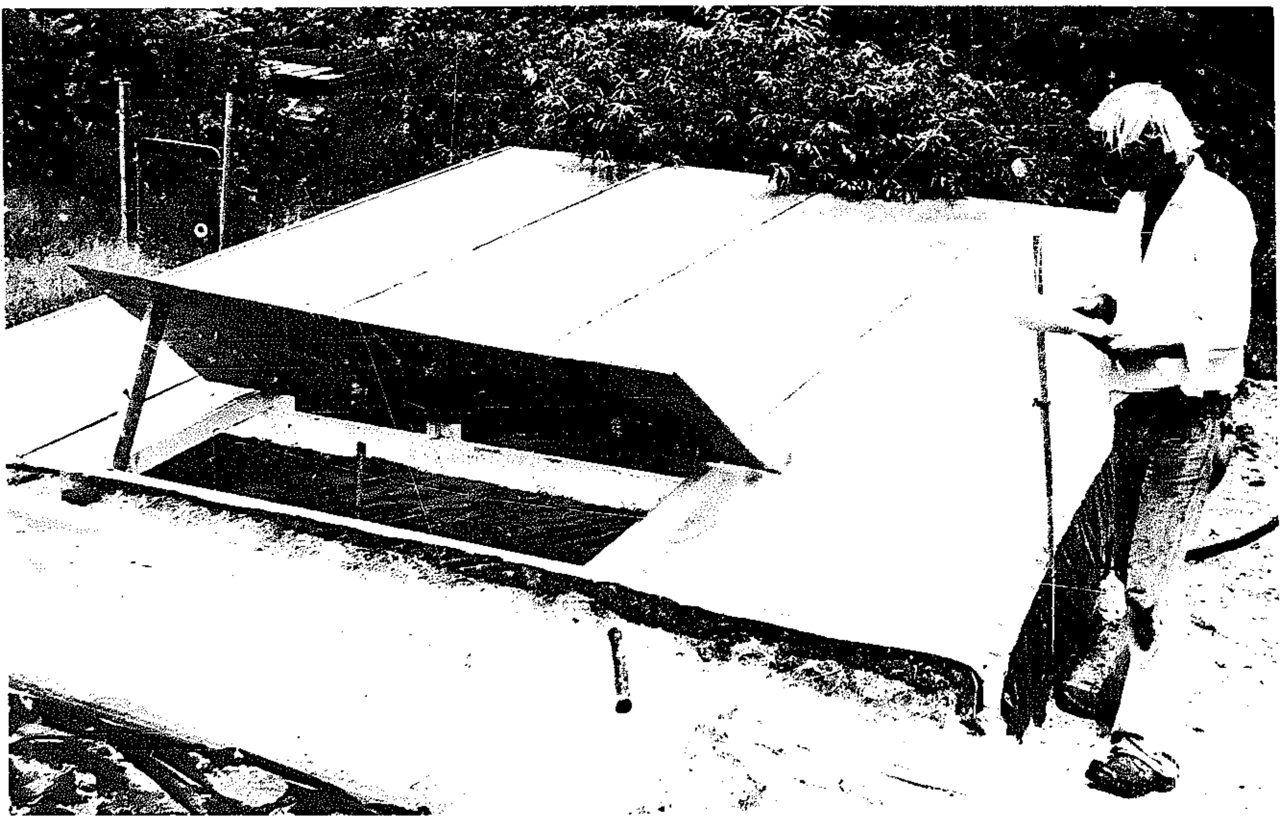
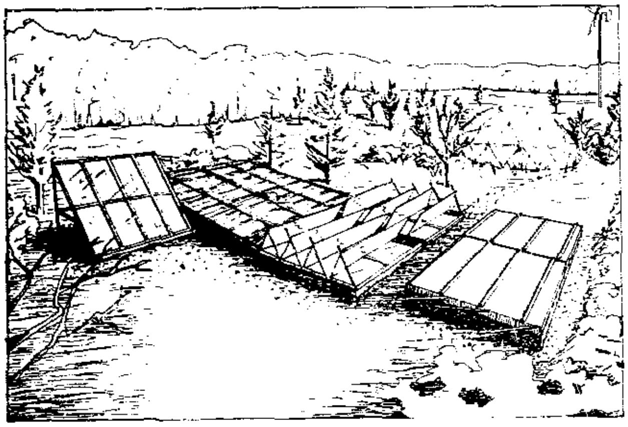


Photo 3 — Flat Top Backyard Fish Farm

Photo by Alan L. Pearlman



NAI'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.

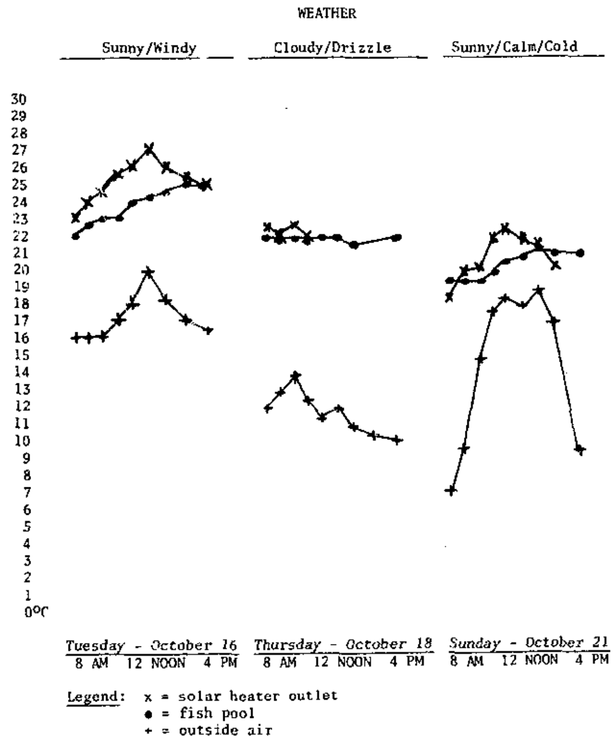
The growing season in the Dome with its internal umbrella was not quite as long as within the Flat Top. However, in more clement or sunnier parts of the country the choice between the Dome and Flat Top becomes a matter of taste. A double-skinned 2" x 4" x 30' dome might perform equally well or better.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

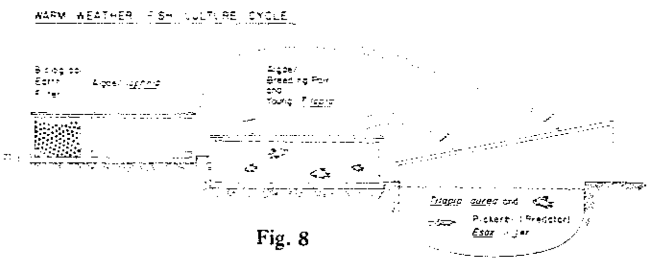


Fig. 8

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.

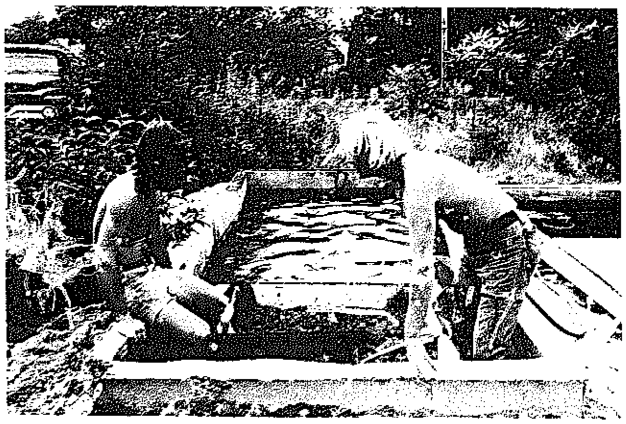


Photo 4 *Photo by John Cressey*

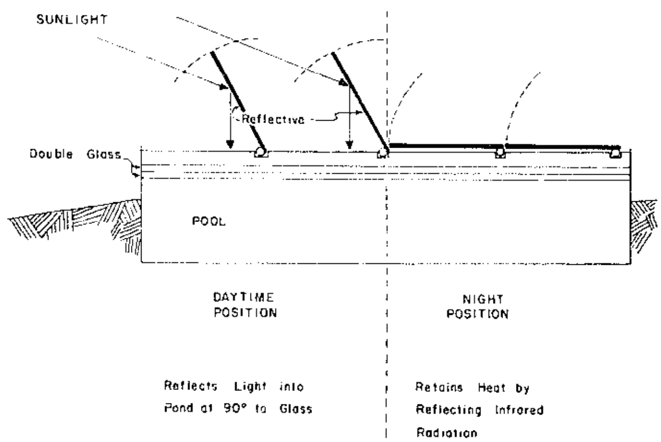


Fig. 9
Night Blind - Reflective Pool Tops

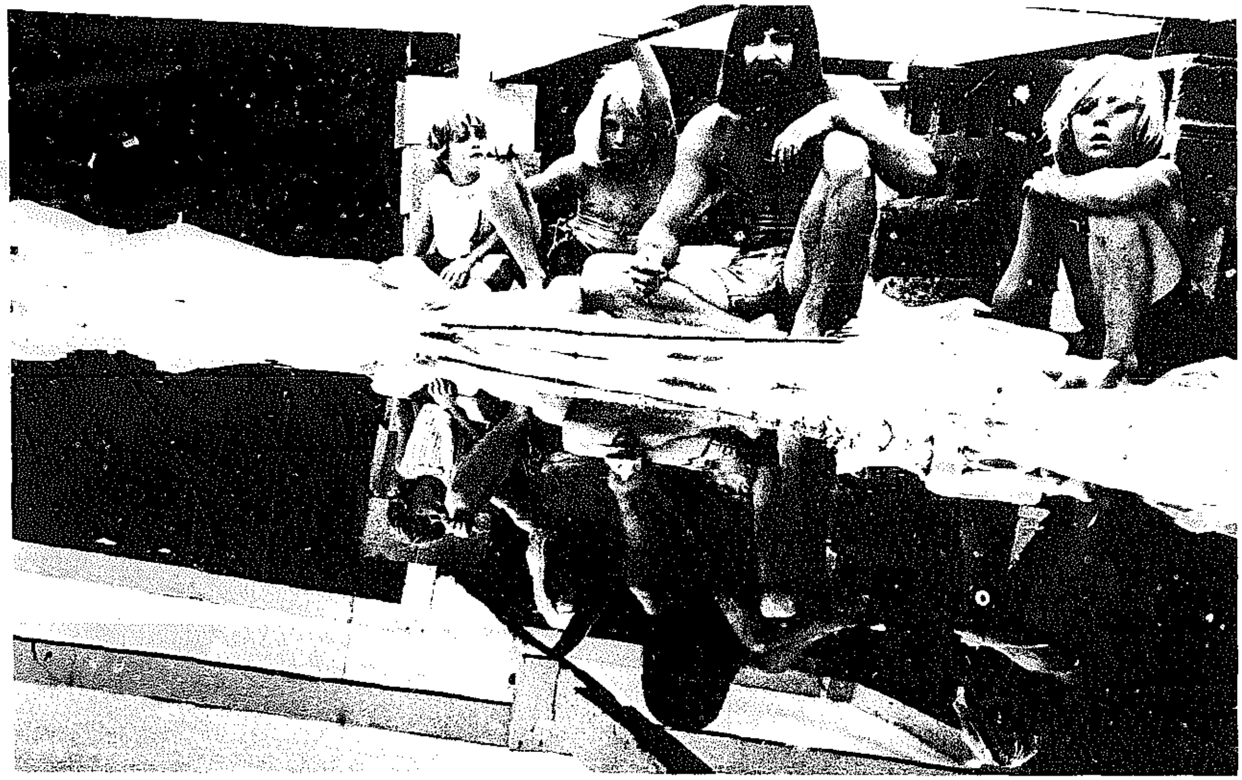


Photo 5
Interior Flat Top

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.

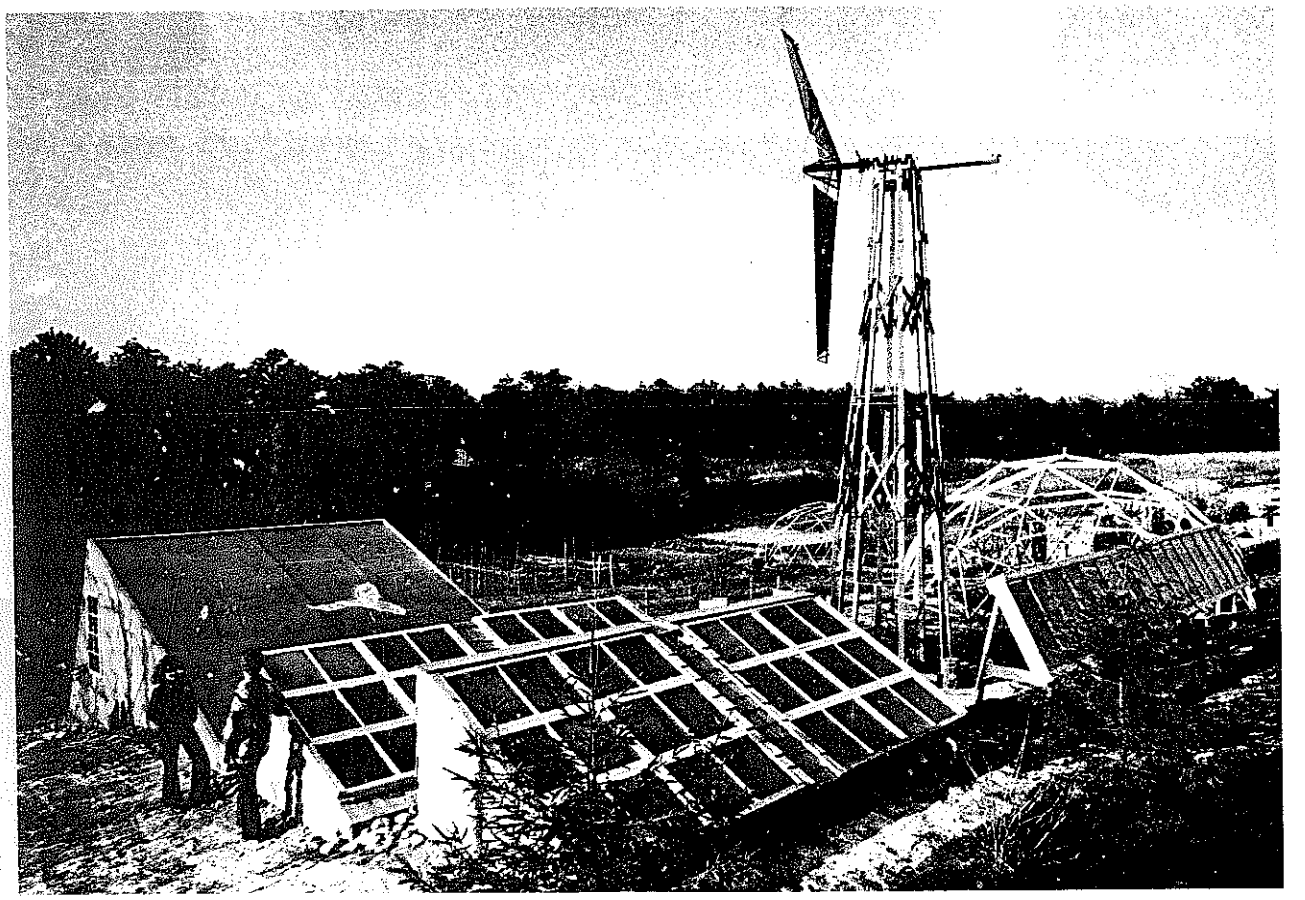


Photo 6 *Photo by Ken Kobré*

MINIATURE ARK

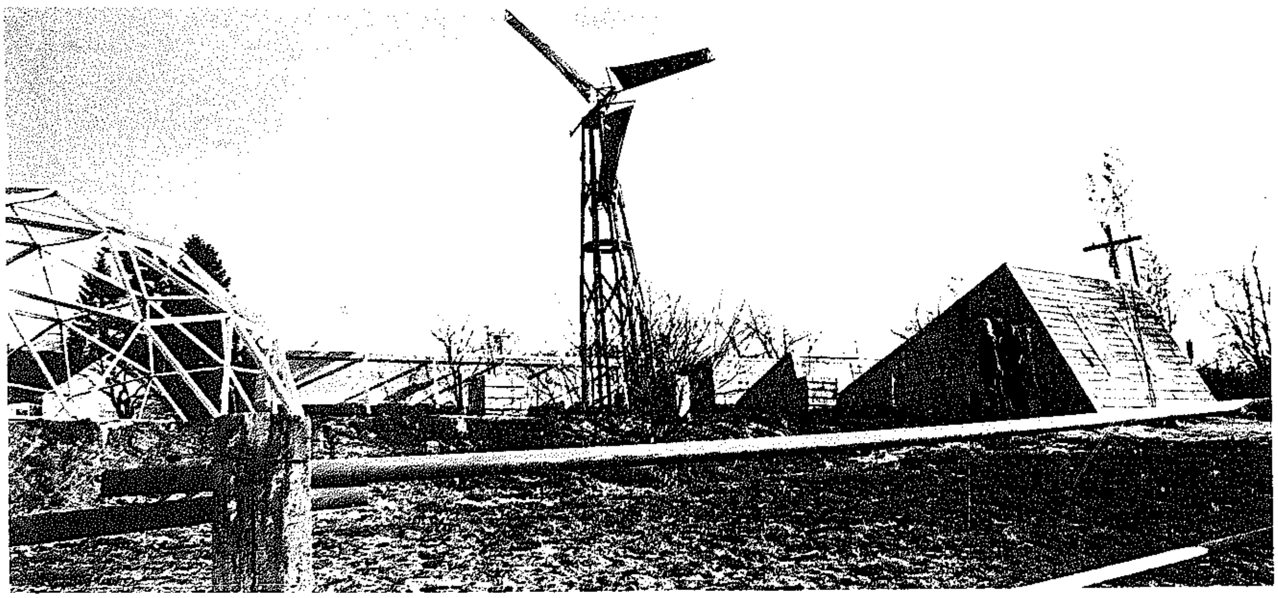


Photo 7 *Photo by Ken Kobré*

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

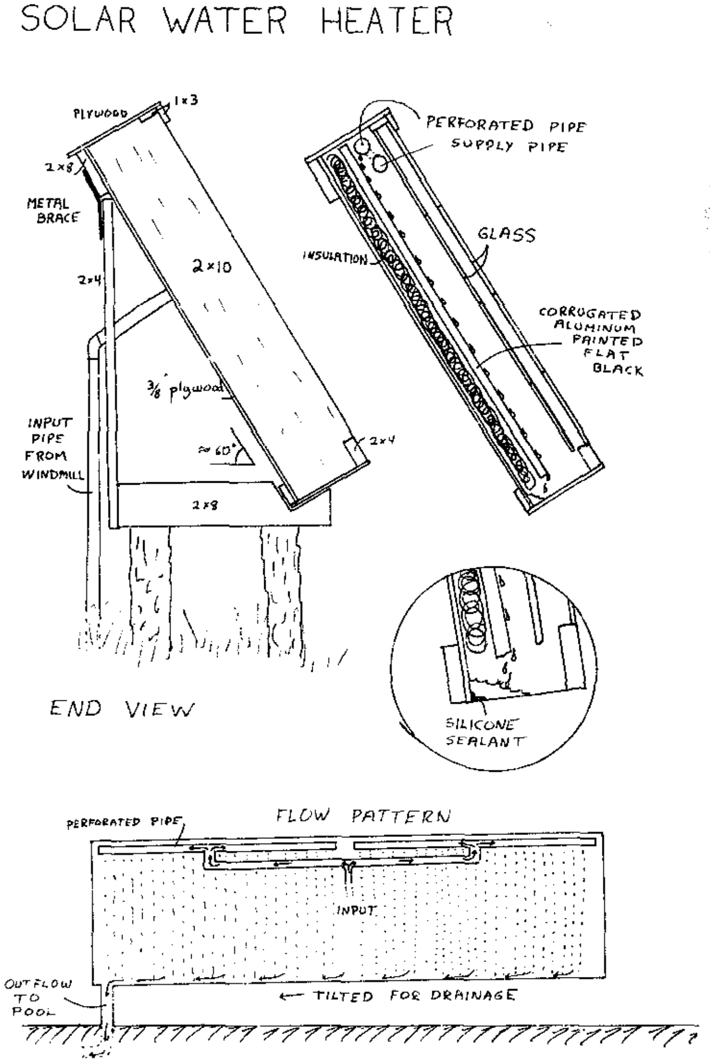


Fig. 10

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.

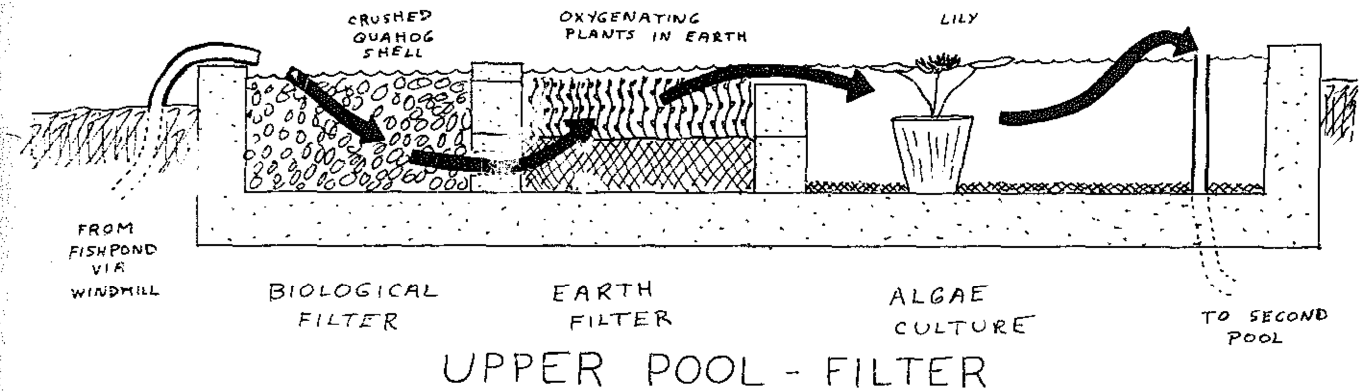


Fig. 11

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

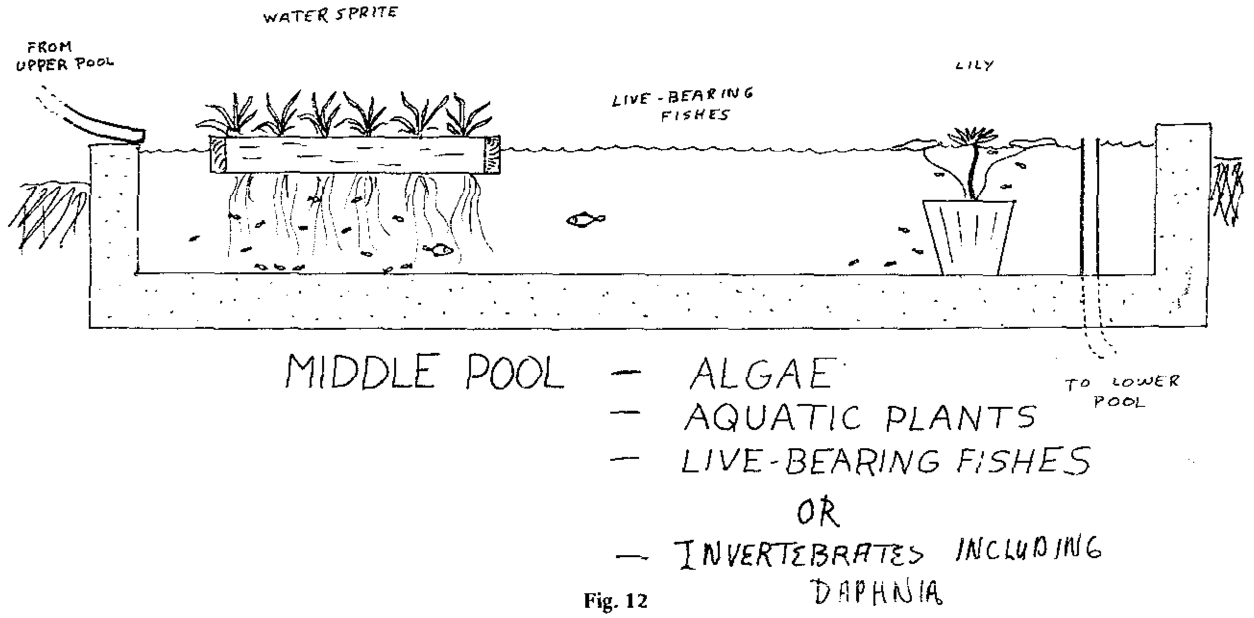


Fig. 12

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

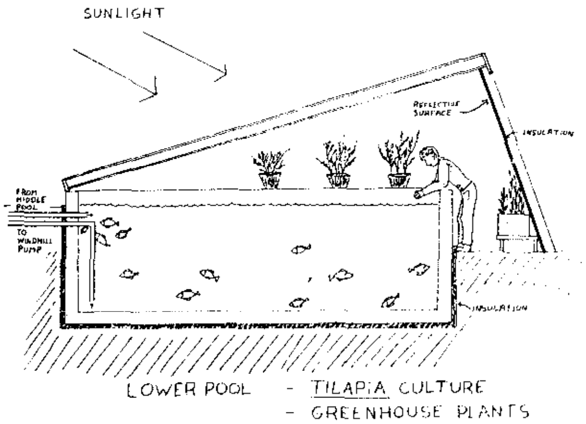


Fig. 13
Greenhouse - Fish Culture Structure

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

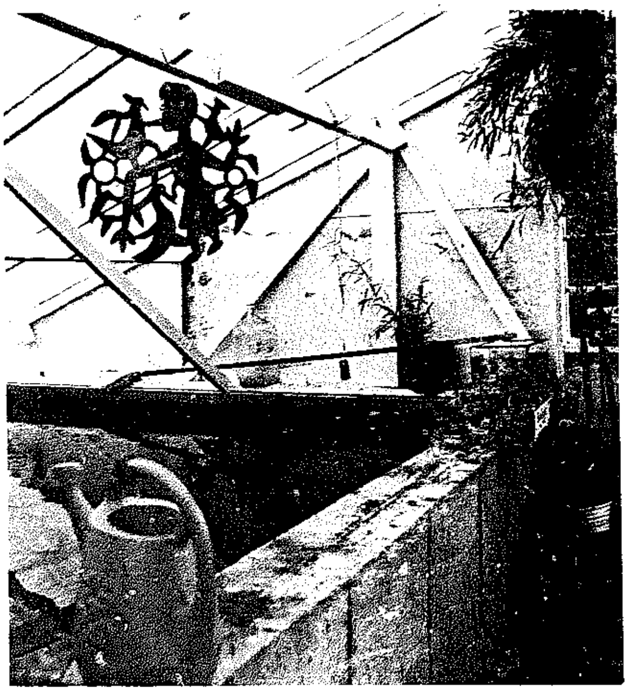


Photo by Peter Sherman

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	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	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	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 pref. 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

Table 2

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

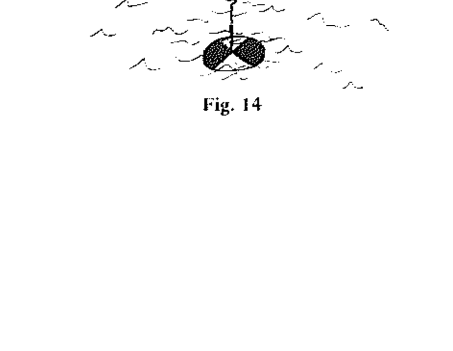


Fig. 14

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.

Photo by Peter Simon

Two Important Notices

1. Be sure you have facilities for holding fish before you order. We can't stress this point strongly enough.

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

PREDATORS AND POPULATION CONTROL

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

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

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

Four small brown bullheads *(Ictalurus 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, *Osteglossum 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.

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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.

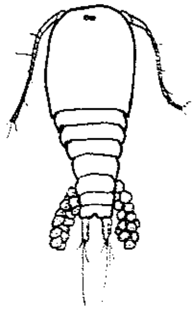
Collecting the Organisms: Before becoming a great hunter-gatherer, you will need to learn when collecting from ponds how to determine amongst these very small aquatic animals which are the good and which are the bad guys. This knowledge is critical and not hard to acquire.

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.

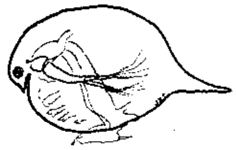
Preliminary identifications of algae, protozoans, rotifers, molluscs, crustaceans, insects and fishes can be made using the keys in the book. You may also need an "old-fashioned" introductory zoology or biology text to learn enough about the structure and morphology of each taxonomic group to be able 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 overwintered in refrigerator liners and the bleaching effect of a long period of time against a white background rendered identifying marks all but invisible. Species composition was determined at harvest time.

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

Supplemental Feeding

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

TABLE 3

Production

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

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.

* * * * *

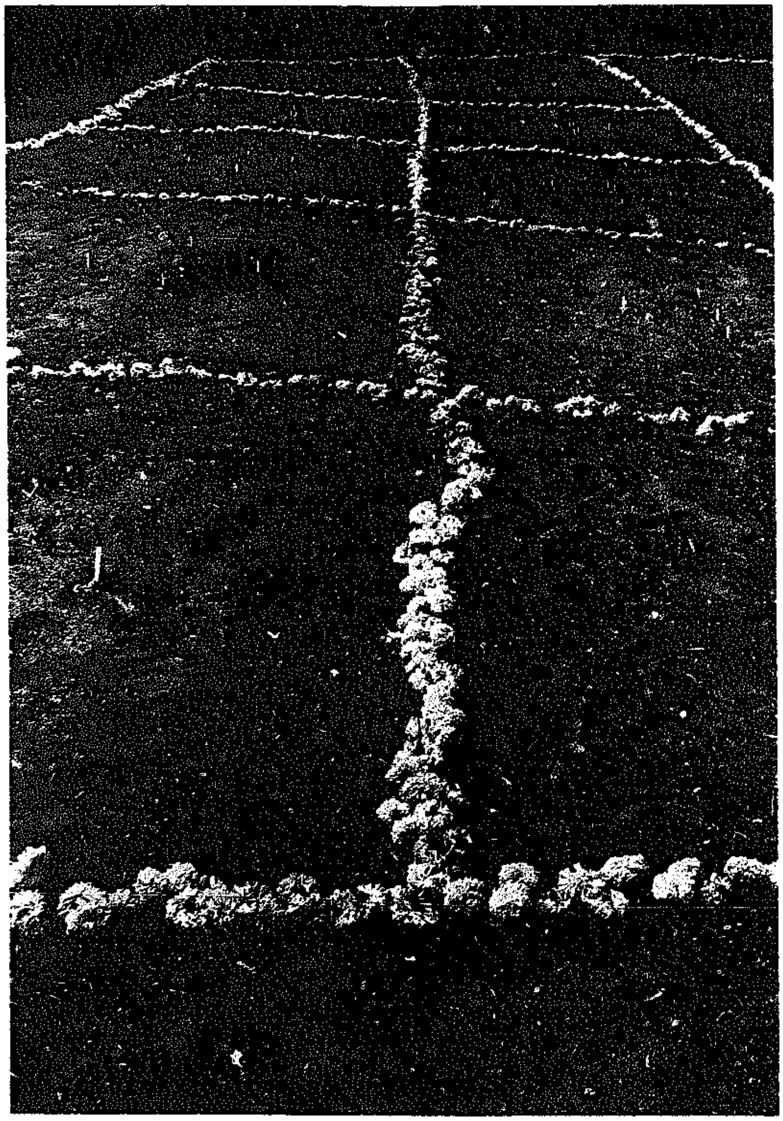


Photo by Alan L. Pearlman

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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.

Cultivo Experimental de Peces en Estanques

PREFACE

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

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

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

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

INTRODUCTION

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

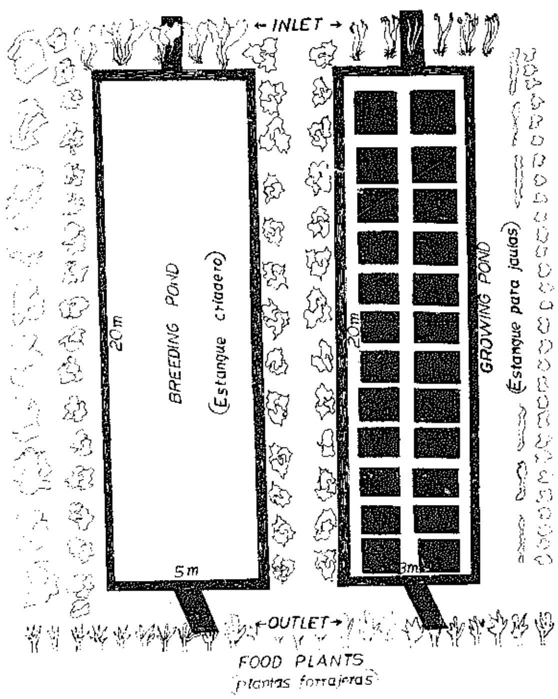
1. He advocates polyculture of certain species of *Tilapia* and local fish species.
2. The primary foods for the fish, apart from those produced by fertilizing the fish pond, are weeds, agricultural wastes or various plants which can be cultivated with a minimum of effort.
3. Selected fish are grown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

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

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

POLYCULTURE

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



To describe briefly the four species:

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

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

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

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

1. What is the behavior of the jetudo when confined in standing water?

2. What is the effect on growth of the bocachico in ponds when combined with *T. mossambica* or *T. rendalli?*

With respect to the first question, it was demonstrated that the jetudo will survive and grow in standing water. This is also true of another edible characin, the machaca, *Brycon guatemalensis,* which occurs naturally only in flowing waters (McLarney, 1973b). Sixty-four jetudo, with a mean weight of 69.3 g, were introduced into one of the ponds. Over a period of twelve months they grew to a mean weight of about 115 g. Only four died. Prior to the introduction of the fish the pond was fertilized with commercial 14-14-14 fertilizer and planted densely with *Elodea canadensis* to maintain high levels of dissolved O_2. The lowest concentration recorded during the experiment was 6.8 ppm. This experiment was disrupted somewhat by the accidental introduction of some young *T. mossambica,* which may have competed for food with the jetudo.

Two ponds were used in the tilapia - bocachico experiments. One was stocked with 150 juvenile bocachico with a mean weight of 34.7 g and 100 *T. mossambica* with a mean weight of 6.0 g. The other pond received an identical lot of bocachico plus 80 *T. rendalli* with a mean weight of 47. 6 g. (It should be noted here that a possible limiting factor in culture of the bocachico is its delicacy with respect to handling. Mortality of bocachico during capture, transport and stocking was thirty-five per cent, that of tilapia less than five per cent.) Prior to stocking, both ponds were fertilized with 14-14-14 at the rate of 1 kg/pond; at the time of stocking the water in both was light green. The *T. rendalli* pond was densely planted with *Elodea canadensis.* Three months later, *Elodea* was placed in the *T. mossambica* pond as well, to aid in oxygenation.

Periodic examination of the stomach contents of sample fish showed that there was more overlap between the feeding niches of the bocachico and *T. mossambica* than between bocachico and *T. rendalli.* While the ponds differed in such respects as size and reproductive rate of tilapia, dissolved O_2 concentration, provision of supplementary food (leaves of various plants supplied daily to the *T. rendalli*), and abundance of aquatic plants, the evidence suggests that the combination bocachico – *T. rendalli* is complementary, while the combination bocachico – *T. mossambica* – is not.

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

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

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

USE OF AGRICULTURAL WASTES OR WEEDS AS FISH FOOD

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

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

1. Their leaves are high in protein (17.2 per cent, 23.25 per cent and 24.2 per cent, respectively).

2. They are easy to grow and can be propagated vegetatively.

3. They grow rapidly and produce large amounts

of useable vegetation.

4. They are tolerant of poor soils.

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

CULTURE OF *T. RENDALLI* IN CAGES

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

1. Careful selection of only male fish for the culture pond.
2. Production of "monosex" hybrids – one hundred per cent male or nearly so.
3. Careful use of predatory fishes to thin, but not eradicate, the tilapia.

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

Other advantages of cage culture include:

1. Intensive culture with minimal labor and materials.
2. Technological and economic feasibility for the campesino.
3. Facilitation of feeding, inspection of the stock and harvest.
4. Continual harvest and replenishment of growing stock.
5. Rendering many types of water bodies useable for fish culture.

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

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

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

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

For purposes of comparison, Professor Patiño cites Kuronuma (1968) who describes the cage culture of various marine fishes in the fertile Inland Sea of Japan. Kuronuma considered an annual production of 29 kg/m^2 remarkable. These fish were fed a high quality dry food with a conversion ratio of 1.6. In Professor Patiño's experiments, the unsupplemented *T. rendalli*, stocked at 100 fish/cage, produced 28.5 kg/m^2 of pond surface in five months. While no attempt was made to determine the conversion ratio of bore leaves, it was undoubtedly much higher than 1.6. At New Alchemy East we have achieved a good conversion rate of 1.5 with *Tilapia aurea* and *Tilapia zillii*, and believe that part of our success is due to small amounts of animal protein (earthworms, insects, etc.) in their diet, particularly when the tilapia are small (McLarney and Todd, 1974).

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

INTEGRATION OF FISH CULTURE WITH CULTURE OF HOGS AND CHICKENS

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

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

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

After four months, the hogs were weighed again. The mean weight of the control animals was 16.5 kg, that of the test animals 24.5 kg, or 33.1 per cent more, even though they had started the experiment being slightly smaller. The mean weight gain of the controls was thus 7.9 kg, or 48 per cent, while the hogs whose diet was supplemented by tilapia had a mean weight gain of 17.0 kg, or 69. 4 per cent.

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

THE "CAMPESINO FISH CULTURE UNIT" AND ITS ECONOMICS

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

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

1. Select a pond site with the help of an expert. New Alchemy's new method of pond sealing should render site selection easier (McLarney and Hunter, see page 85).
2. Plant the area around the pond site with fish food plants. Professor Patiño suggests one hundred stalks of yuca, one hundred roots of bore, chayamansa and other suitable plants as available locally. These need occupy less than ½ hectare. It is important to plant before beginning pond construction, so that the plants are producing by the time the fish need food.
3. Build two ponds:
   a. A nursery pond ("estanque criadero"), 5 m x 20 m x 1 m, connected by a ditch to a good water source, with another ditch for drainage. When filled, the nursery pond should be fertilized. When the water turns green, add five hundred to one thousand juvenile *T. rendalli.*
   b. A growing pond ("estanque para jaulas") near the nursery pond, also provided with inlet and outlet ditches. The growing pond should be at least 3 m x 20 m, and 1.5 m deep. Plant this pond with aquatic plants and introduce twenty-four cages, each measuring 1 m x 1 m x 1 m, spaced equidistantly. Each cage should be equipped with legs to keep it 30 cm off the bottom.
4. When the tilapia start to grow, select individuals 6-8 cm in total length and stock them at 200 per cage. All the cages can be stocked at once, or stocking can be staggered to suit the culturist.
5. Feed the fish in the cages twice daily, in the morning and late afternoon, with leaves of the food plants. Feed as much as the fish will consume, but no more. If feasible, supplement their diet with wheat or rice bran.
6. Inspect each cage monthly to determine if health and growth of the fish are satisfactory. For this purpose, the cages may be lifted slightly so that the quantity of water in them is reduced. They should not be lifted completely out of the water or held up too long, as the fish will become very excited and subsequent losses due to jumping out may occur.
7. Harvest after five months, or when the fish have reached the desired size.

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

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

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

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

As of Summer, 1975, $28.50 Colombian was the equivalent of $1.00, U. S. Funds

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

DISCUSSION

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

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

– Anibal Patiño R.

Précis by William O. McLarney

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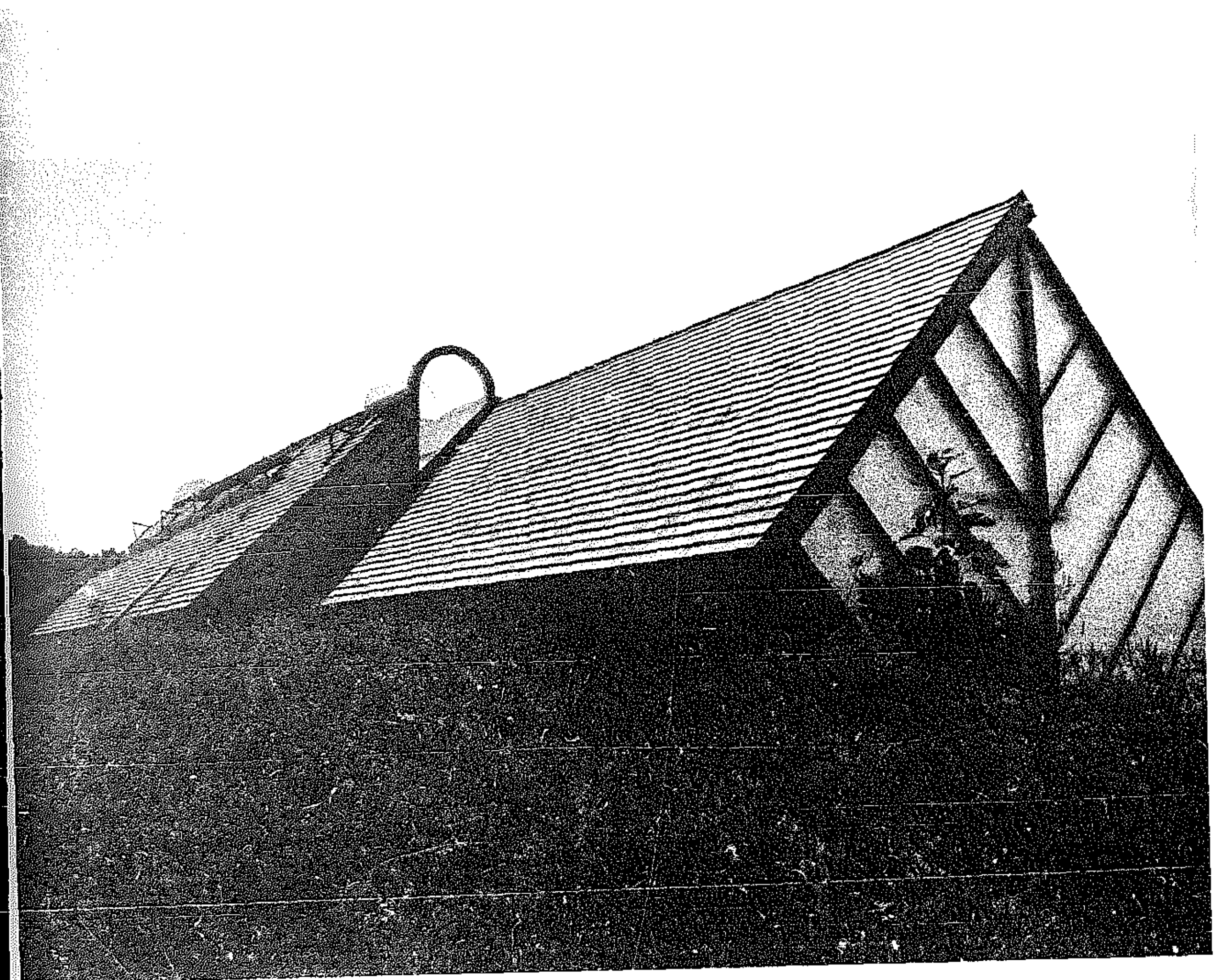


Bioshelters

INTRODUCTION

For New Alchemy, 1976 had the markings of both a culmination and a new beginning. That year saw the bringing together of much of our previous research under one roof in the construction and completion of the bioshelters, or Arks, on Cape Cod and on Prince Edward Island. Yet, because it will take years of observation, testing, experimenting, and adapting to learn the fundamentals of working with semienclosed ecosystems, it was a beginning for us as well.

A bioshelter is a structure that is autonomous or semi-autonomous in relation to its environment. Beyond shelter, it provides its own heating and cooling requirements; recycles its own wastes; in some cases it generates its own electricity and water collection; and finally, it provides a substantial proportion of the food requirements of the occupants. Our first bioshelter dates back to an eighteen-foot geodesic dome built in 1971, which contained a fish tank in the form of a child's swimming pool, and had a few salad greens growing around the periphery of the pool. We have advanced experientially and experimentally from this first dome through various progressions to the bioshelters discussed in the articles that follow.

Both the Cape Cod and Prince Edward Island Arks can be considered autonomous structures in that they have had no reliance on an outside energy source like fossil fuels, but regulate their own internal climates through the collection and storage of solar energy. The Cape Cod Ark is used for food production in all seasons. The Ark on Prince Edward also contains living quarters.

An understanding of the biological workings of a bioshelter should be possible through the subsequent descriptions, but it does seem useful to point out that inherent in a wider adoption of bioshelters are certain political and economic implications. It should also be understood that the bioshelter concept need not be confined to structures as large as the Arks, which are being assessed as productive economic units; in fact, the concept has potential of a wide range, which could include a small family greenhouse annexed to more orthodox housing. (Table 1 in "Tomorrow Is Our Permanent Address" offers a summary of the advantages of a bioshelter over a standard house.)

Although the original bioshelters were designed for temperate climates in a rural or semirural setting, and are based around the family as an economic or residential unit, further experimentation could lead to expansion in a number of areas. Adaption of some of the principles would be possible for enclosed community or neighborhood gardens. Public buildings, cluster housing, and apartments using garden areas, energy collection, and storage or generation and waste recycling are conceivable.

It is unwise to generalize too broadly, because one of the earliest lessons of the bioshelter as a concrete application of a biological analogue is sensitivity to the particular environment. Strategies must be conceived and adapted to the area for which they are intended. A bioregional or biogeographical approach is therefore implicit in the concept. Obviously more solar collection and storage capacity is required in the northeast than in the southwest, where cooling and venting must be emphasized. It is one of the few fortuitous circumstances these days that the developing countries have, in the main, less severe climates. Therefore, where many ideas like water collection and storage, waste recycling, and intensive ecological food raising are applicable, there is less necessity for extensive enclosed areas either for shelter or to extend the growing season. Used adaptively, they can fall legitimately under the heading of appropriate technology. The promise of structures adapted to their particular landscape and climate, and utilizing available regional resources, would be a welcome relief to what is becoming an unaesthetic global monoculture in architecture.

A widespread acceptance and use of bioshelters and their accompanying ecological precepts and technologies would be a step toward a more decentralized, steady state economy. Their comparative self-sufficiency could lead to less incentive to exploit either the environment or other peoples, and their resources and would offer their inhabitants greater personal independence. Beyond this, there lies the thought—or hope—that by working with a structure that is empowered by the same forces that govern the biosphere, perhaps our present feelings of fragmentation in our lives and of alienation from the natural world will slowly heal through a renewed intimacy with the forces upon which we are ultimately dependent. If the purpose of the hermetic vase or athanor of the alchemists was to mirror the workings of the larger world, then our bioshelters with their enclosed ecosystems are our crucibles for transforming the future.

Tomorrow Is Our Permanent Address

Dedicated with love to my children Rebecca, Jonathan, and Susannah.

"That if Nature be a harmony, there must exist a unity and continuity extending through all realms which for me is the physical, organic, aesthetic, and mental."
—Law of Laws, *Henry Drummond*

It is becoming clear from the recently growing knowledge of living systems and from general systems theory that it is the structure, or morphology, of a system that determines its behavior and subsequently its fate. The coefficients or parameters within a system determine only rates or relative dominance. This distinction is significant, since current attempts to adapt technological society to changing conditions are focused on coefficients—such as improved automobile performance, the substitution of materials, conservation, and so on—which are not fate determining.

The comparatively new structure on which contemporary western society is based is the product of a historical moment when petroleum energy was cheap and thought to be limitless. Oil and gas created the structure, the mode of organization, and the constituent parts of society; in addition, they have directed much of science and technology. Mechanized agriculture, large-scale centralized power generation, steel and glass architecture, manufacturing, heating and air conditioning, the car culture, and air and road transport were predicated on the belief that these fuels would continue to be available in abundance and at low cost.

The entire fabric of modern life is built on this fallacy. While the fact that the petroleum supply is finite is now widely acknowledged, we haven't yet faced the fact that our continued dependence amounts to addition. Like addicts, we are attempting to find substitutes (particularly in nuclear and space-solar energy) to sustain what in the long run cannot be sustained. Maintaining the existing structure through new energy sources or improving performance through energy conservation are coefficient-based activities, which can only buy time. This time should be used to seek fundamental changes in design. Amory Lovins, a physicist with an interest in societal structure, thinks that if we confine ourselves to such temporizing rather than restructuring society we are doomed as a culture. If he is right—and I believe he is—then the task of redesigning needs a theoretical framework and a focus.

The most apt early models for a theory of design that might engender adaptive human societies are nonhuman ones. (By "adaptive" I mean having the intrinsic ability to survive and persist through time and change while sustaining environments and deepening human values.) In overall concert, nature has and will adapt, even if some of its components, including humans, disappear. Within nature are strategies and structures that have worked since the dawn of life. Their discovery and emulation in human design could well provide the key to the future.

Unfortunately, modern biology is mainly fixated on adaptability of the individual or the group at the species level and thus has separated the organism from its ecology. As a result of this cleavage we have failed to understand adaptability in a systems context. Even though adaptiveness in multispecies systems (such as ecosystems, bioregions, or the biosphere) is beginning to be studied, the structure or architecture within this framework has yet to be mapped. And this is what we need for the broad knowledge necessary to formulate a design synthesis.

For the present, we know enough about the structure of living things to propose, tentatively, an adaptive design synthesis. Nature is dramatically different from modern technological societies in its underlying structure. Several of these differences need articulating.

Living entities are comprised of subunits, which are, in themselves, whole and complete. This is the opposite of technological society, which is complete only when all of its globally dependent parts remain interlinked. In nature each level of organization is not only complete, but follows design that may well be universal. An organelle within a cell can have most of the attributes of life; in structural terms it is like the cell of which it is a part. The cell, in turn, with its wide range of activities, is in a design sense an image of the organism within which it resides. Complete and autonomous, it is also part of a larger entity. An organism is in structural terms a miniature of the ecosystem that sustains it. The parts of the ecosystem are more diverse, discontinuous, and spread out, but the relationship is one of micro (the organism) to macro (the ecosystem). The ecosystem in turn has the structure of the biosphere of which it is a part.

There is a unity of structure extending from the gene to the planet. The genius of nature lies in its ability to fuse the opposites of autonomy and interdependence to create a whole. A structural continuum exists throughout the biosphere. The bonding seems to lie in the linkage of adjacent biotic components like the weaving of a multidimensional tapestry.

Technological society is not constructed in this way. Not only are its subunits incomplete, but its interdependencies are global and the vehicles of interdependency are extremely vulnerable political and economic networks. *American agriculture cannot function indefinitely without access to Moroccan phosphorus.* Industry and transport would flounder without inexpensive Middle Eastern oil.

DESIGN THEORY: BASIC CHARACTERISTICS

Seven basic guides to design have been culled from biological sources. Several of these are parallel to well-known political ideals. The essential point is that all must occur simultaneously for an adaptive structure to be created.

1. Humans as Direct Participants in Sustaining Culture

With increasing scale, centralization, and specialization, present trends indicate a future in which the majority of people are spectators rather than participants in such essential processes as access to food, energy, and shelter. Currently, most people have no knowledge for basic *survival within the natural world. To achieve personal* freedom and avoid ecological breakdown caused by the present oversized vulnerable networks, society should be restructured so that the majority of people gain direct knowledge of their food, power, and housing needs.

2. Integration and Linking of Subcomponents at Point of End Use

Today agriculture, housing, education, energy production and consumption, and manufacturing exist piecemeal in relation to each other, and this results in pollution, inequity, and overall inefficiency. If everything is linked to everything else in terms of food, energy, shelter, and manufacture, the result will be human-designed ecologies with a symbiotic, self-regulating integration of architectural, technological, and living components.

3. Reduction of Scale

Design criteria 1 and 2 are predicated upon criterion 3. Ecosystems, particularly those that are most diverse and complex, are, by comparison with the industrial state, made up of relatively small components in large numbers. We must recapture humanness in scale, because this may represent, in biological terms, an adaptive state. In an evolutionary time frame, gigantism rarely persists for long.

4. Bioregional Basis for System Coefficients

The quality of sunlight penetrating an overcast New England sky is vastly different from that creating the beating heat on a New Mexico landscape. This produces difference in land form, climate, and biotechnical possibilities. In the east, diffuse light may be the most appropriate source in the service of communities, whereas the dry southwest might require a technology based on concentrated light collection. In both cases scientific research and technology should be designed only after the characteristics of the bioregion are understood. Elegant solutions *will be predicated upon the uniqueness of place.*

5. Biosphere's Needs Met First

Short-term economic gain is destroying the biotic fabric of the globe. The biota of each bioregion should be restored to a condition parallel to its climax state. Regions once forested should be returned to forest; agriculture of such an area should be designed to simulate the characteristics of its climax forest. Such a transformation of agriculture is still possible. Long-range adaptability will not come about without a profound human commitment to the larger ecologies that sustain them.

6. The Sun, Wind, and Biofuels

Living systems derive their power either directly or indirectly from the sun, wind, and processes of biological degradation. Adaptive structures may well evolve from natural energy pulses. *To survive we may have to follow* suit. Fortunately, even very poor people who have neither petroleum nor nuclear fuels have access to these renewable energy sources.

A shift to renewable energy would not sustain the present structure. Through wholistic redesign, using finite substances to assist in the transition, a renewable energy base for society may be possible. The Ark described in this article affirms this possibility.

7. Living Equivalents to Substitute for Machines and Fuel-Consuming Processes

The search for processes in nature equivalent to present technologies will possibly be the greatest scientific challenge for the next generation. Ecologies coupled to architectural and electronic components have undreamed-of potential to work for communities in a gentle and nurturing way. The solar-algae ponds described below are early examples of a transition to a method using a designed ecosystem, a structural framework, and light to grow food. These ponds illustrate a basic shift in thinking about design.

This list of seven traits of adaptability is only a beginning. We are, at the present, limited by an incomplete understanding of nature. However, a deeper science of nature and of natural philosophy is emerging from the fragments of contemporary knowledge. As the practical, the scientific, and the sacred become integral parts of a living whole, a unity takes form. It is a triumph of biology over physics, of life over energy.

The following is an early exploration at New Alchemy of such a theory of design.

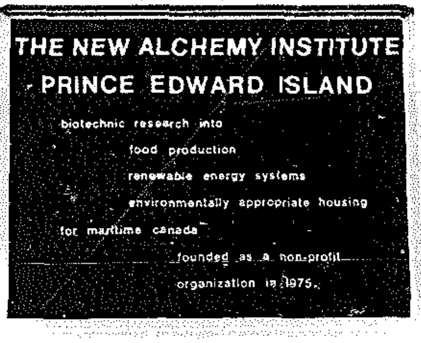


Plate 1. Entrance to the Ark. Spry Point, Prince Edward Island, Canada.

THE ARK

As electricity, fuel, fertilizer, food, storage, and transport costs rise and their petroleum bases dwindle, nations requiring substantial energy will have to reduce their standards of living, which is precisely what is happening at the present. Or they have the option of taking a bolder step and redesigning themselves to accomplish much more with less. The Ark attempts to do the latter. Into one solar and wind powered structure it combines: a household; resident greenhouse; a microfarm, including production aquaculture, a vegetable greenhouse, and tree nursery components; a small barn-shop; a waste-purifying system; and a research laboratory. It is a first attempt to create symbiotic associations out of support functions normally separated in space and time. Unprecedented levels of integration among energy, food, and shelter systems have been attempted. As such, the Ark is a first effort at a new synthesis.

With the Ark on Prince Edward Island, we redefined how people live and sustain themselves by focusing on *redesign and restructuring at the smallest functional unit* of society—the household. Since housing affects the majority of the population and is the major fuel consumer for space heating, human habitations represent a logical starting point in any critique of society. The Ark project began as a question: Is it possible to devise a human habitation as a bioshelter—that is, a structure inspired by biological systems, capable of providing its own energy and climate, trading its own wastes and growing food for the residents?[1-3] We were interested in carrying the concept one step further and designing a human habitation as a bioshelter with the capacity of a small economic unit, which could pay its way through the sale of its surplus power and produce.

In collaboration with Solsearch Architects the New Alchemy Institute has built two Arks, one on Cape Cod and one in Maritime Canada. The Ark on Prince Edward Island to be described here differs from the Ark on Cape Cod in that it is a human habitation as well as a microfarm. It has its own power-generating and waste treatment facilities, as well. In the Prince Edward Island Ark, bioshelter design combines the various support elements into a single structure. The Ark on Cape Cod is exclusively an agricultural bioshelter. The Prince Edward Island structure is much more complex. It has to function in an extreme climate on the eastern end of the Province of Prince Edward Island in the Gulf of St. Lawrence. Its location on Spry Point is surrounded by pack ice during the winter and early spring months. The Cape Cod climate is benign by New England standards. Additional heating, trapping, and storing components were required in the Canadian Ark. In order to function as a human habitation, the degree of its climatic control had to be greater, and internal waste purification and sewage treatment were required. From a design point of view, the Ark on Prince Edward Island is an extension of the concepts developed in the Cape Cod Ark. But because it is more complex in a biosocial sense, there is within it a higher degree of integration. It is technologically as well as biologically more sophisticated than the smaller, less costly Cape Cod Ark. (The Cape Cod Ark is described in the article by E. Barnhart, pp. 134–142.)

A bioshelter that is a human habitation is not just a house, although superficially it may look quite similar. From the north side the Prince Edward Ark resembles an architectually conservative house that is made more modest by the presence of the earthen berm that partially hides its bulk (Plate 2). But the differences between the Ark and an orthodox house are many and fundamental; the Ark is a microcosm designed to serve a range of human needs that housing does not provide now. It is modeled on an ecosystem. Its architecture is solar (Plate 3). Together they are able to perform a wide array of tasks. In many respects the Ark is the antithesis of the

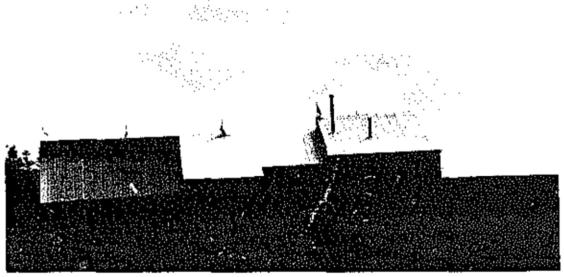


Plate 2. North side of the Ark with barn in foreground.

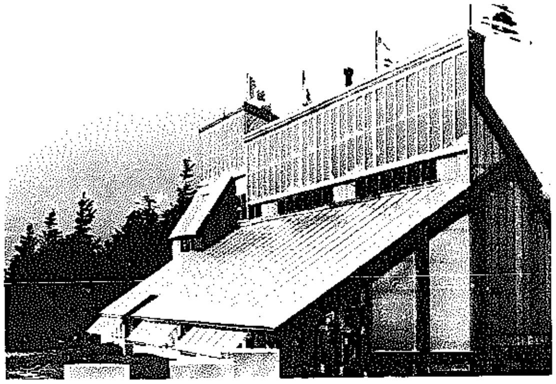


Plate 3. Southern aspect of the Ark. The vertical panels are solar collectors. The translucent roof covers the biotic zones.

contemporary house. Instead of continuously and wastefully consuming finite substances such as petroleum and other fuels, it attains its climate from renewable energy sources, namely the wind and the sun. A comparison of the Ark with orthodox housing is made in Table 1. From a design point of view the differences are radical. The table lists twenty categories or attributes of design. Economics and costs are considered as well as the social and the environmental impact of the two approaches to design. The existing structure of housing and housing networks, with sewage systems that dump human wastes into lakes and rivers and with inefficient heating using finite substances, like natural gas, that require extensive distribution networks, can be compared with a bioshelter that is a semiautonomous entity. Several important differences between houses and the Ark should be touched on: The contemporary house is wasteful of the heat it consumes, while the Ark stores heat, including summer heat, at various temperatures and in different ways for use in several climatic and biological roles. Instead of drawing continuously on external electrical and other energy sources, the Ark will ultimately become an exporter of power by generating more electricity than it needs. A wind-driven power station adapted simultaneously to the needs of the Ark and the requirements of the local utility network has been developed so that power can be produced both for the Province and for the Ark. The Ark accepts power from the Island utility when the wind is not blowing and returns it to the network when it is blowing hard (Plate 4). The New Alchemy experimental windmill, known as Hydrowind, is hydraulic.

Because most houses pollute not only through the burning of fossil fuels but also through the discharge of sewage, the bioshelter wastes are treated internally in a dry toilet-composting system. After being purified wastes are used as nutrient sources in living cycles within. Since the bulk of the heating is solar, emissions from burning are reduced and confined to wood gases from an auxiliary combination fireplace-stove.

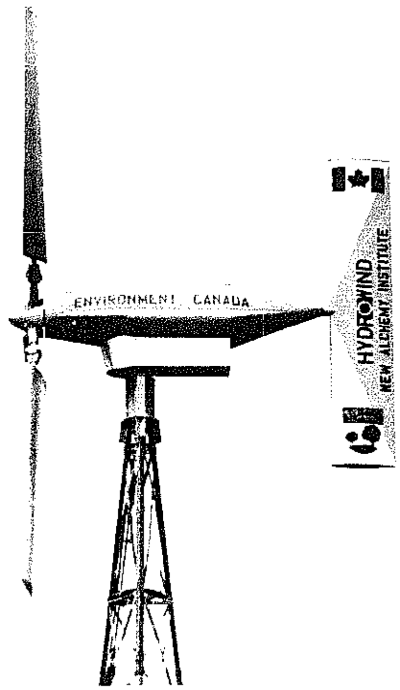


Plate 4. Hydrowind. N.A.I.'s wind driven power plant.

Household dwellers normally consume foods, particularly in winter, that have been stored for long periods, elaborately packaged, highly processed and transported over long distances. The Ark produces fresh foods on a year-round basis. While food autonomy is not a design goal for the Ark, a wide array of fresh produce is cultured within, including fish, vegetables, and greens for the residents. Plate 5 shows part of the residential food growing area adjacent to the kitchen. There is an economic dimension to the Ark unknown in contemporary single-family houses or condominiums, which represent major economic burdens. The Ark is designed to produce significant amounts of food, flowers, and young trees. Much of the Ark research has been and will continue to be directed toward devising internal food-producing ecosystems that will provide a viable economic base for bioshelter dwellers. Plate 6 is an outside view of the Ark's east end. The barn and food processing area is on the right and the commercial food growing area is on the left. Although an Ark is more expensive to build than a conventional house, the fact that it is a combined residence and microfarm with its own internal economy helps it to pay for itself. The processing and sale of crops could underwrite construction, finance, and main-

A COMPARISON OF THE ARK WITH ORTHODOX HOUSING

CATEGORY	ARK	ORTHODOX HOUSING
UTILIZES THE SUN	Source of Heating, Climate, Purification, Food Production and Much Interior Light.	Some Interior Light – Often Negative Role Necessitating Air Conditioning
UTILIZES THE WIND	A Source of Electrical Energy from Windmill Wind-Driven Circulation through Composting Toilet.	Only Negatively, Increasing Fuel Demands through Infiltration.
STORES ENERGY	YES – in Three Systems and Growing Areas.	NO.
MICRO-CLIMATOLOGICAL SITING	Integral to Design.	Rare.
WASTE PURIFICATION	YES – Except for Grey Water which is Piped into Leaching Bed.	Wastes Untreated and Discharged to Pollute.
WASTE UTILIZATION	Purified Wastes are Nutrient Sources in Interior Biological Cycles.	NO.
FUEL USE	Wood, a Renewable Source, as Supplemental Heat.	Heavy Use of Gas, Oil or Inefficient Electricity.
ENERGY CONSERVING	YES – Also Uses Energy to Serve Simultaneous Functions.	NO, or Rarely.
ELECTRICITY CONSUMPTION	About same as Orthodox House but Electricity Used for Many Productive and Economic Functions.	Fairly Heavy Consumer.
FOODS	Diverse Foods Cultured Year-Round	Not Within Often Summer Gardens.
AGRICULTURAL CROPS	Vegetables, Flowers and Young Trees	NO.
AQUACULTURAL PRODUCE	Fish for Market.	NO.
ECONOMIC UNIT	YES Viability to be Determined.	NO Financial Burden.
OPERATIONAL COST	LOW – Ultimately Exporter or Power.	HIGH – Particularly in Fuels and Electricity.
INITIAL COST	HIGH – Due to Energy and Biological Components – Uses Larger Amounts of Quality Materials.	Moderate.
VULNERABILITY TO INFLATION AND SHORTAGES	SLIGHT.	SEVERE.
IMPROVES CLIMATE AND LOCAL ENVIRONMENT	YES – Locally by Windbreak and More Broadly through Reforestation.	RARELY – Most Intensify Weather.
TEACHES ABOUT THE LARGER WORKINGS OF NATURE	YES.	NO.
INCREASES SELF-SUFFICIENCY	YES.	Rarely.
STIMULATES LOCAL AND REGIONAL SOLUTIONS	Possible.	Unlikely.

Table 1. A comparison of the Ark with orthodox housing.

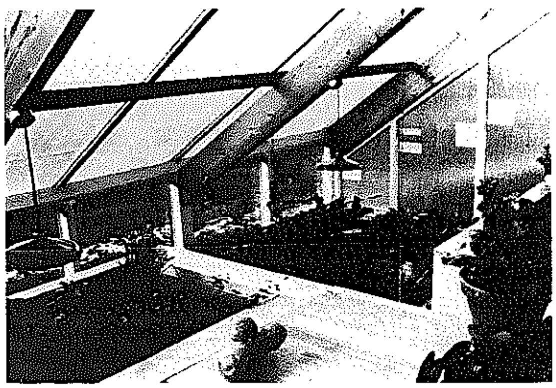


Plate 5. *Area of kitchen that is adjacent to the residential food gardens.*

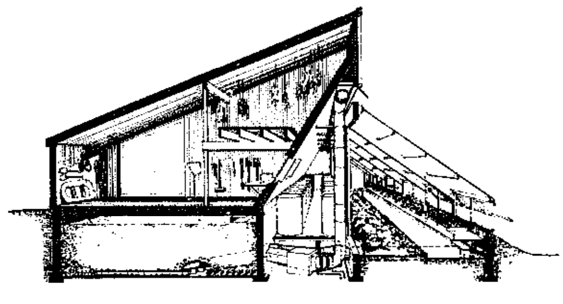


Plate 7. *Section of the Ark through barn, rock storage, and greenhouse areas. The solar-algae ponds are in two rows down the middle.*

tenance costs. This is, however, a design objective, which will take a number of years of research to reach.

There is an urgent need, especially in northern nations, for a dramatic shift in attitudes toward human habitations. In many ways the suburban house represents a failure of design. The designers Day Chahroudi and Sean Wellesley-Miller, in an article called "Bioshelter," have summed up the design failure.

Historically, the various utility systems and services that go to make up a home have been developed in a piecemeal manner in isolation from each other. Consequently, while some components or subsystems may be near optimum, the total system is seriously suboptimal. This state of affairs was relatively unimportant, at least in the short term, during the historical period when the ability of the natural environment to process wastes and supply cheap energy and water was well in excess of the short term demands placed upon it. Now that we are approaching foreseeable limits, this is no longer the case and something more than a piecemeal approach is called for.[1]

DISCOVERIES THROUGH ECOLOGICAL DESIGN

Efforts to apply ecological strategies in the design of the Ark have led to a number of biotechnical breakthroughs. An example of the benefits of a structural shift to a new design paradigm is that the Ark is not only a house; it is among other things a fish farm. The fish culture system is not only for rearing thousands of fish for market; it also provides some of the Ark's climatic needs.

The aquaculture facility was designed as both a low temperature (30–35°C) solar-powered heat collector and a fish culture complex. Plate 7 depicts two rows of 40 solar-algae ponds within the Ark in the center of the drawing. Light enters the building through the translucent south roof and wall exposing the ponds to solar radiation. Plate 8 shows the algae-filled ponds and the commercial food growing area of the Ark. The aquaculture ponds have highly translucent walls and contain

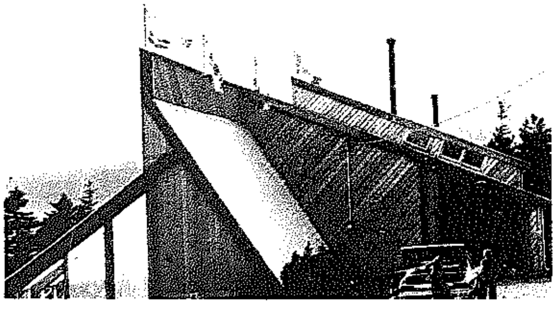


Plate 6. *East end of Ark. Commercial food growing area on the left, and barn-food processing area on the right.*

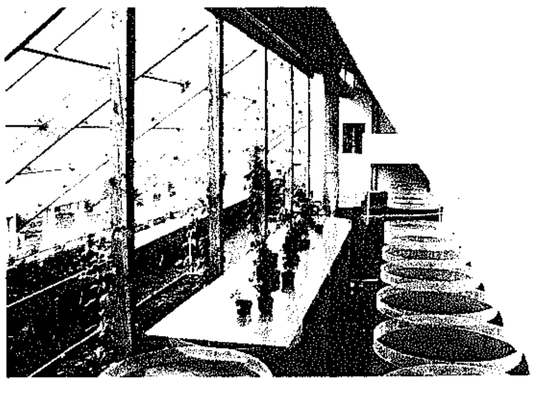


Plate 8. *Part of the food growing zone. The fish culturing solar-algae are on the right.*

dense blooms of light-energy absorbing algae. The algae not only provide feedstock for the fish but act as efficient solar collector surfaces. The water-filled ponds perform as heat storage units. These solar-algae ponds have produced unprecedented levels of biological productivity.[4,5] Fish production per unit volume of water is the highest recorded for a standing water body. This is not the sole function of the aquaculture facility. When temperatures drop in the large greenhouse area and in adjacent rooms including the laboratory, heat is radiated from the ponds and the building is warmed. In a three-day blackout during a violent, late November storm, the solar-algae pond complex was the only operational heating system. Temperatures outside dropped below $-5^{\circ}C$ and winds were in excess of 50 km/hr, yet the crops within survived.

The design of the solar-heated aquaculture facility was the result of our deliberate search for processes in nature that, when combined with appropriate technologies, would substitute for fuel-consuming, capital-intensive hardware. In this case living organisms and a renewable form of energy were sought, to replace some of the functions of machines. For example, light was substituted for a range of energy-consuming and expensive equipment normally used for biological regeneration and circulation in the aquaculture ponds. The ponds are made with walls that allow over 90 percent* of the light to enter through the sides. Their placement in the structure, where they can best receive solar energy, and the introduction of microscopic algae that absorb the incoming energy, purify the water of fish toxins, and provide feedstocks for fish result in a new and ecological approach to fish culture and climate regulation. The bulk of machinery, energy demands, and external fish feeds are eliminated. Light, algae, herbivorous fish, translucent building materials, and a cylindrical and modular design allowed such a substitution. The integration of heating and food production freed us from dependence on technologically complex solar heating involving collectors that contain expensive copper, selective black absorber surfaces, pumps, piping, and heat exchangers. Fossil fuel-burning furnaces are not used in the facility.

Symbiotic relationships at various levels of design are actively sought. Again the example of the aquaculture facility in the Ark is fitting. In addition to nurturing a commercial fish crop and heating the greenhouse, it is a source of irrigation and fertilization for the vegetable, fruit, and tree seedlings within. Metabolic by-products and organic matter from the ponds can increase shallow rooted leafy crop yields up to 120 percent.[6] The process of creating new links between ecological and engineered elements is ongoing and may be increasingly mediated by sensors and electronics devised for this purpose. In one experiment we are coupling fish-raising with leafy crop hydroponics on the pond surfaces. In this experiment the rigid insulating pond tops are replaced with a floating "raft" of styrofoam beads that provide insulation and support for leafy crops such as lettuce. Lettuce is a moisture-loving crop and its roots must be in an oxygen rich milieu for rapid growth.[7] In the experimental system the lettuce roots will penetrate between the floating beads and enter the warmed water. Warmed water that maintains a fairly stable temperature should increase lettuce growth considerably. The plants will derive most of their nutritional needs directly from by-products continuously produced by the aquaculture and carbon dioxide. The oxygen critical for the roots will also come from the pond, having been generated photosynthetically by the algae in a daily rhythm that may match the oscillating requirements of the lettuce.

*These are published figures from the Kalwall Corporation, Manchester, New Hampshire, not readings made within the ponds.

Table 2 compares the biological/structural approach to design in the Ark's fish facility to the most advanced engineered/technological closed-system aquacultures. The fundamental shift in design toward a new structure can be visualized through this comparison. In the Ark an ecosystem powered by light effectively replaces one engineered for raising fish in small spaces. It is more comprehensive in that it provides climate and resources for terrestrial agriculture within. Biological strategies become a genuine alternative in food, energy, and shelter design. Although Table 2 is confined to aquatic systems, it conveys the scope of the new synthesis as well.

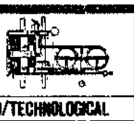
The biological metaphor inherent in the shape, heating, or food raising aspects of the Ark is valid. The end points of the design process meet basic human needs. In this context structure is redefined and moved towards culturally adaptive ends.

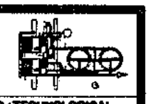
We have dealt with the new bioarchitectural design ideas at the point of interaction of aquaculture and energy within the Ark. Many other aspects of its design are ecologically inspired. Some of the characteristics the Ark shares with ecosystems are:

A. Integration

Energy, nutrient, structural, and biotic components interact through a range of pathways to create a unique environment. An attempt has been made to achieve relative stability, sharing of limited resources, and high efficiencies within each subelement. Plate 9 shows how closely the various components are tied together in an architectural context. The residential food garden is on the left. The hot water storage which contains 20,000 U.S. gallons in three adjacent chambers, the solar heating controls, and the composting chamber of composting-dry toilet are in the basement. Immediately above the hot water storage chambers are the living-dining areas. The living room is shown in Plate 10 and

BIOLOGICALLY DESIGNED VS. ENGINEERED CLOSED SYSTEM AQUACULTURES

CATEGORY	New Alchemy Solar-Algae Multispecies Fish Culture  BIOLOGICAL/STRUCTURAL	Salmonid Culture in Recycling Silo System  ENGINEERED/TECHNOLOGICAL
ENERGY SOURCE	THE SUN	ELECTRICITY
ENERGY USE	**Minimal** – Radiant. Solar energy, plus supplemental compressed air	**Heavy electrical demand** for recirculating, heating, cooling, purifying, etc.
DESIGN EMPHASIS	a. Passive – few moving parts. b. Internal, self-regulating and purifying ecosystems powered by a renewable energy source – THE SUN. c. Internal photosynthetically based	a. Hardware based. b. Energy-intensive with rapid flow-through. c. External foods d. Emphasis on technological regulation; e. Elimination of plants, animals other than cultured species; f. Sterilization.
MATERIALS	a. Light transmitting .060-in. thick fiberglass cylinders. b. Placement in light-reflecting courtyards or walls; c. Auxiliary compressed air equipment.	a. Metal tanks, pumps, filters, water exchangers, heating-cooling units, sterilizers, automatic feeders, cleaners, back-flushing plumbing, columnar gas exchangers, etc.
STRUCTURE	**SIMPLE** – based on maximization of light absorption.	**COMPLEX** – technologically.
BIOTIC ENVIRONMENTS	**Relatively complex** – photosynthetically based ecosystems.	**Simple** – Elimination of most organisms except for micro-organisms in bacterial filters used in water treatment.
CONTROL	**Primarily ecological and internal** through interactions of micro-organisms, phytoplankton, zooplankton, detritus, also through use of several fish species occupying individual niches – occasional water change and sediment siphoning.	**Electrical, chemical and mechanical** controls superimposed onto the water body in which fishes are housed.
LIKELIHOOD OF CONTAMINATING FISH FLESH WITH POISONS	**Slight** – Fish feed predominantly low on food chain particularly algae in a protected environment. Dangerous chemicals NOT USED for disease control and environmental management – Less dependent upon contaminated commercial feeds. Solar-Algae ponds do, however, require thorough initial leaching.	**Highly likely** – Fish fed exclusively upon commercial feed, contaminated with agricultural poisons; also these feeds include fish meal from marine species which might contain poisons – Toxic contamination from disease and sterilizing chemicals, including algicides, and from stabilizers, etc., in pumps, plastics, piping, etc.
RECIRCULATION	**Occasional** – Low-flow, air lift pumps used to exchange water between two Solar-Algae ponds.	**Continuous and rapid** – Up to 1500 litres per minute (23,760 gallons per hour in a 4,888-gallon facility).
THERMAL REGULATION	a. Ponds are efficient year-round solar heaters – Algae absorb solar energy thereby heating water – Summer venting and partial shading with plants prevents overheating. b. **Heat-tolerant species.**	a. Refrigeration and heavy energy requirement for heating to maintain narrow thermal range throughout year. b. **Heat-sensitive species.**
OXYGEN FOR LIFE SUPPORT	**Generated internally** by algae during photosynthesis supplemented at night with compressed air	**Continuously supplied** from industrial oxygen cylinders.
FISH SPECIES	Phytoplankton feeding – tilapia and and Chinese carps Detritus and zooplankton feeding – crayfish, bullheads and Israeli carps All excellent tasting fish	Carnivores – trout and salmon – could also be used for raising channel catfish.
PRIMARY FEEDS	**Internally grown feeds** – particularly attached and planktonic algae, also zooplankton. Bulk of feeds grown with fishes in the Solar-Algae ponds.	**Processed commercial feeds** – prepared from fish meal, soy and grain meals, vitamins, minerals, stabilizers, etc. Most potential feeds also for direct human consumption.
SUPPLEMENTAL FEEDS	Flowers, weeds, vetch, midges, earth worms. Commercial fish feeds are used in moderate amounts to optimize growth.	Often animal by-products prepared from slaughter-house offal.

CATEGORY	New Alchemy Solar-Algae Multispecies Fish Culture  BIOLOGICAL/STRUCTURAL	Salmonid Culture in Recycling Silo System  ENGINEERED/TECHNOLOGICAL
DISEASE CONTROL	Control through emphasis upon disease resistant species, such as tilapia and bullheads. Mass mortalities from disease rare.	Salmonids sensitive to diseases. Control through H_2O sterilization, chemical and antibiotic treatments and quarantine procedures. Mass mortalities from disease common.
BIOPURIFICATION	Toxins purified internally, as algae and other organisms rapidly utilize them as nutrient sources.	Toxins purified through technological steps and tertiary water treatment, including bacterial filtration.
a. Clarification	None – particulates important component of internal ecosystem.	Screening and steam cleaning to remove particulates.
b. Sulfide Toxicity	Not yet experienced.	Occurs when filters clog – requires back-flushing to eliminate anaerobic layers in filters.
c. Nitrite Toxicity	Not yet observed – algae photosynthesis prevents nitrite build-up.	Occurs on occasion – water change most effective treatment.
d. Ammonia Toxicity	Ammonia utilized by ecosystem. Green algae take up ammonium directly during photosynthesis. Nitrification takes place naturally in shallow sediments. If ammonia should ever build up, tilapia carps and bullheads can withstand ammonia levels up to 10 times greater than those lethal to salmonids.	Ammonia toxicity major threat to system. Nitrification through chemical, physical and biological methods. Plastic media trickle filters and/or submerged aerobic bio-nitrification filters are used. Filter bacteria often pre-activated on synthetic growing media.
e. Nitrate Toxicity	Toxic levels not yet observed, as most nitrogen incorporated by algae prior to nitrate stage in nitrification process.	Columnar denitrification requiring introduction of outside chemical sources of organic carbon, such as glucose and methanol – column filled with polypropylene flexi-rings.
HOLDING CAPACITY	Densities of 3 fish/gallon have been held for up to six months – fish ranged from fingerling size to 250 grams.	Salmon smolt densities of 8–10 fish/gallon with continuous dilution of fresh well water at 5–10% rate.
PRODUCTIVITY	Projected fish production of 30–40 kg/m^3 per year. First trials yielded 2.55 kg/m^3 in 100 days (9.31 kg/m^3 per year). Equivalent to approximately 143,000 kg/hectare per year.	Projected fish production of 54 kg/m^3 per year, or 1000 kilograms of 0.5 kilogram salmon in an 18,500-liter system with flow rates up to 1500 litres per minute. Average flow – 620 litres/minute.
LIFE SPAN	Pond material life span – 20-30 years.	Not known. Continual replacement of filters, pumps, sub-units, etc.
MANAGEMENT	Amenable to amateurs familiar with aquarium techniques. Novices start with low densities.	Requiring engineering, therapeutic and and handling skills of high order.
TOLERANT OF MISTAKES	Tolerant, except for too heavy supplemental feeding.	INTOLERANT
ENVIRONMENTAL IMPACT	Beneficial – Pond water and by-products used to irrigate and fertilize gardens and orchards.	Varying from little impact to potentially harmful with discharge of treatment chemicals and back-flushed filter materials.
COST	Capital cost of 25-35 cents/gallon to build depending on light reflecting courtyard for pond, and aeration system. Facilities with additional ponds will cost proportionately less.	Capital cost of scaled-up 2nd and 3rd generation facilities, each with an estimated capacity of 500,000 pounds of fish per year is expected to be 1 million dollars.** Estimated to be equivalent to 80 cents/gallon capacity. Smaller systems much more costly per gallon.
RUNNING COSTS	LOW	HIGH

* Description of "Technology of Closed System Culture of Salmonids," based on 1974 report of Thomas L. Meade, College of Resource Development, University of Rhode Island

** Personal communication with design engineer, 1977

Table 2. Biologically designed vs. engineered closed system aquacultures.

100% 483

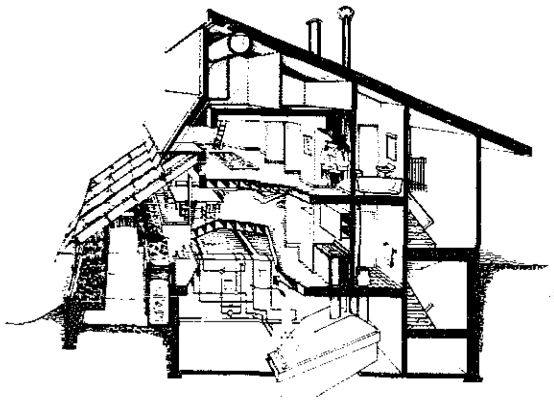


Plate 9. A section through residential greenhouse, heat storage, composting toilet, and living areas of the Ark.

Plate 11. Dining room. Resident greenhouse on left. View of sea on the right.

the dining area and porch overlooking the sea to the southwest in Plate 11. The bedroom areas are directly above.

The integration between structural, heating, and biotic elements are depicted further in Plate 7. Below the barn-food preservation area is the 118 cubic yard rock-hot air storage chamber for the 2000 square foot (185.8 m^2) greenhouse section. Immediately in front is the 20,000 U.S. gallon aquaculture facility. Under the translucent 2500 square foot (232.3 m^2) south roof are areas used for vegetable and flower crops. The bench against the south wall is for the rooting and propagating of young trees using mist irrigation. Plate 12 shows part of this area. Table 3 gives the square footages for the subelements within the structure.

B. Redundancy and Diversity

The Ark's climate is achieved through nine diverse, complementary techniques. It relies upon two active solar hot water systems, including a 700 square foot (≈ 65 m^2) collector for space heating, and a passive warm water aquaculture facility for the bulk of its heating. An active warm air and hot rock storage heating system in which a fan circulates the air in and out of storage utilizes solar heat trapped by the building beneath its translucent south face. A heat exchanger transfers energy from the hot water to the hot air system, providing a relatively sophisticated degree of redundancy and control. A wood-fired furnace, yet to be used, has been installed as an emergency back-up system.

Energy needs have been minimized through a number of conservation techniques. These include few north side windows, tight construction methods and elaborate insulation of up to 12 inches of fiberglass on the ceiling. The overall energy budget is further reduced through attention to microclimatological possibilities. Wind-

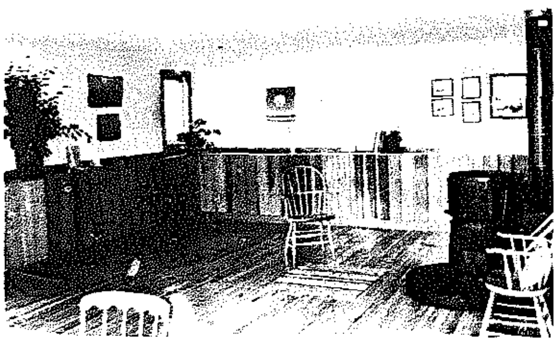


Plate 10. The living room. Hot water heat storage is underneath in three chambers totalling 20,000 gallons.

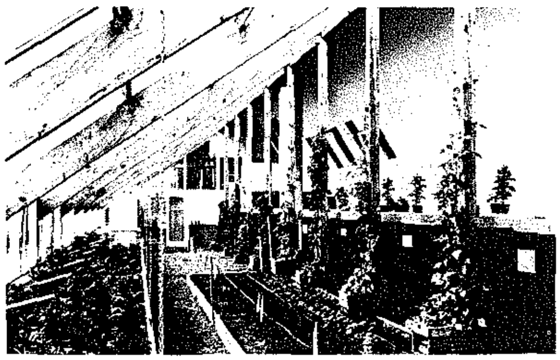


Plate 12. Production greenhouse area. Mist propagating bench on left, vegetable culture in middle, and aquaculture on the right.

ARK SQUARE FOOTAGES

	SQUARE FEET	SQUARE FEET
Mechanical Spaces		
Equipment room (net floor area)	253	
Rock storage duct work space	66.5	
Tanks (gross including walls)	441	
Tanks (net capacity):		
Tank A	49	
Tank B	113	
Tank C	201	
Total tanks		363 square feet ≈2540 cf.
Rock storage area:		
Gross	480	
Net usable	400	
Well room:		
Gross	70	
Net	50	
Gross Area Devoted to Heat Storage		921
Net Area of Tanks and Rocks		763
Net Floor Area Devoted to Mechanical		≈370
Commercial Greenhouse		
Gross area		1910
Net usable:		
Fish tanks	680	
Growing beds	480	
Suspended planters*	272	
Circulation	408	
Family Greenhouse		
Gross area		234
Net:		
Suspended planters and herb planter	128	
Fish tank area	19	
Circulation	80.5	
Attic spaces		400
Workshop		293
Barn/Garage		
Net interior:		
Floor level	430	
Loft	200	
Total		630
Residential Circulation		
Net interior rooms:		
Entry	80	
First floor hall (including closet)	55	
Hall to livingroom and lavatory	32	
Upper hall	40	
Stairs and landings	146	
Total		353

	SQUARE FEET	SQUARE FEET
Service Spaces		
Net interior:		
Lavatory	27.5	
Bath (including linen closet)	47.5	
Laundry	17.5	
Kitchen (plus broom closet)	145.0	(54 square feet counter top)
Total		237.5
Living Spaces		
Net interior:		
Laboratory (plus balcony and closet)	235	
Livingroom/dining room	505	
Small bedroom (including closet and shelf)	170	
Large bedroom (including shelf, closet and loft)	286	
Master bedroom (including closet)	207	
Total		1403
Outdoor Spaces		
Lower deck	225	
Upper deck	72	
Total		297
Gross Residential		
(Less family greenhouse)		1812
Gross Family Greenhouse		234
Residence total		2046
Gross Commercial Greenhouse and Workshop Area		22210
Gross Ancillary Spaces		
Laboratory and balcony	242	
Entry and hall	140	
Barn and loft	572	
Basement	350	
Total		1304
Total Gross Built Area to be Occupied (Doesn't include attics, tanks, and rock storage)		5560
Grand Enclosed Total (Includes attics, tanks, and rock storage)		6861

Table 3. Ark square footages.

breaks help protect the Ark on all sides except the north. Here an earthen berm was constructed to deflect north winds over the building.

The whole system approach to climate control has already proven its worth. During the same November storm mentioned earlier the Ark's windmill was shut down and Island utility electrical power was off for three days. The building was without either its hot air or its fan-coil hot water heating and the standby wood furnace was not used because the resident was in the hospital. The solar-algae ponds provided most of the heat, releasing an estimated million B.T.U.'s to maintain a safe internal climate in the food growing area despite subzero conditions outdoors. Plate 14 shows the building's performance during that period.

C. Renewable Energy Sources

The Ark emulates nature by depending upon the effective utilization of solar energy and its derivatives. The dominant input is the sun. Winds provide some of the electrical power. Wood is used for supplemental heat. Biotic components provide gas exchange, humidity regulation, air purification and waste treatment, absorb solar energy, and produce foods in commercial quantities. The diversity of renewable energy networks enables it to function as a semiautonomous bioshelter.

D. Photosynthetically Based Food Chains

As in a pond, field, or forest, photosynthesis in the Ark provides the basis for its food chains. In the aquaculture facility several species of green algae proliferate, providing feedstocks for fish and regulating the metabolism of the fish culture ponds. (See Table 2 for details.) The growing of food and tree crops is a direct photosynthetic process.

E. Microbial Pathways for Self Regulation

Waste is decomposed using microbial means. Human sewage, kitchen, and garden wastes are biologically composted and sterilized.

The Swedish composting dry toilet reduces water use by approximately ten-thousand gallons per person per year. Since wastes, apart from gray water, are treated internally, no sewage is dumped into the sea, nor does the Ark require a central sewage treatment plant. Such a structure situated in a densely populated urban area would save society an estimated $40,000 in internal waste treatment.[8]

The dry toilet-compost system eliminates sewage sludge, which is a major environmental pollutant and produces instead a high quality fertilizer that is free of human pathogens.[9] The Ark will produce an estimated 550 to 600 pounds of high quality fertilizer per year containing approximately 46 pounds (20.9 kilograms) of nitrogen, 14½ pounds (6.6 kilograms) of potassium,

Plate 13. Research library.

and 6¼ pounds (2.8 kilograms) of phosphorous from human wastes and kitchen garbage. In addition to the fertilizer from household wastes, greenhouse refuse including weeds, roots, and outer leaves of the crops, seaweed, fish offal, and miscellaneous organic matter will be generated. After one year, waste material is reduced some 95 percent by volume and is completely composted and safe for use as a fertilizer.

The dry toilet is a Swedish Clivus Multrum. It is technologically simple but in order to function it contains a biologically complex ecosystem that is based upon chemosynthetic autotrophs. These organisms do not require light to reduce carbon dioxide and to synthesize nutritive substances. A few simple instructions are all that is required to operate dry toilets despite their biological complexity.[10]

Microbial pathways are critical in other components within the Ark. The metabolic waste products of fish are treated in the sediment layers of the solar-algae ponds. They are eventually siphoned into the deep garden beds where they are used as fertilizer. Diverse microbial communities have been introduced into the greenhouse soils to help check plant diseases and pests and to increase carbon dioxide production. Low levels of carbon dioxide would otherwise limit greenhouse crop production.

F. Overall Homeostasis

Homeostasis is accomplished by different routes, several of which have been described. Our design objective has been to achieve a high degree of homeostasis or control within the Ark with a minimum of energy and cost. Much has yet to be learned as this is an area in

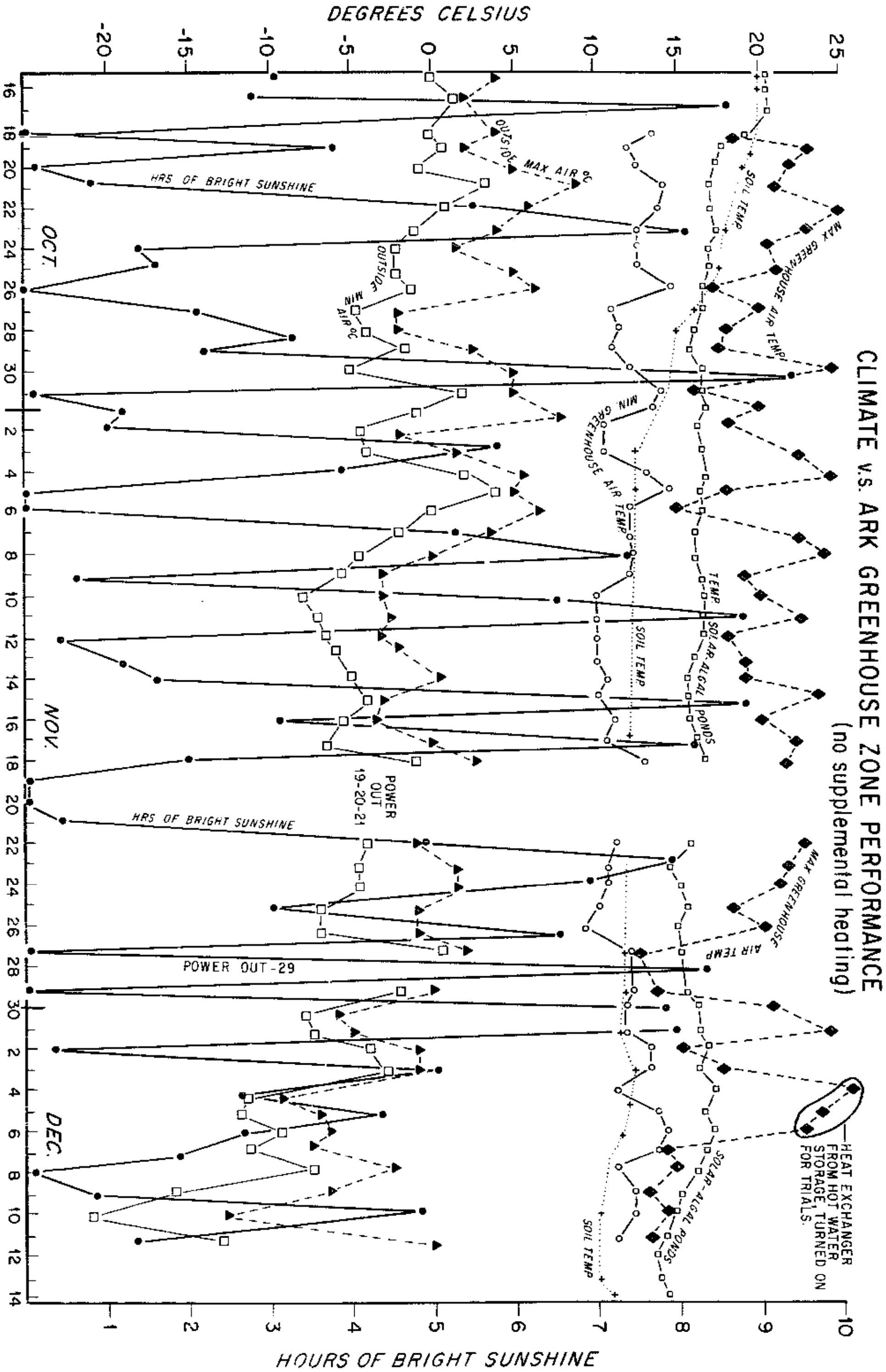


Plate 14. Climate vs. Ark greenhouse zone performance.

architecture that has been little explored. We have made an effort biologically, architecturally, and electronically, to create a number of internal symbiotic elements. Symbiosis characterizes stable and energy efficient living systems. By coupling food production to internal purification cycles nutrients are conserved and continuously recycled. We chose to assemble deep and diverse soil ecosystems for the Ark. We wanted soils that would be productive for commercial crops, fertile, and intrinsically capable of regulating disease and pest organisms. Our "homeostatic" approach to terrestrial greenhouse gardening is not common. It differs from commercial greenhouse practices in that the latter incorporate sterile growing mixtures in shallow benches or growing beds as a substrate for crop culture and are heavily fertilized and frequently sprayed, fumigated, and sterilized.

In the Ark we sought to create soils that were semipermanent and would continue to increase in fertility over time.

A greenhouse glazing (Rohaglass SDP16—a new acrylic double-glazing) was used, permitting ultraviolet wavelengths to penetrate and strike soil and plant surfaces, thus helping to regulate bacterial and fungal populations and possibly reduce the probability of plant diseases. There were a number of reasons for opting for a deep soil ecosystem instead of sterilized, chemically managed shallow growing beds. In the first place, the former does not require biocides which threaten fish life. Secondly, sterilization is an energy intensive process requiring heat or toxic fumigants such as methyl bromide or chloropicrin, whereas viable soils are ecosystems capable of utilizing available energy and are highly efficient in energy use. Third, a rich soil environment can generate the high levels of carbon dioxide necessary for optimal plant production. These high levels are often supplied industrially in many commercial greenhouses which are otherwise incapable of supplying their own CO_2 needs. Fourth, weeds and crop by-products, if not sprayed, can be fed to the fishes. Over the next few years it is our intention to compare the biological approach employed in the Ark's contained environments with standard greenhouse practices. During fall-winter 1976–77 lettuce, kale, spinach, chard, broccoii, parsley, bean, herb, and flower crops, have grown well, being free of disease and relatively unaffected by pests.

The Ark's climatic stability or resistance to external perturbations seems to be remarkably high for a northern climate solar facility that is situated in a region of sporadic sunlight. With its large solar façade the structure oscillates thermally more than a termostatically regulated building heated with fossil fuels but as Plate 14 shows the environment within remain stable with outside temperatures as much as 34.5°C colder than inside the greenhouse area. After November 5 the minimum interior air temperature varied only 5°C, the pond temperatures 3.5°C and soil temperatures 2.5°C. After a year of collecting solar heat full storage capacity will be attained. At that point oscillations should dampen and the Ark's thermal stability will be further enhanced.

In common with natural ecosystems the Ark has high levels of internal information and low entropy. It is a miniature world. Its information tends to be organized, internal, and complete rather than spread loosely among interconnected elements as occurs in highly stressed environments or in relatively wasteful industrial societies. The comparatively low levels of entropy within the bioshelter enable it to make a more positive contribution than an ordinary household to the exterior environments or to society. We are attempting to study homeostasis, information and energetics within the Ark. Plate 11 shows the laboratory where 33 climatological, biological, and performance characteristics are monitored. It is hoped that through measurement, analysis, and computer modeling using "real time" information, the broader question of design can be extended.

G. Interphasing with Adjacent Ecosystems

Designers tend to neglect creative interphasing with adjacent ecosystems. It should be possible for a household or a building to contribute to its surrounding environment.[11] Most reduce neighboring ecological integrity and pollute. Ecosystems tend to interact with each other in more subtle and beneficial ways that include ameliorating and stabilizing climates, and exchanging nutrients and organisms. The Ark minimizes the release of toxic materials from a human habitation. It contains a tree propagating facility that is intended to help reforest the surrounding region. Mist propagators assist in germinating seedlings and in propagating rooting cuttings of thousands of valuable trees. Most will be fruit, nut, and fodder trees destined for orchards, windbreaks, and ecologically derived agricultureal forests. The tree facility epitomizes the ideal that bioshelters not be retreats from the larger world but building blocks for a society rooted in concepts of stewardship.

ACCEPTANCE OF AN ARK-TYPE LIFESTYLE

The following comments are subjective impressions condensed from those of the designers, architects, builders, and tenders.

Living in the Ark can be an extraordinary experience. Living and working in a structure where the sun, the wind, architecture, and ecosystems are operating in concert has affected most of us. It seems to foretell what the future could bring. Each of us involved in the project would like to one day live in an Ark-inspired bioshelter. Its psychological impact is not easily articulated. The Ark, as a humanly-derived microcosm, creates a sense of wholeness and integrity engendered by a high degree of self-sufficiency. The growing areas function as half-way stations between the residential and the external environment. There are no barriers, only external "membranes" separating inner living and laboratory spaces from the biological working areas and the out-of-doors. There is a natural progression from one subenvironment to another. Because of this, the world outside is less alien and even an ally as the source of one's fuel and power needs.

Working with vegetable crops, flowers or trees, or tending the fish while a howling blizzard rages is exciting. Watching the sensors in the laboratory read out the Ark's various functions and monitor its health while the cold wind blows connects one consciously to the forces sustaining all life. One feels useful knowing that tree seedlings will halp in reforesting and that the crops will help to feed the community. Knowing it is a center for gathering knowledge leads to a sense that untold possibilities exist and that the dialogue has begun. It is our feeling that bioshelters can extend the human experience in northern climates.

ADOPTION OF BIOLOGICAL DESIGN MODELS

Material and fuel scarcities and increased pollution will necessitate that society shift to more semiclosed systems for performing crucial tasks. But the shift could take place within the old paradigm rather than through a new synthesis. We do not know that design approaches borrowed from nature will be adopted. A totally engineered approach is still a possibility, and this overlooks the necessity of a partnership with nature. It assumes erroneously that strictly physical and chemical technologies can cope without massive and cheap fuel subsidies. Yet only living systems can do this. The recent debate over U.S. plans for the colonization of space has exposed the fallacy of relying on completely engineered life-support systems for long periods of time.[12,13] Nor is an all-technological solution elegant. It has a tendency to be bulky and to use too many materials. It is neither reproductive nor self-maintaining, and if all its structure, functions, and controls are comprised of metallic hardware engineering, it will be poor at energy utilization.[14] A greater potential lies in the ecological design and engineering of complex ecosystems. These have the advantages of self-maintenance, respiration, and controls partly in the form of multiple species of organisms that allow for natural cominations of circuits and "biohardware" selected probably at thermodynamic limits for power and miniaturization for millions of years.

The Ark is one of the first synthetically framed explorations of a new direction for human habitations. With its use of diverse biotic elements, energy sources impinging upon or generated at the site, and internal integration of human support components normally exterior to households, it begins to redefine how people might live. The Ark is not an end point, but an early investigation of a viable new direction. As such it gives concrete form to conserver society concepts.

EXTRAPOLATION OF ARK CONCEPTS TO OTHER DESIGNS AND REGIONS

The Ark has over 30 sensors that continuously monitor the performance of energy, climatological, and biological processes and phenomena. These are printed out, at present, in analogue form onto recorders. This year we will install a computer-based system for modeling and simulations.

Computer models using the experience of the Ark will rapidly improve the design of bioshelters. The Ark is unusual in the sense that it can be monitored as a "complete" system containing biotic and engineered elements. It can also be divided into subcomponents to elucidate couplings and dependencies. The monitoring has already defined the Ark as a dynamic system of interacting components. This growing body of information can be used to develop computer models of the Ark's dynamic systems. The models can be verified accurately by comparing their predictions to the subsequent behavior of the Ark. Once the model is proven realistic and accurate, it can be extended to model hypothetical bioshelters of differing design in environments unlike that of Prince Edward Island.

Such uses of simulation are well known in industry: While they have been attempted for environmental studies and ecosystems, it is rare that the systems under study can be carefully monitored or manipulated. The Ark provides us with a powerful tool for approaching larger theoretical questions of design. The computer techniques applied to design aircraft or chemical plants can be applied within the Ark to exploring wholistic design theories from an ecological point of view. Ecologists have used systems analysis before but not in the conceptual and useful way as will be possible with the Ark.[15] A mini-computer installed in the structure can be used for much of the initial modeling as well as for monitoring and regulating the behavior of the systems. Thus simulation and observation can be done together in "real time."

THE APPLICATION OF ARKS THROUGHOUT SOCIETY

The widespread usefulness of bioshelters and bioshelter concepts will be questioned and opposed on a number of social, legal, agricultural, and economic levels. One senior agriculturalist has criticized the concept on the grounds that Canadians are demanding increasingly that their food be prepackaged, predigested, preprepared, and ready to heat and serve. Bioshelters producing fresh food run counter to current trends. Yet despite rising food costs, fresh produce from Florida, California, and Mexico is extensively imported, and Canada still sustains an approximately $15,000,000 a year greenhouse food crop in the face of rising fuel costs and inefficiently designed structures.

At the same time, there is a small but growing number of people wanting high quality foods. Another sector, one which often overlaps with the prior group, wants to know the source of their foods and to be assured that they are grown in relatively biocide-free environments. They will pay a premium for such foods. On Prince Edward Island, where food tastes are not generally sophisticated, the demand for produce from the Ark has outstripped our supplies. Even if the Ark were altered from an experimental to a production facility, we could not meet the demand in the rural area where the Institute is situated. A large number of bioshelters producing year-round foods would have ready access to local outlets as such a market is not easily saturated. When projected against increases in food, transport, processing, and storage costs, bioshelter produce might, in the near future, become competitive.

The full value of bioshelters for northern societies will not be realized until power and fuel costs increase further and shortages and disruptions of fuel supplies take place, as has been the case with natural gas in many parts of the U.S. Compared with poorly built and poorly insulated oil or gas heated houses, the higher initial capital costs of bioshelters may limit their adoption for a number of years. This period should allow for the design and testing of second and third generation structures with increasing emphasis on sophistication of design and minimization of costs. We are beginning to foresee a potent new direction for bioshelter development, where passive heating-architectural components and ecological entities play an even greater role than in the present New Alchemy Arks.

Possibly the most serious criticism of bioshelters is that they are too complex. Being engineered ecosystems containing high levels of information they are esoteric, beyond the ability of the average person to operate and maintain. It is true that the Ark is the product of a synthesis created by biological designers, materials experts, agriculturalists, a soil specialist, an integrated pest control scientist, algologists, fishery experts and fish culturalists, architects, solar energy scientists, electronic and computer designers, a systems ecologist, a philosopher, and aeronautical and hydraulic engineers; but is is also true that the overall design objective was to fabricate a system with its accompanying controls that can be taught to and even improved upon by nonspecialists. There has been a conscious effort to design the Ark for lay people.

New Alchemist Ron Zweig[16] describes part of this process in chronicling a small food growing bioshelter built over four years ago. Just prior to the quote he has described the sensor-monitoring instruments he has devised.

Through the use of information gained with this instrumentation, it will be possible to describe how such a micro-environment could be maintained optimally with much simpler recording devices. Also we shall be able eventually to compile a list of parameters which can be monitored chiefly through human observation. This could be done in terms of humidity, temperature, sight, smell, etc. If, for instance, a pond began to smell oddly, one would know that possibly a portion of the water should be changed with fresh or that the flow through the filtering system should be increased. A color change, from green to brownish hue, for example, would evoke a similar reaction. High temperatures or humidity could require venting the inside atmosphere with the outside cooler, drier one. An overcast day would indicate a decrease in the amount of feed for the fish during the cloudy period to allow for the low oxygen or toxic waste metabolism; i.e., ammonia, by the phytoplankton.

There are many factors that have been well documented, and others that we are discovering which we shall have to incorporate in a simple guide to managing these systems. This addition of instrumentation to our work allows us to redefine our bioshelter research and optimize productivity through integrating basic biological principles and the information gained in our observations of their interactions.

Through sophisticated and sensitive instrumentation we are searching for signposts to enable future tenders of bioshelters to do without expensive mechanical and electrical controls.

A complementary approach is being followed by Albert Doolittle, monitoring-computer specialist for the Ark. He is devising tiny micro-computers to match precisely the needs of the Ark's subsystems. Their capacity and programing will be simplified and the cost of their fabrication will ultimately be much less than most microporcessors available today. His work will interphase human, biological, and electronic controls so that a relatively inexperienced bioshelter resident could be trained by the systems themselves without having to worry that his or her inexperience might lead to failure in any major subcomponent. For example, on an overcast day, the micro-processor, basing its decision on accumulated information and incoming sensory inputs, might print out or display instructions telling the resident to cut back 50 percent on supplementary feeding to the fish. It would further explain that the low light had reduced the ability of the algae to produce enough oxygen to cope with the biological oxygen demand that would be created by normal levels of supplemental feeding. Under other circumstances it might request reduced feeding because of an unexplainable build up of ammonia. Based on "real time" information it could go on to suggest diagnostic procedures.

In our specialist society we tend to under-rate the capabilities of a majority of people. There is a deep human tendency to seek a dialogue with nonhuman organisms. While it often appears in an atrophied form in pet owners, for example, the tendency is almost universal. Plant-filled windows of high rise apartments attest to this. Although feeding a dog from a can or watering a plant is hardly tending a complex ecosystem, there are people who maintain vegetable gardens or tropical fish aquaria and in so doing are, in a simplified form, caring for ecosystems. The step from the garden or the aquarium to a bioshelter is one of degree, not kind. In 1976 over half of the householders in North America had some kind of food garden. There are many million tropical fish hobbyists. Both these facts suggest that people are willing to work with ecologies based on the same principles as exist within the Ark. These people represent a broad cross-section of society.

There is yet another way of looking at our contention that the prerequisites for bioshelter living exist widely in our culture. A few generations ago the majority of North Americans lived directly off the land. Although sound stewardship was not a characteristic common to these rural agriculturists, most of them had enough biological savvy to operate highly diversified family farms and homesteads and to build the culture we have inherited. Most people knew how to sustain themselves. If the need or desire were broadly felt, in a few years enough modern ecological, engineering, electronic, and agricultural knowledge to manage a bioshelter could be taught. The Ark at Prince Edward Island is a first test of these assumptions.

—John Todd

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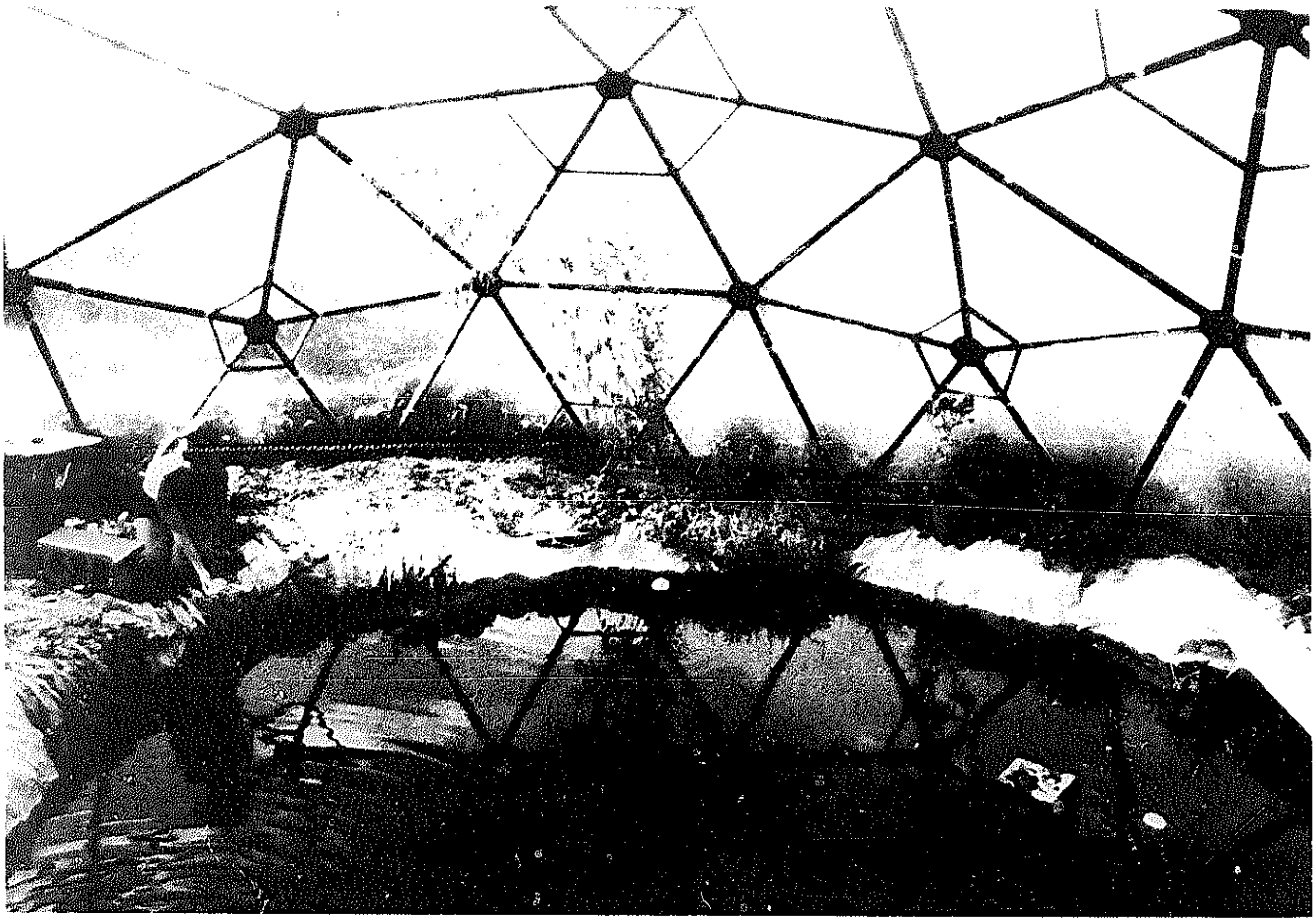

Bioshelters as Organisms

Our work with the design and operation of bioshelters is perhaps the most complex aspect of the research at New Alchemy. Initially, translucent structures such as the dome, the Miniature Ark, and our bioshelter prototype (a small solar-heated greenhouse), were built to extend the growing season for both tropical and temperate organisms to be used for human food. This was done through the collection and storage of solar energy in aquatic systems using the pools in these systems to raise fish, store heat, and irrigate both inside and outside crops. From these initial experimental studies, the biological complexities and interrelationships within such systems became more apparent. The structures themselves were found to function as "living" organisms using the microenvironment defined by their external membranes as the basis of their "life." Subsequently, two large structures, the Cape Cod and the Prince Edward Island Arks have been designed and constructed based on both the information gathered from our own work and on other sources that were discovered in biological and greenhouse literature. The Prince Edward Island Ark includes living quarters for a family.

Our approach to the selection of the components for these structures came first from looking to the natural environment and choosing the biological phenomena that would be necessary for them to function as living structures and to be productive and healthy. We focused on biological solutions as opposed to technological ones, choosing the former whenever possible.

These bioshelters or semiclosed ecosystems can be seen as analogous to life as it is found on this planet. In looking at the Earth, it becomes evident that it, too, is a semiclosed ecosystem, receiving much of its energy from an outside source, the sun. Sunlight strikes the atmosphere or outer translucent membrane enveloping the planet. Its outer ozone layer creates a semipermeability that filters out much of the lethal ultraviolet rays, allowing most of the other wavelengths to pass through unaffected. Life, thereby protected, exists on the Earth's surface within its own evolved, ecological balance, changing through evolution or through major physical disruptions such as earthquakes, floods, droughts, etc. This is an idealized state, working solely within ecological parameters without human interference.

We can find many similarities if we compare the macrocosm of the Earth to the microcosms of the individual cell and of the bioshelters. Like the earth, the single cell is also a semiclosed ecosystem. It requires nutrients from outside to allow it to function and replicate. The complexity within is enormous and the balance of its interaction allows the cell to live. An analogy surprisingly close to the eucaryote* cell can be made with our dome or backyard fish farm, the early bioshelter, as described in the second Journal of the New Alchemists. This analogy is the theme of this essay.

The outer structure of the dome is covered with two layers of translucent fiberglass, three quarters of an inch apart, which form a thermal pane and function as a protective membrane for the system. There is a two-inch-thick vertical layer of styrofoam four feet deep beneath the dome's circumference. This membrane, which is much like that of the earth's atmosphere and of the single cell, allows sunlight to enter, and to be absorbed and converted into heat energy. The thermal pane traps this heat energy and retards its loss.

The microenvironment within the dome can be compared to the protoplasm of the eucaryotic cell. There are many organelles** within the cytoplasm and many components including organisms within the air and water encompassed by the dome. Several loose analogies can be made between these systems. The chloroplasts of a living plant cell produce oxygen through photosynthesis, which, in terms of the dome system, can be compared to the activities of the aquatic and terrestrial plants living within it. These include the vegetables and herbs growing around the periphery of the ponds, and the phytoplankton and other photosynthesizing organisms in the pool and in the biological filter. Each component of the biological filter and the polyculture pool can be related to the vacuoles† of a single cell. Their function is the purification of toxic compounds that could kill the animal components. The relationship between the use of the fish waste in the pond water as a fertile nutrient source for aquatic and terrestrial plants can be seen to be similar to that of some biochemical pathways within the cell in the action of the nitrifying bacteria in both the soil and on the quahog shells in the filter. The use of these procaryotic‡

bacteria is clearly one of the eucaryotic mechanisms, in that they are incorporated into a subcomponent in the dome system. By converting the ammonia within the system to a nitrate form, a plant food is created. The plants that feed on these nitrates are then fed to the herbivorous fish, such as the *Tilapia*. This completes the cycle, since it was originally the fish that released the wastes into the system because of their inability to use more than about ten percent of what they ingest. The cycle is continuous. The filtration system can be compared to that of a circular river.

The electric pump used to circulate the water through the filtering beds can be compared to a ribosome at the cell level. A ribosome, so far as is known, is the center for the coordination of protein synthesis in a cell. It is, however, autonomous from its final protein product in a chemical sense as the pump, at the same time, is autonomous from the pond water.

The energy for the electric pump could come from a wind generator. At present in the dome, we are still using public utilities. If a windmill were to be used, it could be considered the mitochondria§ of the dome and other water-pumping systems. In this analogy this electrical energy would be the replacement of the chemical energy of the cell. The windmill, though, would be an external

Eucaryote: applied to organisms having membrane-bound nuclei, Golgi apparatus and mitochondria. Includes the cells of most organisms except blue-green algae and bacteria.

***Organelle:* an entity with specific functions within a cell similar to the organs in our body.

†*Vacuole:* a membrane-bound fluid or crystal-filled space within a cell.

‡*Procaryotic:* lacking a membrane-bound nucleus, plastids, Golgi apparatus, and mitochondria, as in bacteria and blue-green algae.

§*Mitochondria:* the centers for the production of biochemical energy.

component. Excess electrical energy could be stored in batteries, much as it is stored in sugars and starches in the cell.

The chief information center for the cell is known to be the nucleus; its genetic material is DNA. In this regard, much of the monitoring of the dome system and the other bioshelters is left to the humans. We are now considering the use of small computers to aid in this. They could be used not only to record information but also to regulate the environment within the ecosystems. For instance, if the dome's environment were to become too warm, the mini-computer could trigger the opening of vents.

The nucleus within the cell is not the only center of information. The mitochondria and chloroplasts have their own genetic material that governs their replication and behavior. Theoretically, this is carried over from their initial procaryotic existence before their evolution within eucaryote cells. Other genetic factors have been known to lie elsewhere in the cytoplasm regarding heredity. In the dome, in addition to the larger physical components themselves, interactions between them can be observed and in many cases predicted.

Among the plants, fish, and other animals within the structure, there is a situation similar to the semiindependence of the mitochondria and the chloroplasts. These plants and animals are controlled to a large extent by their physical and chemical environment. There are many interactions, both biological and chemical, in the dome system that as yet we have neither defined nor understood. This is especially true of the many microenvironments within the confines of the dome.

Although the dome system was designed to raise food—a definitive biological activity—the architecture of many buildings and habitats could take existing natural phenomena into consideration to their advantage. Among the most obvious are proper orientation for the use of solar energy, the collection of rain water, or even a composting toilet. Small greenhouses could be included, such as have been used in the Prince Edward Island Ark.

Throughout this analogy, the dome has demonstrated the possibility of looking at physical structures as living systems. This is done through an initial consideration of the biological components to be established in a system and by building to allow for the necessary parameters. The interrelationships between the organisms inside must be taken into consideration to achieve a balanced, healthy system. As mentioned previously, we have included in the dome a polyculture pond, a filtering system, and an agricultural area on the pond's periphery. All of those interrelate. We have begun measuring certain physical and chemical parameters within the structure, including air and water temperatures, relative humidity, pH of the water, and dissolved oxygen in the water. We monitor solar radiation striking the outside membrane as well as that penetrating the fiberglass membrane and reaching the pond surface. In addition, we shall be measuring ammonia concentrations in the polyculture ponds, carbon dioxide concentrations in both the pond and air, and moisture levels in the soil. These measurements will be used not only to understand how these systems behave and how they respond to environmental changes as they are set up, but they also will be used to optimize food production through modeling. With such physical and chemical data, we can interrelate our previously recorded information on fish and vegetable production such as the numbers of each species in relation to the makeup of the total population for the most successful polyculture strategies.

—Ron Zweig

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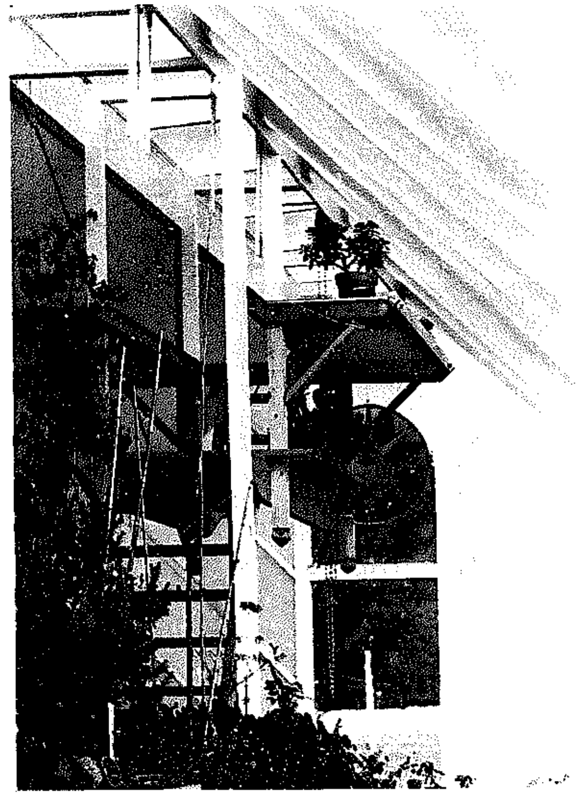
Bioshelter Primer

The Intentional Design of Microcosms



Oh investigator, do not flatter yourself that you know the things nature performs for herself, but rejoice in knowing the purpose of those things designed by your own mind.

—Leonardo Da Vinci, Madrid Codices

I. INTRODUCTION

The process of creating a microcosm of life, protected and nurtured by an architecture that is responsive to its environment, is at once exhilarating and sobering. The realization of the human role within the mystery and complexity of biological systems comes slowly. As designers and maintainers of bioshelters, we are attempting to unravel the complex relationships that exist between living organisms and their substrates, between biological organizations and their environment, and between human actions and their consequences. In bioshelters we have a unique opportunity for investigating some of these relationships on a human scale, as we simultaneously provide ourselves with year-round food supplies.

All of the plants, animals, and microorganisms used in agriculture have developed, over time, in a matrix of physical and biological conditions that influence their present suitability for human manipulation and use. Where human communities are mindful of their physical dependence on the health of their landscape, symbiotic partnerships develop. When human communities ignore or forget basic ecological dynamics, the biological environment that protects and nurtures them deteriorates, often resulting in deserts or floods, droughts, or famine. The rate at which large-scale degradation can occur is frightening. Recently in Costa Rica, large regions have evolved from tropical forest to desert in less than a decade. If humanity is to survive, we must learn to recognize and respect successful ecological patterns, whether in the wilderness, a garden, or a bioshelter. Sensitivity to the dynamics of the whole is crucial. The investigation of biological microcosms is one path to the kind of sensitivity required to comprehend wholes. It is hoped that the subsequent knowledge will enable us to act more wisely in the world.

The reality of a winter food garden in northern climates has become possible for significant numbers of people only in this century. Enclosed-plant communities range from sterile commercial monocrop factory-greenhouses to exquisite and exotic zoological gardens. New Alchemy's development of bioshelters is part of a long-range program for year-round fresh food production. We are trying a number of methods of extending the annual growing season. We are working with cold frames, solar-based cloches, and several kinds of greenhouses for vegetable and aquaculture gardening. For mid-winter conditions, research is now centered on medium-sized, solar-heated structures that enclose an internal garden ecosystem of plant, animal, and soil communities. The aim is to develop an interesting, productive microcosm of vegetables, vines, insects, trees, and aquaculture ponds for winter food production.

The Cape Cod and Prince Edward Island Arks, are comparable in size to small, family-operated, commercial greenhouses. Each was designed in response to its particular climate, and is intended to require no fossil fuels for maintaining its internal climate. The Cape Cod Ark is limited to vegetable and fish production, and has appropriate climate control facilities to sustain it. The Prince Edward Island Ark includes not only agriculture and aquaculture, but also a residential area for a family, which takes advantage of the heating and climate control of the rest of the structure. Similar architectural and ecological strategies are employed in both Arks, many of which will be discussed here.

II. ARCHITECTURAL STRATEGIES

The general appearance of the Cape Cod Ark is shown by the accompanying architectural drawings and photographs. The major features are calculated to stabilize external weather oscillations and to form diverse internal microclimates of temperature, light, and moisture conditions. The ecologist Eugene Odum suggests that in nature the great diversity and organic structure of a mature ecosystem have survival value in the resulting ability to achieve some measure of stability or homeostasis but that in a fluctuating physical environment this is at the cost of a decrease in net productivity. We are testing the idea of using the physical structure of the Ark to supply the desired environmental stability of a mature ecosystem, while maintaining the productivity of a "young" one. By sustaining a more stable internal climate comprised of many diverse microclimates, we are able to grow a large variety of food plants in the winter season. This results in a more diverse biotic community in the Ark, and in an interesting winter diet for us. Architectural elements such as terraces, aquaculture ponds, stone walls, and vertical trellises all contribute to the structural complexity of the interior.

The major components of the building include:

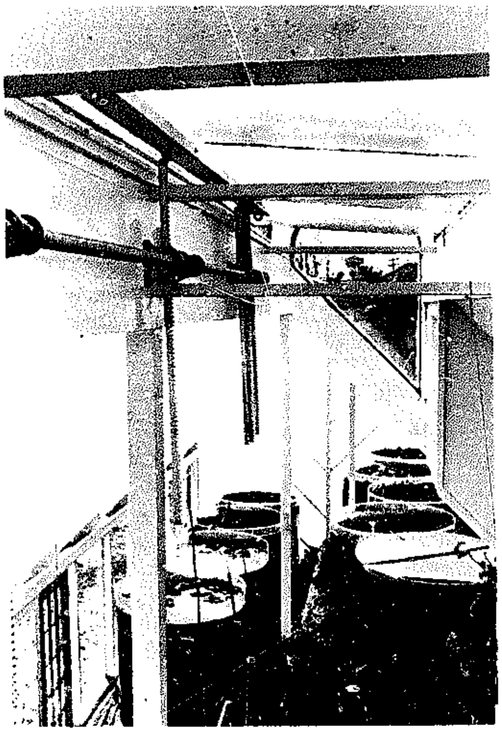
Solar Membranes. The south-facing roof and parts of the east and west walls are formed of double-glazed fiberglass, which allows light to enter the structure, but retains warm air. The fiberglass tends to diffuse incoming light, spreading it evenly to all corners of the growing area. This characteristic avoids "burning" of delicate greenhouse plants in seasons of intense radiation. The fiberglass also admits some of the natural ultraviolet light, important in the control of fungus. Curved into transparent cylinders, the same material is used in solar aquaculture ponds because it allows for maximum photosynthesis and dense algae growth.

Passive Thermal Mass. Only a fraction of the light entering the bioshelter is used directly by the plants for photosynthesis. Much of it turns to heat and is used in the evaporation of water. Some is absorbed as heat by soil and plants. The absorbed heat is valuable in warming the plants' microclimate at night. We have tried to maximize the mid-day passive heat absorption process to use for later night warming in the following ways:

1. The retaining walls of the vegetable terraces are made of field stone.

2. The high, north foundation wall and the walls of the rock storage bin are of solid concrete and are insulated from the outside soil to reduce conductive losses. These walls absorb heat from both direct sunlight and warm daytime air.

3. The solar aquaculture ponds used in the Ark are important units of heat storage. Previous experience with these ponds in greenhouses, where the ponds are the major thermal mass, have shown that a body of water is remarkably effective at moderating the diurnal temperature cycle. We are now discovering that above-ground transparent ponds containing an algae culture are even more effective than ground ponds. The solar ponds have a better absorbing surface in low-angle winter sunlight. Light entering at all levels allows thermal mixing instead of thermal stratification as in ground ponds. At night, more heat enters the air by convection because less is lost into the ground by conduction. By



careful placement of solar ponds, one can create special temperature zones for tender plants, and the rate of heat release at night can be regulated by double-glazing the pond or using a lid.

4. The open concrete pond absorbs light and heat, and the warmed water is used for irrigation.

Active Diurnal Heat Cycling. Even with large amounts of thermal mass in the structure, on bright sunny days there is often a surplus of heat that accumulates in warm air near the ceiling. It is drawn by fans into an air duct in the north wall and the warm air is blown into a large concrete bin of fist-sized stones. As the warm air passes through the matrix of stones, it loses some of its heat to the stones before being exhausted back into the building again. During the warm portion of the day, excess heat is stored in the stones, keeping the plants from overheating. Halfway through the next night, when the passive thermal masses have already cooled, the fan comes on and circulates air through the warm stones, then into the greenhouse in the premorning hours when it is most needed.

Light Reflecting Ceiling. The sloping inner surface of the insulated north roof is painted white to reflect light downward onto the plant canopy. In some northern greenhouse tests of this design, light intensities at the plant canopy were greatly increased due to the reflection.

Convective Venting. In the summer months when no heat storage is required and excess heat must be removed, ventilation panels at the peak of the roof are left open and hot air rises from the building by convection and is replaced by air entering through the open doors. If necessary, the fan can actively exhaust hot air to the exterior.

III. BIOTECHNICS

Within the confines of the climate-modifying structure just described, we have begun to assemble an ecosystem of plant, animal, and soil communities that will be productive, healthy, and beautiful. Many of the basic principles of ecosystem structure and function have been formulated by diligent scientific research, but no comprehensive design theory relating humans, agriculture, and nature has been proposed that is directly applicable to our task. We are engaged, then, in a subtle challenge, to understand the apparent workings of the natural world deeply enough to live and to coexist permanently and creatively within it. Speculating on the possibility of such a symbiosis between the earth and humankind, René Dubos is optimistic:

> *Symbiotic relationships mean creative partnerships. The earth is to be seen neither as an ecosystem to be preserved unchanged nor as a quarry to be exploited for selfish and short-range economic reasons, but as a garden to be cultivated for the development of its own potentialities of the human adventure. The goal of this relationship is not the maintenance of the new status quo, but the emergence of new phenomena and new values. Millennia of experience show that by entering into a symbiotic relationship with nature, humankind can invent and generate futures not predictable from the deterministic order of things, and thus can engage in a continuous process of creation.*

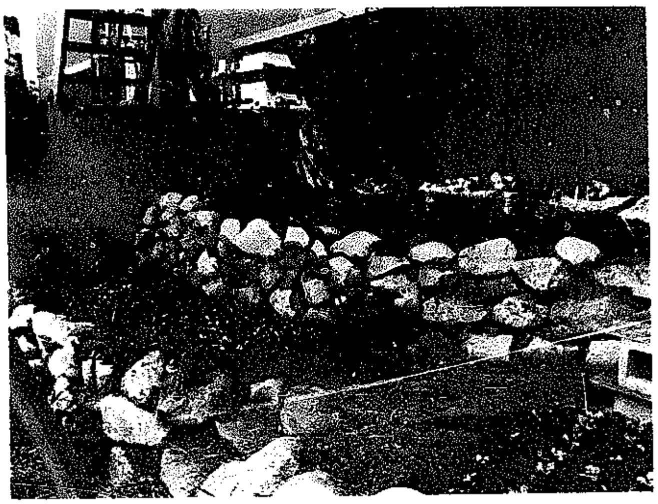
The reciprocal transformations required to evolve such a symbiosis implies that humans must learn—and learn well—their responsibilities to the whole of which they are a part.

Some general patterns in the workings of nature can guide us. The accepted indicator of health in natural ecosystems is diversity—diversity of species, niches, food chains, and so on. Most present agricultural ecosystems are purposely *not* diverse, since high net productivity of food demands a simplified food web with humans occupying many of the top positions.

The immediate aim of agriculture, then, is to act upon an ecosystem to promote a net productivity of food and materials in excess of that required within the ecosystem by its members. The wider task is to accept the fact that humans are *in* the ecosystem (as large omnivores), and to discover which patterns of behavior within the ecosystem offer the chance of ongoing coexistence between themselves and the earth, sustaining both human culture and all other species. Possible models for such continuing coexistence would be those human cultures that have remained in one region for centuries without causing the progressive degradation of their supporting ecosystem. Although absolute failures are easy to observe and well documented, successes are difficult to ascertain. Potential candidates, though, exist at two interesting extremes. One is the slash and burn agriculture of the Maring people in the New Guinea rain forests, where the forest ecosystem is allowed to remain complex, doing the regeneration and recycling work essential to maintain fertility. The other extreme is labor-intensive garden agriculture in Southeast Asia in which people regenerate domesticated species and recycle nutrients manually within the ecosystem. Conceptually, the bioshelter tends to resemble the latter, insofar as intense care and management of carefully selected food plants maintain a stable "young" ecosystem, completely domesticated yet highly productive. In such an agriculture, each species is selected for its value to humans, and is continuously sustained by them.

A. MICROCLIMATES

In constructing the bioshelter ecosystem, we have chosen valued traditional food plants as major species and have tried to calculate the optimum microclimate and required auxiliary species for each one. For instance, some fruiting vegetables need pollinating insects while others require predators for aphids. The entire garden



ecosystem of food plants, insects, soil organisms, etc., by virtue of its historical domestication, is simplified yet productive. By providing and encouraging essential regulating species, and discouraging competitive or non-adapting ones, a new community can be formed that will adapt to the bioshelter conditions.

Each garden organism is somewhat specialized in such habitat requirements as root depth, soil temperature, light/shade preferences and moisture. Therefore the initial design criterion for the Ark was that it provide a moderate overall climate with numerous microclimates, so that a wide range of food plants could be grown. Examples of these microclimates include:

Terraces. In the smaller prototype of the Ark studied last winter, we observed that a general temperature gradient existed; cold air from windows and cracks settled on the floor, while warm air rose to the ceiling. The few degrees difference in soil and air temperature was sufficient in the same light conditions to produce green peppers on a raised bed but not on the floor. In the Cape Cod Ark there are several terrace levels. On ground level, we are growing the most hardy vegetables, such as lettuce, chard, kale, and parsley. On middle levels, we grow head lettuce, snow peas, green beans, and herbs. On the high terrace during spring and fall months are tomatoes, peppers, cucumbers, and bamboo.

Terrace Walls. The retaining walls of the terraces are of fieldstone, each containing numerous pockets of soil for plants. Because the stones are warmed by the sun daily, the plants there have a slightly drier, warm zone. Some of the clinging or hanging plants used are New Zealand spinach, strawberries, nasturtiums, thyme, parsley, and other herbs. Another retaining wall, this one below the main aquaculture ponds, is of concrete blocks set with their holes running horizontally. This area is dry and shady; plants growing in these soil pockets are herbs, ivy, comfrey, vetch, purslane, and other fish foods.

North Wall Trellises. The high concrete north wall creates a vertical warm zone for climbing and espaliered plants. The wall remains warm in the evening, where tomatoes, malabar spinach, figs, grapes, and cucumbers grow.

Heat Storage Bin. A unique area for subtropical species is on top of the heat storage bin, which is at a generally warm elevation and is warmed from below by stored heat. On this surface are many tropical and subtropical species, planted permanently or temporarily overwintering. Several plants from New Alchemy's Costa Rican Center are there, including perennial sweet peppers, lemon grass, papayas, naranjilla, and hibiscus. In addition, there is dwarf citrus, dwarf cherry, a large rosemary, and various palms and ornamentals.

Seedling Bench. Circulating air from the heat storage bin is distributed to the Ark through a long, low air chamber along the southern wall. The surface of this chamber is ideal for the propagation of vegetable seedlings, tree cuttings, and tree seedlings, as it receives bottom warmth from the air passing beneath. On this surface we grow seedlings for periodic winter replacements, and large numbers of seedlings for spring use. This bench also serves as a potting area.

Compost. Any vegetable waste and weeds not fed to fish are composted in one corner of the ground level. This is a somewhat controversial practice in terms of greenhouse sanitation, so until we have further evidence, we shall compost wastes indoors but use the compost outside. It remains a slow, constant source of CO_2 and heat as it decomposes, and provides a home for crickets, spiders, beetles, sowbugs, and other insects.

Herb Area. One portion of the growing area has been reserved as a permanent habitat and food source for predatory and pollinating insects. It contains many flowering herbs, wild flowers, and garden-edge plants to provide continuous shelter, nectar, and pollen. Within this area there is also a tiny pond for use by insects, toads, and other residents.

Open Pond. The garden area is irrigated with water from the concrete pond. The water is partially warmed through the wall that divides it from the heat storage bin, and is a biotic reservoir of aquatic species for aquaculture purposes. In it are a variety of plants and animals, including several species of fish, *Azolla,* water hyacinths, turtles, a frog, freshwater mussels, and crayfish.

Solar Aquaculture Ponds. At various locations in the garden area we have placed solar aquaculture ponds to provide a localized microclimate for plants that might benefit from warmth radiated from the ponds at night. By careful positioning of one or more ponds near a wall, specialized zones for sensitive plants can be created.

B. BIOTA SELECTION

In the selection of organisms for a bioshelter, some knowledge of the dynamics of an outdoor garden is helpful. We have tried to establish a polyculture of garden vegetables, herbs, flowers, and several small trees and vines, together with obvious associated pests and predators, in a rich, biologically active soil. While all of the interactions of combined organisms cannot be predicted, we can approximate patterns that appear in successful gardens.

Soil. The soil in the growing area and terraces is comprised of a twenty-four-inch-deep mixture of field topsoil, leaf mold, and rotted manure, with small inoculations of garden, meadow, lakeside, and forest soil organisms. The health of soil life is more difficult to observe than that of larger organisms, but the soil's function of nutrient processing and recycling is vital to the long-term performance of the ecosystem. The soil

CAPE COD ARK

1 INTAKE VENT FOR ROCKSTORAGE: WARM AIR FROM THE TOP OF THE GREENHOUSE IS DRAWN DOWN BY A ½ HP FAN & BLOWN INTO ONE CORNER OF THE ROCKSTORAGE.

2 ROCKSTORAGE: A 2000 CU. FT. BED OF 3"-5" DIAMETER ROCKS TRAPS & HOLDS HEAT FROM WARM AIR DURING THE DAY. AT NIGHT, COLD AIR COMING THROUGH THE ROCKS PICKS UP STORED HEAT FROM THE ROCKS AND HELPS MAINTAIN GREENHOUSE TEMPERATURE.

3 OUTLET PLENUM: AIR FROM ROCKSTORAGE IS RETURNED TO THE LOW PART OF THE PLANTED AREA THROUGH ADJUSTABLE BLOCK VENTS IN THE CONCRETE BLOCK PLENUM WALL. WARM AIR HELPS PREVENT FREEZING ON SUNLESS DAYS & AT NIGHT; AIR MOTION BREAKS UP STRATIFIED AIR, REDUCING PROBLEMS SUCH AS MILDEW & OTHER MOISTURE-RELATED DIFFICULTIES.

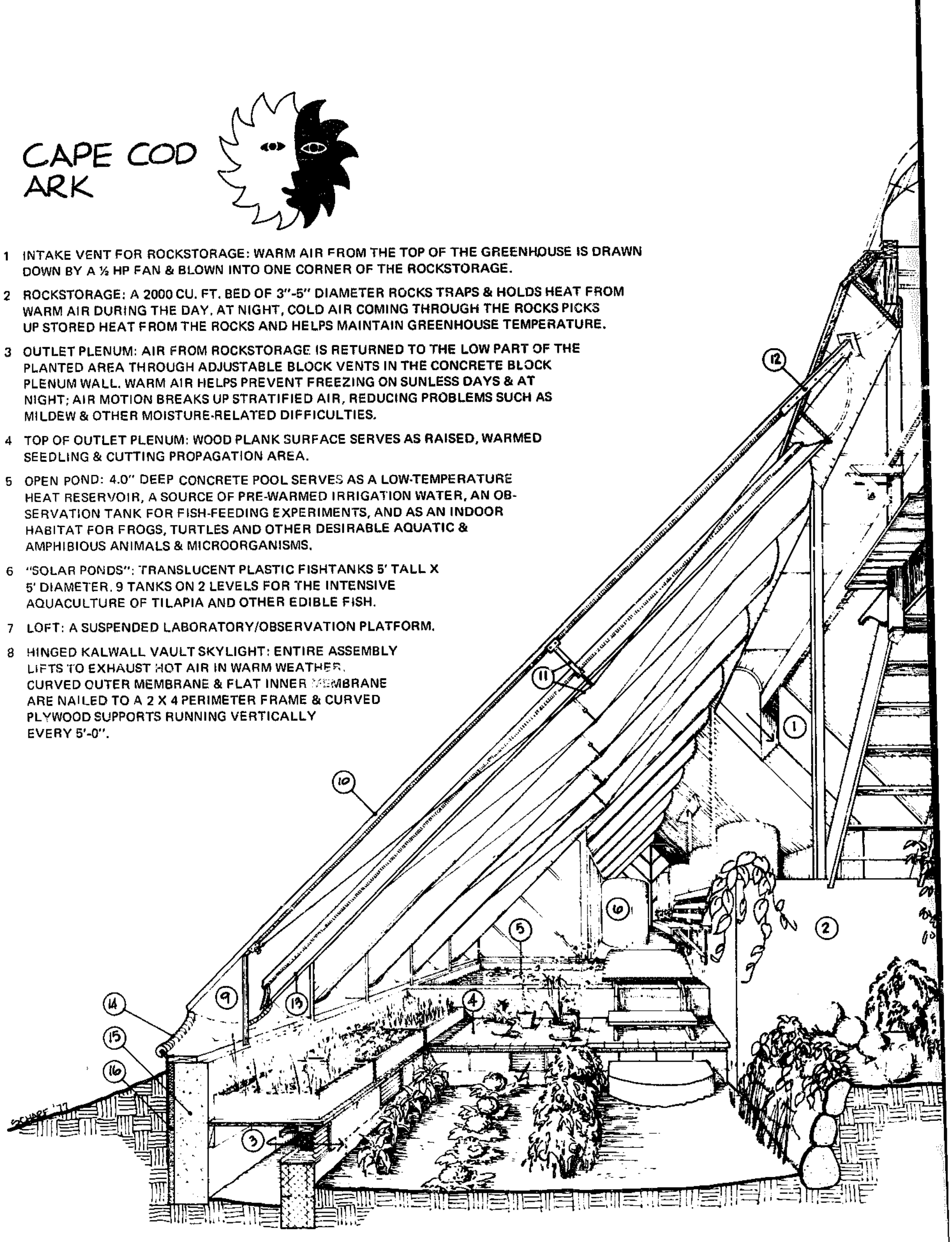
4 TOP OF OUTLET PLENUM: WOOD PLANK SURFACE SERVES AS RAISED, WARMED SEEDLING & CUTTING PROPAGATION AREA.

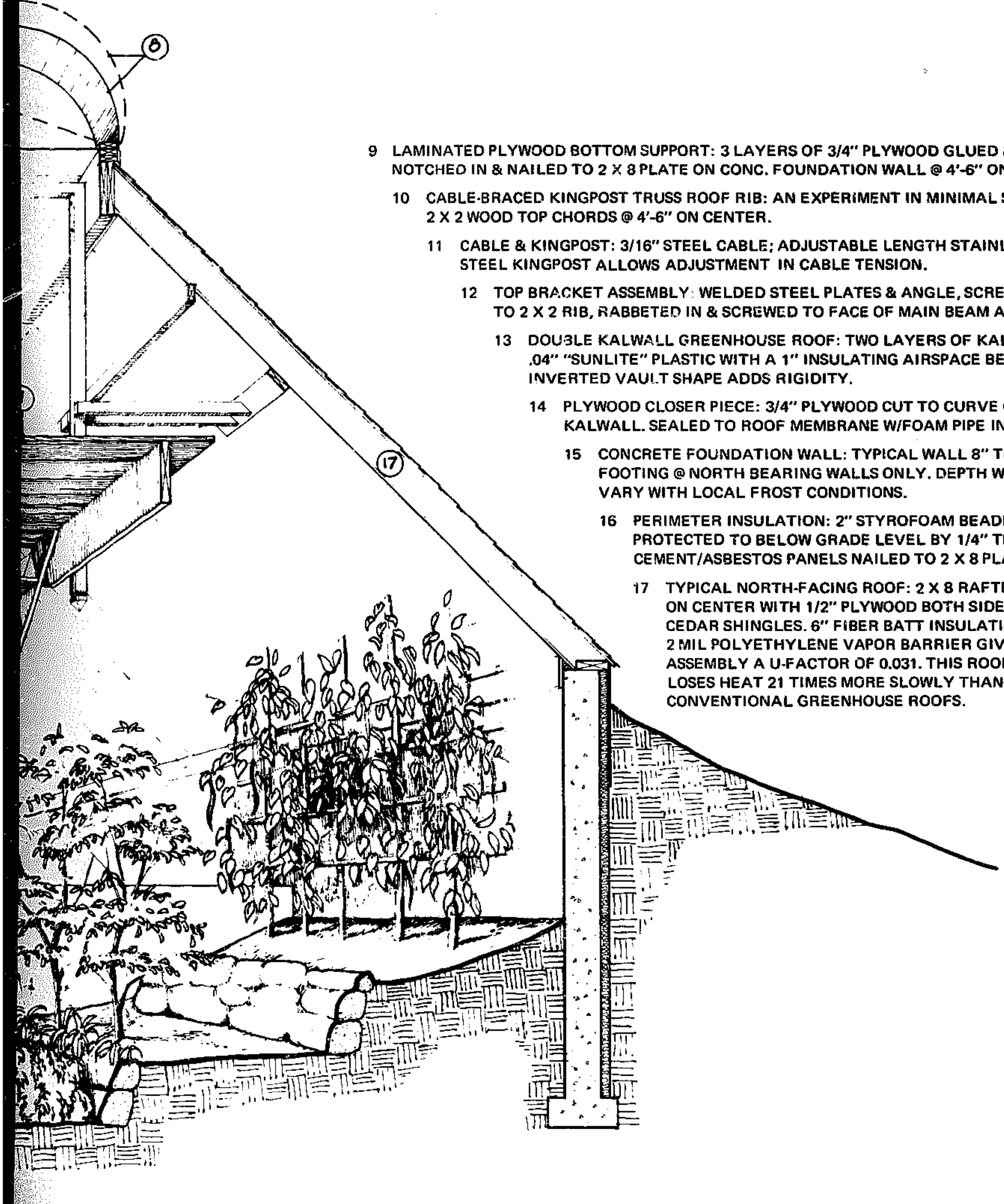
5 OPEN POND: 4.0" DEEP CONCRETE POOL SERVES AS A LOW-TEMPERATURE HEAT RESERVOIR, A SOURCE OF PRE-WARMED IRRIGATION WATER, AN OBSERVATION TANK FOR FISH-FEEDING EXPERIMENTS, AND AS AN INDOOR HABITAT FOR FROGS, TURTLES AND OTHER DESIRABLE AQUATIC & AMPHIBIOUS ANIMALS & MICROORGANISMS.

6 "SOLAR PONDS": TRANSLUCENT PLASTIC FISHTANKS 5' TALL X 5' DIAMETER, 9 TANKS ON 2 LEVELS FOR THE INTENSIVE AQUACULTURE OF TILAPIA AND OTHER EDIBLE FISH.

7 LOFT: A SUSPENDED LABORATORY/OBSERVATION PLATFORM.

8 HINGED KALWALL VAULT SKYLIGHT: ENTIRE ASSEMBLY LIFTS TO EXHAUST HOT AIR IN WARM WEATHER. CURVED OUTER MEMBRANE & FLAT INNER MEMBRANE ARE NAILED TO A 2 X 4 PERIMETER FRAME & CURVED PLYWOOD SUPPORTS RUNNING VERTICALLY EVERY 5'-0".





9 LAMINATED PLYWOOD BOTTOM SUPPORT: 3 LAYERS OF 3/4" PLYWOOD GLUED & NAILED. NOTCHED IN & NAILED TO 2 X 8 PLATE ON CONC. FOUNDATION WALL @ 4'-6" ON CENTER.

10 CABLE-BRACED KINGPOST TRUSS ROOF RIB: AN EXPERIMENT IN MINIMAL STRUCTURE. 2 X 2 WOOD TOP CHORDS @ 4'-6" ON CENTER.

11 CABLE & KINGPOST: 3/16" STEEL CABLE; ADJUSTABLE LENGTH STAINLESS STEEL KINGPOST ALLOWS ADJUSTMENT IN CABLE TENSION.

12 TOP BRACKET ASSEMBLY: WELDED STEEL PLATES & ANGLE, SCREWED TO 2 X 2 RIB, RABBETED IN & SCREWED TO FACE OF MAIN BEAM ASSEMBLY.

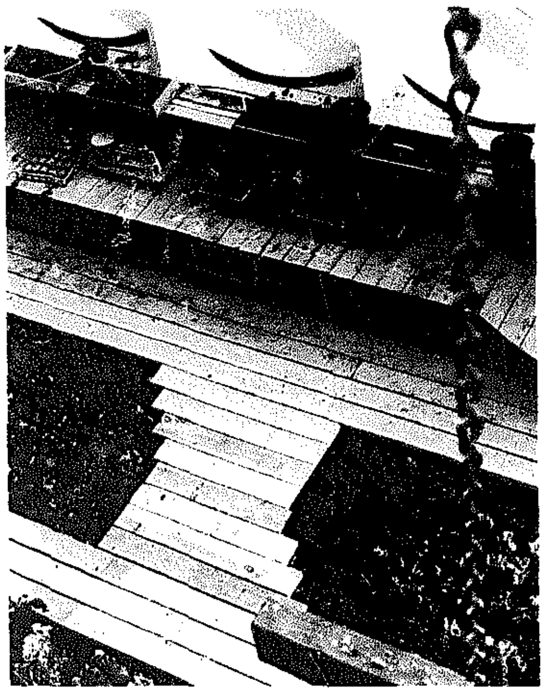
13 DOUBLE KALWALL GREENHOUSE ROOF: TWO LAYERS OF KALWALL .04" "SUNLITE" PLASTIC WITH A 1" INSULATING AIRSPACE BETWEEN. INVERTED VAULT SHAPE ADDS RIGIDITY.

14 PLYWOOD CLOSER PIECE: 3/4" PLYWOOD CUT TO CURVE OF KALWALL. SEALED TO ROOF MEMBRANE W/FOAM PIPE INSULATION.

15 CONCRETE FOUNDATION WALL: TYPICAL WALL 8" THICK; FOOTING @ NORTH BEARING WALLS ONLY. DEPTH WILL VARY WITH LOCAL FROST CONDITIONS.

16 PERIMETER INSULATION: 2" STYROFOAM BEADBOARD PROTECTED TO BELOW GRADE LEVEL BY 1/4" THICK CEMENT/ASBESTOS PANELS NAILED TO 2 X 8 PLATE.

17 TYPICAL NORTH-FACING ROOF: 2 X 8 RAFTERS 24" ON CENTER WITH 1/2" PLYWOOD BOTH SIDES & CEDAR SHINGLES. 6" FIBER BATT INSULATION & 2 MIL POLYETHYLENE VAPOR BARRIER GIVE THIS ASSEMBLY A U-FACTOR OF 0.031. THIS ROOF LOSES HEAT 21 TIMES MORE SLOWLY THAN CONVENTIONAL GREENHOUSE ROOFS.



community may also be crucial to the maintenance of the gaseous equilibrium of the internal atmosphere. Earthworms were added to the soil to aid in mixing and decomposing the initial rough organic matter and to distribute soil microorganisms. Earthworm density may eventually be used as an indicator of the soil condition.

Plants. The majority of plants tested over the past two winters have been food plants—garden fruits and vegetables. Other categories have been herbs, tropical tree seedlings, ornamentals, houseplant cuttings, and vegetable seedlings. Varieties that thrive and produce well are being tested for optimum microclimate and growth periods; varieties that sicken or are overwhelmed by pests are removed. Another group of plants, those that spontaneously appear from weed seeds, are not listed, but include hairy vetch, purslane, clover, and buckwheat.

Animals. Animals include humans, soil organisms, insect pests and predators, toads, birds, bees, wasps, spiders, and many others that are obvious members of garden fauna. Some were intentionally introduced, but most entered on plants, in soil, or as colonists during the fall. Several intriguing immigrants are: a tree frog that provides jungle sound effects, paper wasps that perform most pollination duties, and visiting birds who drop in occasionally for a bite to eat.

An interesting analogy on the population dynamics of the Ark ecosystem is that of the species on an island located near a mainland. Population ecologists now theorize that newly formed islands absorb colonizing species rapidly until an equilibrium is reached between immigration and random extinction of species on the island. Mathematical models of this theory have been verified in several instances, and may be appropriate in understanding a bioshelter.

Pseudo-Organisms. In a sense, a solar aquaculture pond could be compared to a new type of organism, exhibiting mixed characteristics of a cell, an organism, and an ecosystem. It admits light, has an internal photosynthesis/respiration process and a "body" temperature and metabolism, and is linked to the gaseous equilibrium of the bioshelter atmosphere. Distinctions between levels of biological organization become hazy when analyzing such a community.

IV. INVESTIGATIONS: PURSUING THE STATE OF THE ARK

We are now engaged in several directions of research: (1) testing food plants for adaptivity and productivity; (2) monitoring succession and development of new food web relationships; and (3) investigating climatic control patterns and their effect on ecosystem productivity. These activities are closely interrelated and the methodology is evolving with the structure. What follows is a brief discussion of the main concepts of each investigation.

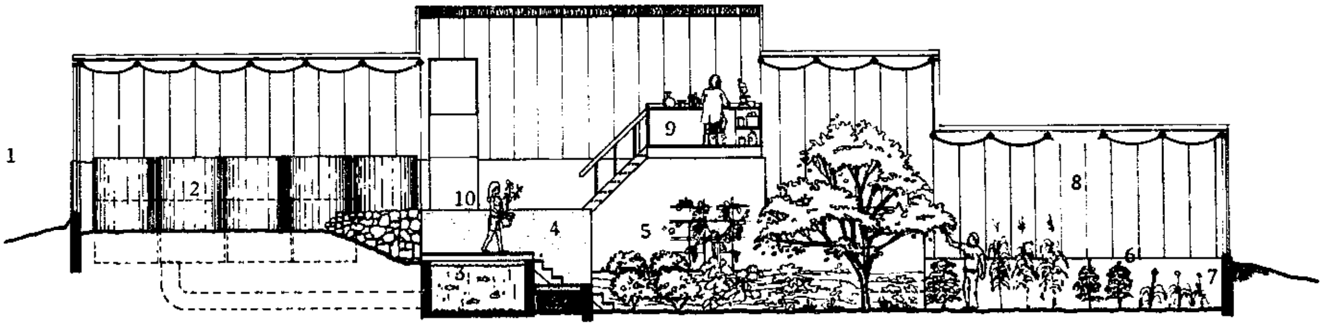
Testing Food Plants. The food production aspect of the bioshelter is considered part of a larger agricultural process, including summer gardens, food forests, and animal husbandry. The function of the present bioshelter in that scheme is to produce a source of winter vegetables, a year-round supply of fish protein, vegetable seedlings for summer gardens, and valuable fruit and nut seedlings. Of particular interest to us is whether such an integrated agriculture can sustain a family or small group by supplying their food needs with enough surplus to market to their community.

We are concentrating on vegetables that are enjoyed fresh or that cannot be easily stored from the summer. By monitoring growth rates and production periods, we hope to develop a seasonal planting sequence to supply constant fresh food and seedlings as needed. Certain crops grown commercially in northern greenhouses are being analyzed to discover whether bioshelter production could be competitive with greenhouses using fossil fuels.

Monitoring Succession. Soon after the construction of a microclimate and the introduction of desired species, a natural phenomenon occurs, of which all gardeners are painfully aware—pests and unexpected weeds appear. Since we do not completely understand the functions of minor organisms, and indeed are often not even aware of their existence, it is wise to respect their presence until it becomes apparent that they cause a difficulty. We have allowed most species to remain observed but unmolested as we determine their roles. Weeds in the

Cross Sections of the Cape Cod Ark

BIOSHELTER 1



1–Courtyards (Not Shown) Housing 33 Solar-Algae Ponds Connected To Interior Aquaculture Facility

2–Solar Pond Aquaculture Elements–Warm Water Heat Storage

3–Demonstration Pool

4–Rock Hot Air Heat Storage

5–Experimental Economic Plant Culture Zone

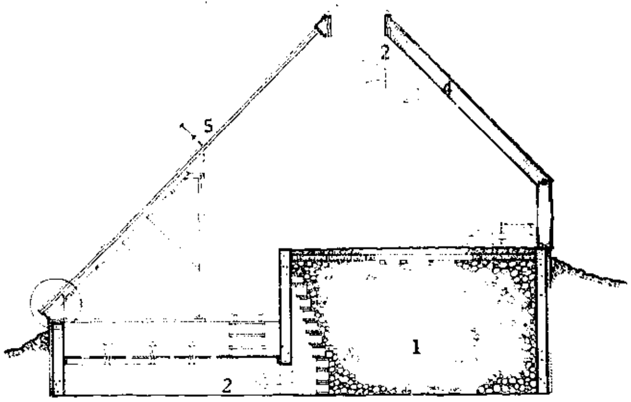
6–Production Zone

7–Food Crop

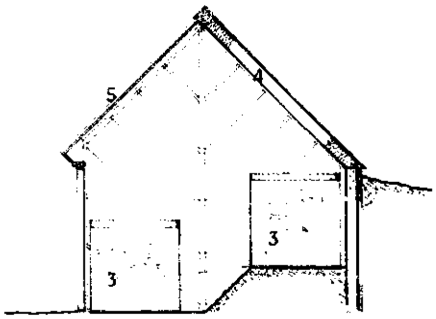
8–Insulated North Reflective Interior Surface

9–Research Laboratory Pedestal

10–Fan for Removing Hot Air to Rock Storage



SECTION AA



SECTION BB

1–Rock Storage

2–Air Flow

3–Translucent Solar-Algae Pond for Intensive Fish Culture

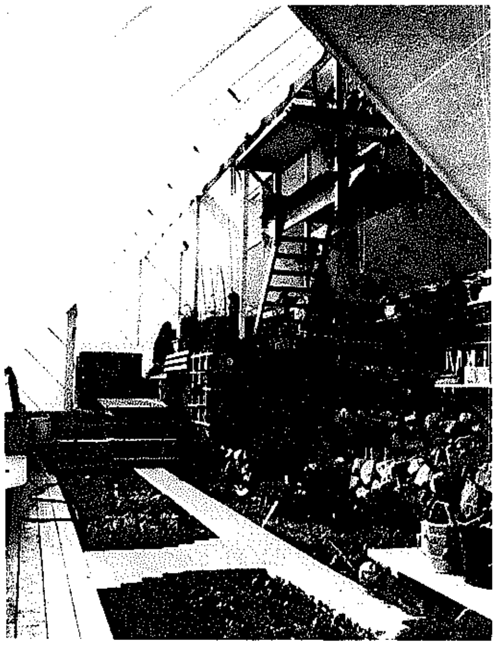
4–Insulated North Wall

5–Fiberglass (Double Layer) Southern Exposure

6–Fan

soil are allowed to grow until it appears that either the root system or leaf canopy is interfering with a food plant. The weed is then either removed or dug into the soil at that spot. Undoubtedly the presence of the weed in the soil stimulates some segment of soil microorganisms, and such diversity of process may be valuable. Yearly applications of outdoor garden compost and seasonal migrations of insects guarantee a continuous influx of species over time, and careful observation should reveal new relationships as they arise.

Climate Control: Fine Tuning. The type of climate controls now possible are temperature microclimates. This is accomplished through permanent architectural elements and through variable control of active heat storage and air circulation. A further possibility is an auxiliary wood stove for cold, cloudy periods. The mechanical and fuel energy required for these controls, and the resulting benefit in productivity, is of great



importance in determining the ultimate effectiveness and viability of bioshelters.

Other fundamental problems for further investigation include: the overall effect of great or small temperature fluctuations on the productivity of the ecosystem; the importance of air movement to productivity; and the addition and optimum utilization of auxiliary heat. We are developing instrumentation to help us begin to investigate these problems.

V. EXPLORATIONS

A great many facets of bioshelters remain to be explored. Fields of research that New Alchemy is initiating are:

Sheltering Bioshelters. Biological climate modification of architectural structures using winter windbreaks and summer shading with vines and trees.

Plant Selection. Developing plants genetically adapted to bioshelter existence.

Computer Modeling. Use of instruments and mathematics to test predictive models for improved bioshelters.

Wind and Solar Power Sources. Development of windmill-compressed air for mechanical tasks and solar cells for electrical controls.

Human Bioshelters. New hybrids between human housing and bioshelters, in which each benefits from the sharing of solar energy and climate moderation.

The Cape Cod Ark is an early stage in the development of the bioshelter concept. We are just beginning to sense its potential as a catalyst in humankind's understanding of nature. The most captivating vision is one that includes people in the system, as is being tried in the Prince Edward Island Ark in Canada. To assume the conscious responsibility of the ecosystem that sustains one is a fundamental change in awareness that has been sadly lacking in the industrialized West. Perhaps by this route, by first contemplating and internalizing the microcosm, larger changes can follow.

—Earle Barnhart

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Explorations

Photo by Hilde Atema Maingay

INTRODUCTION

It is sometimes interesting to speculate as to how events and ideas might have taken shape in times other than those in which they actually occurred. What, for example, might a group like New Alchemy been like at various other points in history? Certainly the need for such a group has long existed. The origins of human alienation from the natural order are as old or older than the beginnings of agriculture ten thousand years ago, even though there have been and are yet peoples who have achieved a harmonious balance with their environment. Once an initial differentiation had been made and humanity had been seen as existing separately or apart from the natural world, and that world felt to be vulnerable to human manipulation and exploitation, the dynamic was set in motion that has led to the present drastic imbalance in our relation to it.

New Alchemy, while still a child of necessity, is also very much of this moment. Much of the work would be impossible without the profound biological knowledge of the present. Similarly, modern technology has provided us with materials that enable us to open structures to light and to monitor subtle ecological interrelations and interactions that would have been unavailable to us until recently. This type of sensitive application of technology recalls Gary Snyder's metaphor of computer technicians who walk with the elk for part of each year..

New Alchemy is also an expression of this time in history in that it has grown synergistically with a particular network of people and their ideas and work. Although from the beginning we have been connected with like-minded people, fellow travelers, and related groups, with the founding of the Lindisfarne Association by William Irwin Thompson, there has been a nexus for individuals and ideas that were formerly rather disparate and unrelated. By dedicating itself to the task of cultural transformation and a rediscovery of the sacred in what is ordinarily seen as secular, Lindisfarne has brought together people from such disciplines as economics, biology, and cybernetics, ecology, religion, politics, sociology, space science, and the arts. Like pinpoints on a map whose interconnectedness slowly becomes apparent through exposure to the work of others, a broader pattern emerges for each. New Alchemy can be seen as the rather earthy component, having to offer the possible biological underpinnings to a potential future course. They would work in concert with the elegantly frugal economics of E. F. Schumacher, which indicate a path away from the accepted norms of expanding growth and increased consumption and toward a decentralized steady state economy that would have greater ecology sanity. The political thinking of Richard Falk and Saul Mendlovitz of the Institute for World Order proposes political order based on a type of global populism in combination with supranational cooperation that would do much to alleviate the inequities that are a primary cause of international tension. Murray Bookchin has long been a humane influence at the interface of ideas of ecology, politics, and libertarian technology. Their application is given reality in the work of the Zen Center in San Francisco under the leadership of Baker Roshi. And the mindset of Stewart Brand and his excellent magazine, the *CoEvolution Quarterly*, by unearthing ideas and thinkers like Gregory Bateson who are on the forefront of human thought, keeps all the components in a state of ongoing mental flux so that no one is allowed complacency with his or her private, or the collective, vision.

Such interdisciplinary meetings as these and the many others that are frequently being held can affect not only the awareness of the participants, but by encouraging flexible, creative, wholistic thinking, something like a synergy of thought occurs that can have the effect of a catalyst on public consciousness and subsequently, we hope, on the course of events. There is great need for such forums where all of culture can be reviewed and the possifiercely at this time, in Bill Thompson's phrase, at the edge of history, is hardly surprising when as bearers of life they see all life threatened and are increasingly frustrated at their powerlessness to affect events that are potentially so disastrous. As a piece of writing it is merely representative of the many that echo the current feminine and ultimately human identity crisis and see through a rebirth in understanding and balance between the masculine and the feminine, and between the human and the animate, a hope of breaching the gaps in understanding that have grown between us.

The above articles are presented as a very partial sampling of the climate of thought in which New Alchemy has been fostered and which has in turn been influenced by New Alchemy. Underlying it is the knowing that no one individual group or intellectual paradigm is sufficiently wise or strong or encompassing, but there remains the hope that, together, we may yet make a difference. bilities of new directions, new symbols, and new myths can be envisioned.

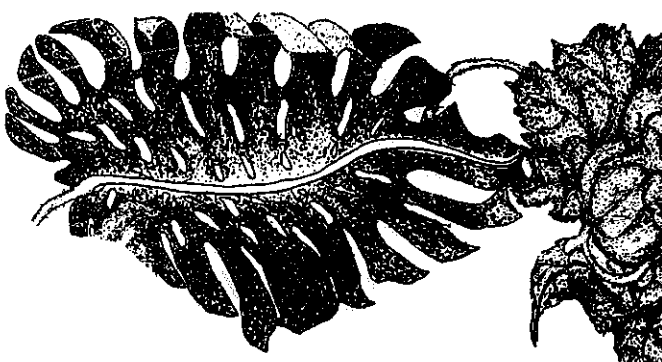
The article by William Irwin Thompson in this section puts the inherent dynamic of such ideas in a historical and cultural perspective.

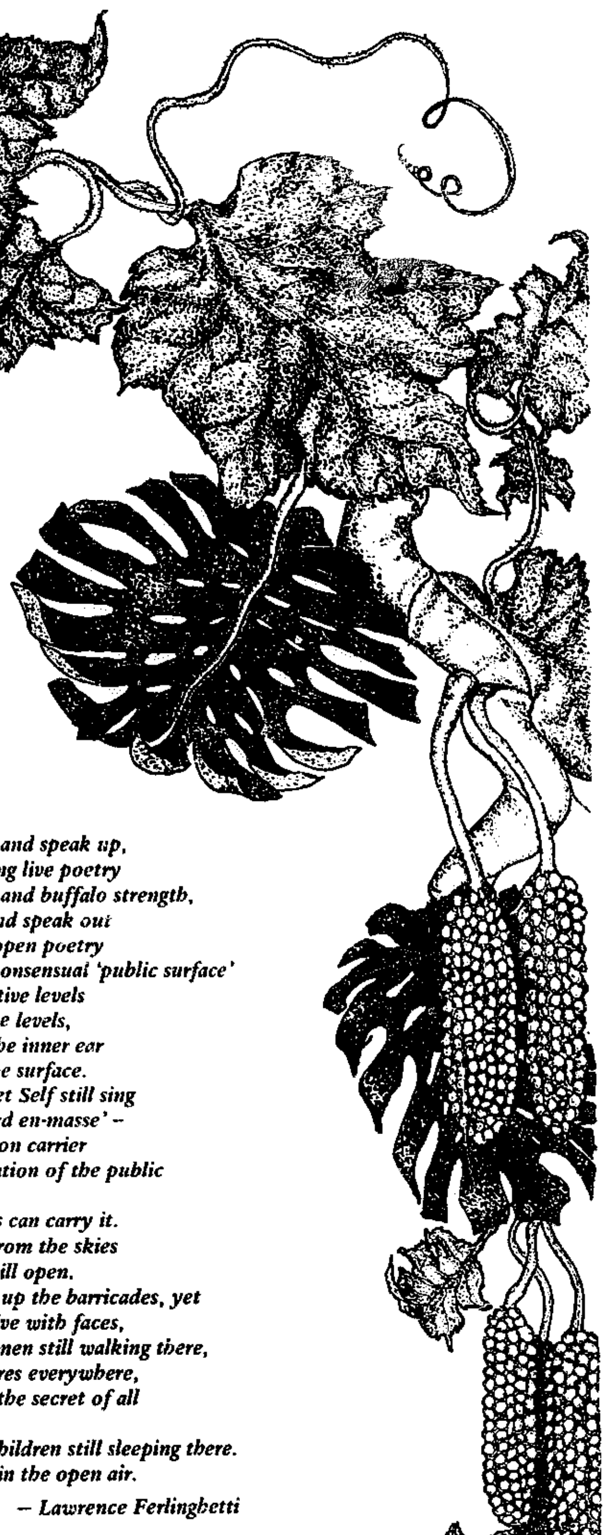
My own article touches on aspects of an issue that seems to me to be of primary importance. The gulf in understanding between the sexes is perhaps one of the most ancient to our species, although symptomatic of such other dichotomies as those between mind and body, and of human awareness from a sense of immanence in the natural world. That women should be protesting so

Populist Manifesto

for Poets with Love

Poets, come out of your closets,
Open your windows, open your doors,
You have been holed-up too long
in your closed worlds.
Come down, come down
from your Russian Hills and your Telegraph Hills,
your Beacon Hills and your Chapel Hills,
your Brooklyn Heights and Montparnasses,
down from your foot hills and mountains,
out of your tepees and domes.
The trees are still falling
and we'll to the woods no more.
No time now for sitting in them
As man burns down his own house
to roast his pig.
No more chanting Hare Krishna
while Rome burns.
San Francisco's burning,
Mayakovsky's Moscow's burning
the fossil-fuels of life.
Night & the Horse approaches
eating light, heat & power,
and the clouds have trousers.
No time now for the artist to hide
above, beyond, behind the scenes,
indifferent, paring his fingernails,
refining himself out of existence.
No time now for our little literary games,
no time now for our paranoias & hypochondrias,
no time now for fear & loathing,
time now only for light & love.
We have seen the best minds of our generation
destroyed by boredom at poetry readings.
Poetry isn't a secret society,
It isn't a temple either.
Secret words & chants won't do any longer.
The hour of oming is over,
the time of keening come,
a time for keening & rejoicing
over the coming end
of industrial civilization
which is bad for earth & Man.
Time now to face outward
in the full lotus position
with eyes wide open,
Time now to open your mouths
with a new open speech,
time now to communicate with all sentient beings,
All you 'Poets of the Cities'
hung in museums, including myself,
All you poet's poets writing poetry
about poetry,
All you poetry workshop poets
in the boondock heart of America,
All you house-broken Ezra Pounds,
All you far-out freaked-out cut-up poets,
All you pre-stressed Concrete poets,





All you cunnilingual poets,
All you pay-toilet poets groaning with graffitti,
All you A-train swingers who never swing on birches,
All you masters of the sawmill haiku
in the Siberias of America,
All you eyeless unrealists,
All you self-occulting supersurrealists,
All you bedroom visionaries
and closet agitpropagators,
All you Groucho Marxist poets
and leisure-class Comrades
who lie around all day
and talk about the workingclass proletariat,
All you Catholic anarchists of poetry,
All you Black Mountaineers of poetry,
All you Boston Brahmins and Bolinas bucolics,
All you den mothers of poetry,
All you zen brothers of poetry,
All you suicide lovers of poetry,
All you hairy professors of poesie,
All you poetry reviewers
drinking the blood of the poet,
All you Poetry Police --
Where are Whitman's wild children,
where the great voices speaking out
with a sense of sweetness & sublimity,
where the great new vision,
the great world-view,
the high prophetic song
of the immense earth
and all that sings in it
And our relation to it --
Poets, descend
to the street of the world once more
And open your minds & eyes
with the old visual delight,
Clear your throat and speak up,
Poetry is dead, long live poetry
with terrible eyes and buffalo strength,
Stop mumbling and speak out
with a new wide-open poetry
with a new commonsensual 'public surface'
with other subjective levels
or other subversive levels,
a tuning fork in the inner ear
to strike below the surface.
Of your own sweet Self still sing
yet utter 'the word en-masse' --
Poetry the common carrier
for the transportation of the public
to higher places
than other wheels can carry it.
Poetry still falls from the skies
into our streets still open.
They haven't put up the barricades, yet
the streets still alive with faces,
lovely men & women still walking there,
still lovely creatures everywhere,
in the eyes of all the secret of all
still buried there,
Whitman's wild children still sleeping there.
Awake and walk in the open air.

— Lawrence Ferlinghetti

Meditation on the Dark Ages, Past and Present

All forms hold energy against the flow of time. Spread the energy of a sun equitably throughout space, and you will subtract a star from the heavens. Gather up the galactic dust of space in a spiral, and you can compress the dust into a sun. Expansion and contraction, expression and compression: so the universe goes. Once it was a single atom that began to expand in an explosion; and now it will continue to expand until it reaches the ultimate limit of entropy. With the energies of the aboriginal cosmic atom spread equitably throughout space, it will all be over in the heat-death of the universe. It is only a matter of time, or, rather, *the* matter of time. From hot to cold, from order to disorder, from creation to entropy: over it all the Second Law keeps watch, and black holes compose the light of gravity-collapsing stars.

Modern optimists like Buckminster Fuller like to speak of "synergy," as if there were some magic form that could hold out against the laws of thermodynamics. Surrounded by the signs of an impending tragedy, the collapse of his whole industrial civilization, the liberal optimist refuses to believe in tragedies anymore: the past was tragic because they did not have computers in those days. Liberals like Zbigniew Brzezinski and Herman Kahn believe we can eliminate the tragic flaw in man; following Brzezinski, we can replace the chaos of politics with the systems of management; following Kahn, we can hook up the brain to computers to create an electronic superman.[1] In the science-fiction vision of Arthur C. Clarke[2], the ultimate society of the future will be programed by a giant computer, and politics, economics, art, and entertainment will be taken care of in a domed city whose magic circle keeps out chaos and old night.

Although that miracle seems far off, Buckminster Fuller is still reaching out for it and has already drawn a sketch of a dome over Manhattan. For men like Fuller, Brzezinski, and Kahn, tragedy is inconceivable. Their faith in progress is so unthinking that they cannot help but believe that some technological miracle will deliver us at the last dramatic moment. Though we have not been reared on myth, we have all been raised on movies and believe that just as all seems lost and the savages are about to burn the circle of covered wagons, the cavalry will charge in with a joyous noise of bugles and salvation.

The Greeks knew better. Anaximander presided over the case in 560 B. C. and delivered the following judgment:

> *The Non-limited is the original material of existing things; further, the source from which existing things derive their existence is also that to which they return at their destruction, according to necessity; for they give justice and make reparation to one another for their injustice, according to the arrangement of Time.*[3]

They make reparation for the sin of their existence, for the breaking up of the One into the many. The pieces of the One are things, and things are what man holds onto to maintain the vanity of his own existence.

And before Anaximander, Homer knew better. When the Achaeans invade Troy, they build a wall upon the shore where their ships are beached. Nature builds permeable membranes, but only man is vain enough to build a wall. Behind that human form set between the opposites of sea and land, man holds out for a while. But after that while, the forces of erosion wear it down, and all that bright armor is tumbled into mud.

So within the shelter the warlike son of Menoitos tended the stricken Eurypylos, and meanwhile the Argives and Trojans fought on in massed battle, nor was the Danaans' ditch going to hold them back nor the wide wall above it they had built for the sake of their ships, and driven a deep ditch about it, and had not given to the gods grand sacrifices so that it might guard their running ships and their masses of spoil within it. It had been built in despite of the immortal gods, and therefore it was not to stand firm for a long time. So long as Hektor was still alive, and Achilleus was angry, so long as the citadel of Lord Priam was a city untaken, for this time the great wall of the Achaeans stood firm. But afterwards when all the bravest among the Trojans had died in the fighting, and many of the Argives gone in their ships to the beloved land of their fathers, then at last Poseidon and Apollo took counsel to wreck the wall, letting loose the strength of rivers upon it, all the rivers that run to the sea from the mountains of Ida, Rhesos and Heptaporos, Karesos and Rhodios, Grenikos and Aisepos, and immortal Skamandros, and Simoeis, where much ox-hide armour and helmets were tumbled in the river mud, *and many of the race of the half-god mortals. Phoibos Apollo turned the mouths of these waters together and nine days long threw the flood against the wall, and Zeus rained incessantly, to break the wall faster and wash it seaward. And the shaker of the earth himself holding in his hands the trident guided them, and hurled into the waves all the bastions' strengthening of logs and stones the toiling Achaeans had set in position and made all smooth again by the hard-running passage of Helle and once again piled the great beach under sand, having wrecked the wall, and turned the rivers again to make the way down the same channel where before they had run the bright stream of their water.*[4]

As long as Achilles is angry, the war goes on. As long as passion is attached to form, the conflict rages.

Beneath us is the molten core of earth, above us is the burning radiation of the solar wind. Behind the wall of the earth's magnetic field, we keep ourselves together until those apocalyptic times when the poles reverse themselves and every valley is exalted and every hill made plain.

Whether it is the thin film of the biosphere, or the thin wall of the Achaeans, man lives at an interface between opposites: earth and sky, sea and shore, life and death. Yet it is precisely the interface between opposites that is the place of transformation, and the energy of that transformation comes from remaining poised at the perilous edge; a slight movement to either side brings dissolution into uniformity.

We live at an interface between order and disorder, and cannot move into one singly without destroying the disequilibrium that is basic to change and evolution. Order and disorder, energy and transformation: it almost seems molecular. Put enough energy into the lattice, and the metal will turn into a gas; slow down the volatile gas, and you can have metal to outlast an eon. Once again, the Greeks seems to have understood the nature of the choice. In Thucydides' *Peloponnesian War,* the choice is dramatized in the conflict between Sparta and Athens. Be like Sparta and you can live with your highly ordered, barrack-like institutions intact for eight hundred years; be like Athens and you can create everything we know as Greek culture and burn out in ninety years. It is a choice between a Spartan death in life, or an Athenian life in death. And the choice is all a matter of values.

How does one hold onto values in an age of the collapse of values? How does one create forms in an age when all forms are coming apart? Like the wall of the Achaeans, our industrial civilization has been built in despite of the gods and now the forces of nature are wearing away at it. But this is not the first time individuals have had to live on while the light of their civilization sputtered.

Like the sixth century A. D., the sixth century B. C. was an age of darkness. The civilizational waves of Sumer and Egypt were receding; whatever was left of the original cultures was lost in the mud and shallows of militaristic states. R. M. Adams has shown that, in the evolution of urban society in Mesopotamia and Mesoamerica, cultures began as theocracies, became militaristic polities, and ended up as conquest states.[5] Another way of looking at this evolutionary process is to see that a culture begins in an explosion of myth, a sacred image of nature, self, and society that unites all men in a common dream, and then slowly the forces of routinization take over and the dream begins to fade. The prophet becomes a priest; the shepherd-king becomes a Solomon the Magnificent. As the forces of palace, marketplace, and army develop, the myth decays until nothing holds man together but brute force. The disintegrating polity is finally compressed into the militaristic fascist state. Since every state organized for conquest also organizes its enemies to conquer it, such militarism creates the dismal cycle which leads to the destruction of civilization.

According to tradition, Pythagoras was carried away from Egypt to Babylon by the conquering armies of Cambyses. One can picture the historical landscape against which the sage moved: nothing left of the civilization of either Egypt or Babylon, only a recent memory of the unending movement of armies: Hebrew, Assyrian, Persian, and Mede. The light of civilization that had flamed up in the fourth millennium B. C. was now going out, but in the dim light the shadows threw into greater relief the very weakness of that form of human culture.

Civilization had been based upon writing, on the break-up of the unity of the tribe into the literate and the illiterate. It had been based upon urbanization, on standing monuments and standing armies, and, ultimately, upon slavery. The polarities of the age of civilization were the center and the periphery, the temple of the priest and the desert of the prophet. As the centers had decayed, the pastoral vision of the eternal desert had been expressed by Abraham, Moses, and Amos. Then in the sixth century B. C. a new wave of prophecy arose and addressed itself not merely to the moral decay of one center, but to the moral decay of the very idea of civilization itself. Across the world, from Italy to China, a new race of prophets confronted the contradictions of civilization. The vision of the prophets was one of universal religions. It was not a validation of one's own tribal god, for that too easily could grow into the civil religion of a conquest state; it was a vision of the aboriginal brotherhood of man that stood before the walls and battlements of civilization had been raised.

The sixth century B. C. is one of the darkest and the brightest periods in history; it is the age of the Second Isaiah and Daniel, Jeremiah, of Pythagoras and Zoroaster, of Buddha, Lao Tzu, and Confucius. Why did they all come at the same time? A Jungian would invoke the collective unconscious of the race, a Hopi would speak of the *kachinas* from other worlds who supervise our evolutionary development, and a Christian poet would answer:

Because the Holy Ghost over the bent
World broods with warm breast and with ah!
bright wings.

Let us indulge in a Pynchonesque paranoid fantasy to image that the prophets of the sixth century are part of one universal conspiracy. Religion is, after all, supposed to be a subversive conspiracy, "For we wrestle not against flesh and blood, but against principalities, against powers, against the rulers of the darkness of this world, against spiritual wickedness in high places."[6] Certainly the conspiracy-theory of history would explain what Pythagoras and Zoroaster were doing together in Persia.[7]

From Egypt and Mesopotamia, Pythagoras took his experience of the mystery schools to the western lands of Magna Graecia in Italy to establish something new, not a hierophantic mystery school for temple initiates, but a secular school for the leaders of society. In short, Pythagoras built the first university and laid the foundations in mathematics, music, and physics for the science upon which Western Civilization is built.

Marshall McLuhan has described the process of change as one in which the sloughed-off environment becomes a work of art in the new invisible environment.[8] This is one way to present the Hegelian dialectic of historical growth. A visual image of the process of *aufheben* is the spiral: we turn back to the past, reconstitute it, and then turn away from it in a new direction. The strategy of change for Pythagoras was to make a synthesis of the religion and science of the dying Near Eastern civilizations, and then miniaturize them as a work of art in the new and still invisible environment of Western Civilization. The old culture became a curriculum in the new culture. In terms of paleontology, this kind of evolutionary change is an example of the principle of Romer's Rule: "The initial survival value of a favorable innovation is conservative, in that it renders possible the maintenance of a traditional way of life in the face of changed circumstances."[9]

At the time of Pythagoras, the Egyptian mystery schools were no longer forces of culture and civilization-building; they were probably priestly bureaucracies subsidized by the state to pass on harmless traditions by rote. The only way to recreate the original purpose of the mystery school was to do something radical, radically conservative. And so Pythagoras created the secular school, the university. As civilization was moving toward entropy, he created a new form to hold old values against the flow of time.

The tragic background against which the school of Pythagoras at Croton was figured continued, however, to its end. Many were accepted into the Pythagorean discipline, but some were rejected as morally unfit. One of the rejected students is reputed to have raised a rebellion against the influence of the school. In the conflict, the school was burnt to the ground. The Pythagoreans fled throughout Greece, but, in their flight, they took the message to the Greek world. Like a seed-pod exploding in its death, the school created new lives, and one of those lives was Plato and his Academy.

Plato's Academy lasted from 385 B. C. to 529 A. D.; it became the archetype for all the universities that followed. Pythagoras's school at Croton lasted for only twenty years. The Pythagorean tradition went underground, but like an underground spring it flowed beneath the foundations of many of the schools that came after. Iamblichus in Syria, Ficino in Florence, Copernicus in Frauenberg, Bruno in Nola, and Heisenberg in Munich: all identified themselves as Pythagoreans. Pythagoras may have died as an old man in exile and despair at the destruction of his life's work, but the success of his short-lived experiment rivals the success of institutions that endured for centuries.

The Pythagorean school at Croton and the Platonic Academy in Athens exemplify two different ways to hold values against the forces of disorder. One form is the cultural strategy, the other is the permanent institution. One short-lived strategy that affected the life of British civilization, with such longer-lived institutions as Canterbury, Oxford, and Cambridge, was the monastery-school of Lindesfarne. Founded in 634 on Holy Island off the coast of Northumbria, Lindisfarne was another attempt to create light in an age of darkness.

Once again, the sloughed-off environment became a work of art in the new invisible environment. The old Graeco-Roman civilization became a curriculum in the new invisible environment of Christian civilization. The school at Croton was not an Egyptian mystery school, and the monastery-school at Lindisfarne was not a Roman Catholic church, but an Irish one. The Roman Church was based upon the imperial model; each city contained a bishop who was answerable to the bishop of bishops in the mother of cities in Rome. There were no cities in ancient Ireland and Scotland, and so the monastery was set in a totally different culture. The abbot of a monastery was no prince of a church, but a common priest. The Irish Church was no outpost of an imperial ecclesiastical Roman legion, but the continuation of archaic religious forms derived from pagan Ireland and syncretistic Egypt.

If, according to Romer's Rule every innovation is conservative, it is easy to see that the innovations of the Celtic Church enabled some of the old mystical traditions of archaic Ireland to live on under changed historical circumstances. As Pythagoras had out-mystified the hierophants of the mystery schools of Egypt, so St. Columba out-druided the druids.[10] In each case, the innovator was more in the spirit of the tradition than the traditionalists.

The Celtic Church identified itself as the mystical Church of John and not the temporal Church of Peter, and, until the Synod of Whitby in 664, which was to shift the influence away from the Celtic to the Roman Church, Lindisfarne was the voice of Christianity in England. With the monastery school as their base, the great saints Aidan and Cuthbert went forth to convert pagan England. In less than thirty years, the work was done. After the defeat of the Synod of Whitby, the Irish monks under Colman went back to Iona from Lindisfarne. Though some monks stayed behind, the great age of Lindisfarne was over. At the turn of the eighth century, the Lindisfarne Gospels were illuminated in memory of Cuthbert, but even great art could not defend the vision. A few years later, Lindisfarne was overrun by the Danes and burnt to the ground.

The burning of Lindisfarne, like the burning of the school at Croton, reveals that many of these efforts to create light are figured against intensely dark backgrounds. In modern times the Bauhaus seems to be a preeminent example of a cultural force arising at the same time that the opposite forces of Nazism were growing all around it. And once again, it was the very dissolution of the Bauhaus that carried its energies to London and Chicago.[11]

What we can learn from Croton, Lindisfarne, or the Bauhaus is that a small and short-lived community can serve as a catalytic enzyme to effect a change in the entire organism of a civilization, and that sometimes these changes are as important as the more obvious contributions of permanent institutions. Institutions are appropriate structures for the continuation of a tradition, but they are not appropriate forms for the creation of the new or the revitalization of the old.

The other principle we can learn from Croton and Lindisfarne is the necessity of conserving a civilization by intensifying it through miniaturization. Pythagoras miniaturized the Near-Eastern civilization; the Irish monks miniaturized Graeco-Roman civilization; now we need to miniaturize industrial civilization.

The sloughed-off environment is industrial civilization; the invisible environment is what Teilhard de Chardin called "the Planetization of Mankind." To turn industrial civilization into a work of art in this still invisible environment, we must not only miniaturize our factories, we must also miniaturize the great universal religions which created the basis of internationalism. The universal religions were created in response to the contradictions of civilization, but we are no longer living in civilization. The polarities between elitist center and provincial periphery have been overcome by modern communications and spiritual consciousness. Planetary culture is not the international civilization of London, Paris, Tokyo, and New York; it is the new consciousness in which "The center is everywhere and the circumference nowhere." The universal religions were the precursors of planetary culture, but now that we are moving from civilization to planetization, we need to take up *(aufheben)* these religions and miniaturize them in a curriculum for a new culture.

If we are going to humanize a technology that now contains thermonuclear warfare, ecological destruction, and such subtler destructions as psychosurgery, electronic manipulation of the brain, aversive therapy, and behavioral modification, we will need more than the liberal humanism expressed in the implicit system of values of the behavioral sciences and the traditional humanities. The world view of the liberal intellectual is a Marxist-Freudian mapping of the outer world of society and the inner world of the psyche; but that sophisticated world view does not contain the celestial and cthonic energies we need to appreciate the machine for what it is worth. To see technology in proper scale, we need cosmic consciousness, and that consciousness comes more often from meditation than from reading Marx or Freud.

If we cannot humanize our technology with liberal humanism, we can with animism. And that is the importance to the contemporary world of animistic communities like Findhorn.[12] If we can converse with plants, hear the spirits of wind and water, and listen to the molecular chorus singing the ninety-nine names of God in the crystal lattice of the metal of our machines, then we can have the consciousness we need to live in a culture in harmony with the universe.

In an unconscious fashion, man has already begun to shift away from materialism to information, and the giantism of the machines he once worshiped is giving way to tiny circuitry. If the space program sent off rockets to the moon that were taller than skyscrapers, it spun off to earth machines in which millions of electrons danced on the head of a pin. As our entire technology becomes as miniaturized as our hand-held calculators and desk-top computers, the whole scale of the human body to technology changes. Like paleolithic hunters of the Solutrean culture, whose tools were pieces of sculpture in their hands, we will hold our technology and not be held by it.

As the scale of man to machine changes, so does the scale of the individual to institutions. In an electronic technology, one need not drive to a

Berkeley-type university to watch a lecture on a television console with four hundred other students: he can stay home to watch the Berkeley university program on cable television, and, if he doesn't like Berkeley, he can switch the channel to Harvard or Oxford. As more students stay home, and as more information is carried on cable, the university will no longer have to sustain a huge complex of buildings. The university will grow smaller as it grows larger and the university will be everywhere and the campus nowhere.

As more and more information is carried in the home, the individual will experience a need for new groupings. On the turn of the spiral, man will return to the tribal forms of the hunters and gatherers, and in these societies, "The magic numbers are 25 and 500."[13] As the individual moves out of the environment of the institution, a symbolic environment in which he gains his information through the reading of buildings and books, he moves into the larger environment of the Noosphere, a vibratory environment he experiences through meditation, ritual chanting, and dance. As the cosmic environment expands in the Noosphere, the human community compensatorily contracts into the hunting band of 25 or the planetary village of 500.

As one moves from the institutions of civilization in church, university, and capital-intensive factory into the new planetary villages, he moves into a religion without priests, a university without professors, and manufacture without factories. The factory mass produces cheap goods with built-in obsolescence, but in an era of scarcity of materials in which "The Limits to Growth" are envisaged, we will no longer be able to afford the waste of energy and materials contained in the mass production of cheap goods. Of necessity, we will have to return to the medieval craft-guild workshop. Since the goods will have to be crafted to last a lifetime, they will have to be built with a Zen mindfulness to every detail, and so the labor-intensive workshop will contain, not an army of workers, but a mystery-guild of contemplatives. Like the furniture of the Shakers, the goods of the planetary village will be very good indeed.[14]

In a labor-intensive community of contemplatives, more is done with less capital, so money is surrounded, compressed, and miniaturized by a culture not based upon greed. As inflation prices industrial civilization out of existence, communities of caring and sharing are brought into being and families are forced into finding other means than money to structure their lives. In a culture of Buddhist "Right Livelihood", money is not eliminated, any more than technology; both are miniaturized. The Buddhist tone of "Right Livelihood" may sound foreign to the American Way, but, interestingly enough, just such a political economy was envisioned by Jefferson. In words that ring out as a startling prophecy of our contemporary fascination with decentralized China, Jefferson wrote to Hogendorp in 1785:

> *You ask what I think on the expediency of encouraging our States to be commercial? Were I to indulge my own theory, I should wish them to practise neither commerce nor navigation, but to stand, with respect to Europe, precisely on the footing of China.*[15]

As the Church lost the vision of its founder, so has the country lost the vision of its founding fathers, but now that industrial society is strangling in its own contradictions, we have one last chance to re-vision human society.

The Protestant Ethic and the Spirit of Capitalism spurred the growth of industrial civilization, so it is natural to assume that the growth of planetary culture is being spurred by a new spiritual sensibility. Side by side with the miniaturization of technology, we are also experiencing the miniaturization of the great universal religions. The esoteric is the miniaturization of religion, and just about every esoteric school is now opening itself to the new global culture of our technological society. Yoga, Sufism, Tibetan and Zen Buddhism, Yaqui Shamanism, and Celtic animism: the planet has become a Ptolemaic Egypt of syncretistic religious movements and the Alexandria of it all is America. And this is no accident, for all these esoteric techniques have what we need to transform our exoteric technologies. Europe and Asia groan under the burden of their own past greatness, but America is still the place where all the cultures of the world can come together in consummation of the past and realization of the future.

At the contemporary Lindisfarne in America, we have tried to turn the old culture into a new curriculum. We have neither guru and disciples nor Church and worshippers, but we do have a spiritual fellowship in which men and women serve as teaching fellows in Yoga, Buddhism, Sufism, Esoteric Christianity, and Mystical Judaism. In a college, the curriculum is based upon the Great Books of Western Civilization, but at Lindisfarne the curriculum is based upon the Great Techniques for the transformation of consciousness. Lindisfarne's scientists, artists, and scholars have one thing in common: their lives are rooted in one of the great contemplative paths of transformation. As the school at Croton was not a mystery school, and as the monastery at Lindisfarne was not a Roman Catholic Church, so we are not a simple continuation of the past. We *have* a farm, but *are* not a farm; we have children in the community; but we are not a private school; we have post-doctoral fellows, but are not a think-tank; we have retired people, but are not a retirement community; and we have yogis, but we are not an ashram. We have gone back on the spiral to the pre-industrial community to create, on a higher plane with the most advanced scientific and spiritual thought we can achieve, the planetary village. We have moved in consciousness out of the large nation-state into the even larger planet; we have moved out in body from the city to the smaller multi-generational community. With the economic thought of E. F. Schumacher of London, the technological thought of the New Alchemists, the agriculture of Findhorn, the scientific philosophy of Whitehead, and the religious thought of Sri Aurobindo and Teilhard de Chardin, we are trying to create an educational community that can become a mutational deme in which cultural evolution can move from civilization to planetization.

In the nineteenth century the polarities of culture were the romantic artist and the industrial engineer. Then Shelley could say that: "Poets are the unacknowledged legislators of the world." But now that is no longer true. In the shift from civilization to planetization it is the mystic who has become the unacknowledged legislator of the world: a Sri Aurobindo or a Teilhard de Chardin, and not a Norman Mailer or an Andy Warhol. The artist cannot save civilization, and in the search for form it is not the artist who will discover and create the new culture. We have lived long enough with the myth of The Artist, and now that the paintings decorate banks and the poems lead to suicide, it is time to move on and let the artist remain behind, whimpering in the corners of his mind.[16]

In abandoning The Artist we will not lose the beautiful, we will regain the beauty the artist lost sight of. Pythagoras, Columba, Quetzalcoatl: the builders of cultures were themselves versed in the arts of civilization and could provide the myths that would sustain new artists for generations.

Art is dead. Science is dead.[17] Now even the Pope is willing to say that: "It seems the Church is destined to die."[18] Our entire civilization is dying. But what is death? Consider the yogi: when he stops his heart consciously, he is dead by technical definition, but actually he is reborn, for in taking the energy out of the cardiovascular into the central nervous system, he experiences ecstasy and enlightenment. He does not die, he dances his death. So now we need to dance out the death of industrial civilization and experience, not its painful, apocalyptic destruction, but its joyous, millennial de-structuring. And if we cannot, then we will not create our destiny, but be forced to endure our fate.

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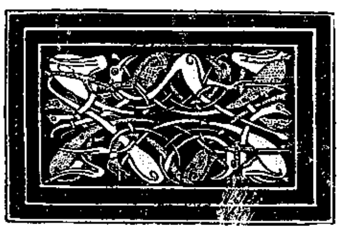
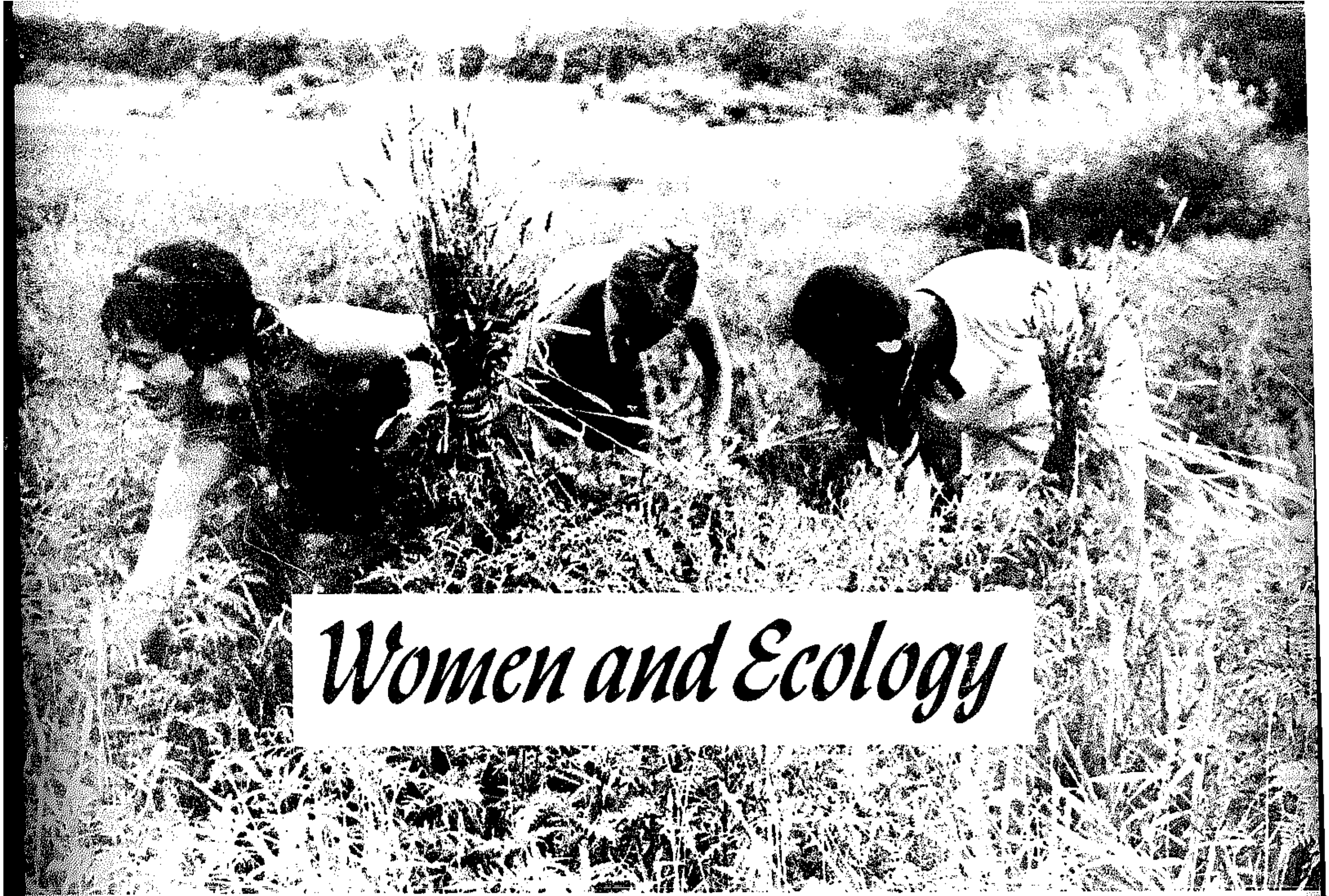
The ideas of miniaturization used in this essay come from Teilhard de Chardin (See *Man's Place in Nature*, p. 47), and from Paolo Soleri's development of Chardin in *Arcology: the City in the Image of Man.* (M.I.T., Cambridge, 1969).

- William Irwin Thompson





Women and Ecology

I have long had in mind the idea of writing something on women and ecology. Such a project had its beginnings in two causes that have been very important to me. After several years in the peace movement, crowned with the rather hollow triumph of replacing Johnson with Nixon, I had become discouraged with the prospect of reform within the system and began, to borrow a phrase from biology, to look more closely at the microcosm – meaning my more immediate environment. Talk of pollution and ecology was everywhere, and surrounded (as I was at the time) by biologists engaged in issuing gloomy prophesies, the concepts and implications of ecology seemed well worth exploring.

My interest in the state of women is self-explanatory.

The link between the two subjects was originally rather intuitive and vague, based on two tentative, hopeful assumptions. The first was something that continually distressed me in the fastness of southern California suburbia, and that was the amount of wasted energy in a physical, psychic and economic sense that

We women went from there into wider fields. A dozen or so of us organized a "March 8th" tree-planting team. We had no saplings, as we had not yet a tree nursery, so we would walk for miles in a day collecting tree seeds. In three years we had over 110,000 trees planted on more than 20 hectares of sandy wasteland. By 1971, we women, whose labour force was augmented by that of the poor and lower-middle peasants of our village, had planted more than a million timber and fruit trees, covering 220 hectares of sandy land with green. This checked wind and shifting sand, and we began to have good harvests every year. Our grain yields increased in some cases by as much as 650 per cent. The old view of women's "place" underwent a change, and people were saying, "The women are really doing their share of the collective work!"*

*International Working Women's Day, established in 1910.

– *from "New Women in New China" Foreign Languages Press Peking 1972*

I saw in the lives of so many women. Particularly among the privileged, so many hours are spent in front of the television, shopping, having hair done, in short on an enormous variety of empty activities and meaningless busyness. Yet beneath the vacuousness, I felt, were untapped resources of brain and energy, which could surely be put to use for the common good. The second assumption, even more conjectural, was that women with their life-giving powers, could they be made to understand the desperateness of our ecological plight, would never permit the world to gutter to a smoggy and ignoble end. Not for this do we bear children!

The ideas kept nagging at me, but when it actually came to putting pen to paper I procrastinated — successfully-knowing that I was afraid that all the ideas that bubbled about so satisfyingly in my head might fade to little or nothing on the impersonal medium of the blank page.

Help came unexpectedly via Gregory Bateson. According to an article in *Harper's*, Bateson is reported to have said, "My complaint with the kids I teach nowadays — graduate students and such — is that they don't really believe anything enough to get the tension between the data and the hypothesis. What they may find out doesn't really impact on theory, because they don't have any theory they're willing to hold tight enough to get an impact. It slides all the time." I understood this to mean a certain stick-to-it-iveness in riding the current of one's thoughts without being sure of the destination or endpoint. This is what I decided to do.

On the one hand we have slightly more than half of humanity operating well below its potential. On the other, we have a world threatening collapse and disaster for much or all of humanity. What I hope to do in this paper is to describe my own exploration of these two ideas and the tension of their relation to each other.

I begin with the assumption that there is some agreement on the status of women, although my own path toward liberation has been hindered by the fact that I was, for a long time, either too thick-skinned or too dim-witted to realize fully the limitations placed on women by virtue of their sex. I am, perhaps, a case of reverse programming. As a child, I had no brothers to envy either their penises or the greater favours bestowed on them in the way of freedom or education. In our family, there was a great deal of laughter shared between the women and the children. We told rambling family tales and talked endlessly as we worked in the kitchen. The men, my father or my uncle, came home from the office, almost always tired, sometimes irritable. Occasionally they joined us in the kitchen. More often they did not. From time to time I thought, but perhaps I was wrong, that there was an aura of wistfulness emanating from behind the newspaper. They would have liked to have joined in our laughter

but were not sure how. Whatever they felt, my childhood memories of home are that it was for all of us a refuge, with the kitchen at the heart, cheerful and warm. Women, I understood, stayed and tended this heart and men went off to offices that had ugly desks and chairs and a few interesting machines. This to me was WORK, the OFFICE. It had much the same significance to me as is attached to Mr. Banks' work in *Mary Poppins*. "Now the City was a place where Mr. Banks went every day – except Sundays, of course, and Bank Holidays – and while he was there he sat on a large chair in front of a large desk and made money. All day long he worked, cutting out pennies and shillings, and half-crowns and three-penny bits. And he brought them home with him in his little black bag."

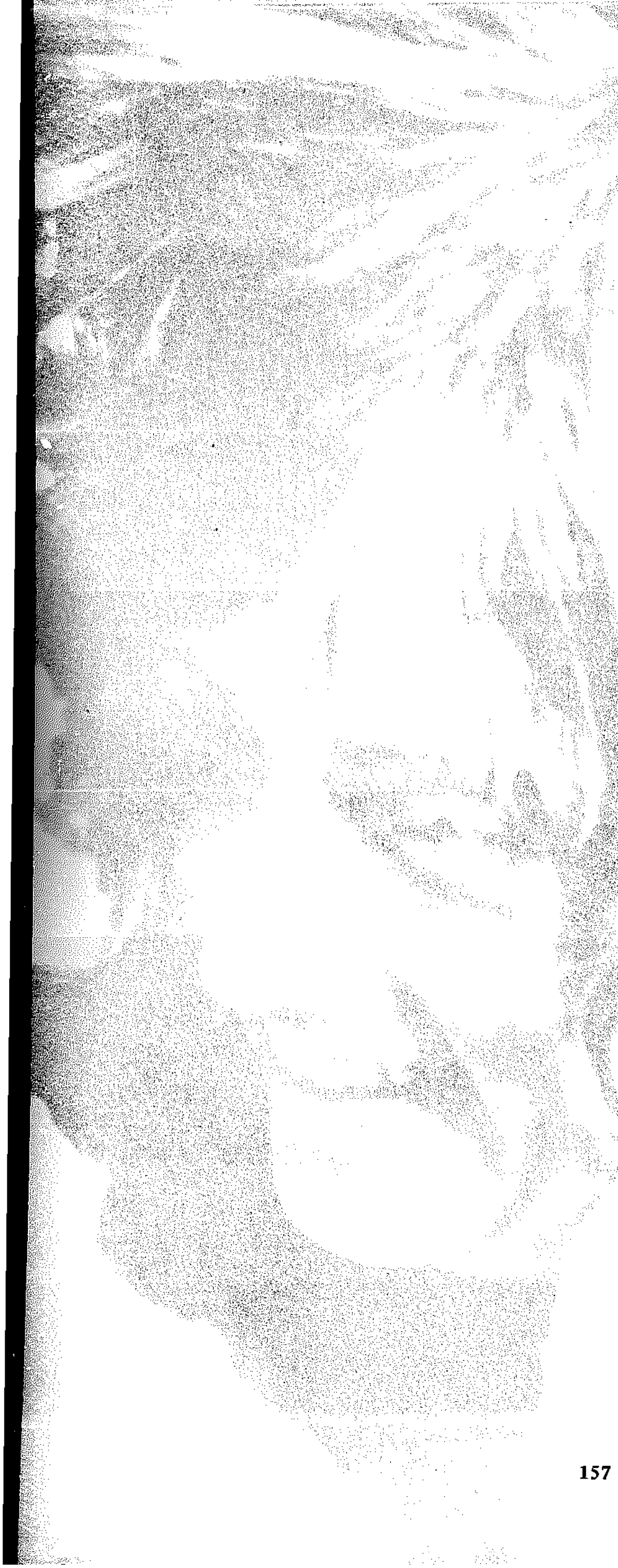
And my feelings as a child and on through my teens – even now – were that rather than face work that seemed so dull and unrewarding, yet so tiring, I would choose the bright kitchen even if it meant attendant chores of housekeeping and laundry. The smells of baking, the companionship and the chatter seemed more tangible and capable of producing results that were directly and observably useful.

Then through my childhood echoed the guns of World War II. The radio was an oracle, around which the grown-ups hovered anxiously. It brought news of air raids, bombings, invasions. The name my sister and I gave to evil and fear that is so often nameless for children was Hitler. He used to visit us in the night. He lived in a drawer in Barbie's dresser and curved around the top of my mirror. Stories of children whose fathers would never come home were whispered among the adults and we overheard them with dread. War meant, never drums and trumpets and brass buttons and dashing young soldiers, but destruction, fear, loss, death – valiant young men lost over Germany. And in my mind, then, and perhaps still, war joined dreary offices in my comprehension of the world of men. So it took me an awfully long time to realize that I was barred from this world because, in the main, I didn't want any part of it.

This has been my own peculiarity. I do entirely accept the fact that women have been dominated and exploited far beyond recorded history.

WHY?

The why is very important to me. I have never felt inferior to men. I am not. We are not, as a sex,

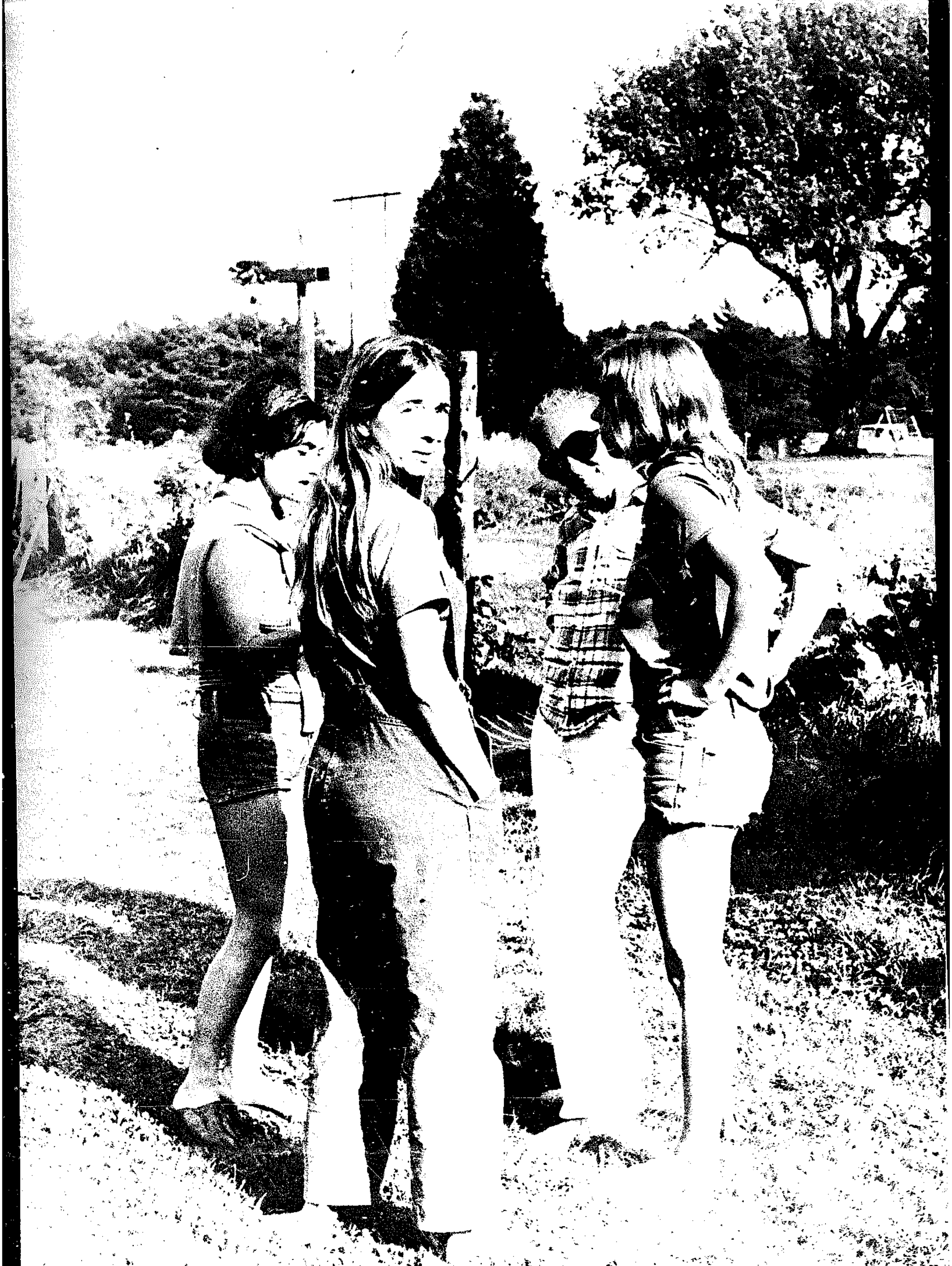


inferior. Different yes, but not inferior. Why then, have we not painted sistine chapels, erected monuments and cathedrals, moved millions with our poems and our symphonies and touched the stars with our instruments? Why have we never made a discernible impact on human affairs? Why for one Madam Curie are there hundreds of men of greater fame? Why can we point so readily to Joan of Arc, Florence Nightingale and all the well-worn heroines as exceptions to the rule of our commonplace lot? The argument that child-bearing and child-rearing are at once profoundly creative and exhausting is valid but insufficient. Let's go on with the whys.

I found what has been for me the most subtle yet satisfying answer from Simone de Beauvoir. In the introduction to *The Second Sex*, she refers to "the idea of the Other" which is as primordial as consciousness itself. She goes on to say, "In the most primitive societies, in the most ancient mythologies one finds the expression of a duality — that of Self and Other." This duality did not refer solely to the division of the sexes, but was basic to concepts of Sun and Moon, Day and Night, Good and Evil, Lucky and Unlucky. Otherness is a fundamental aspect of human thought. No individual or group becomes aware of itself, or sets itself up as the One without setting up the Other against itself. Hegel stated that in every consciousness there is a fundamental hostility toward every other consciousness. In other words, the subject can be posed only in being opposed to the other, the inessential — the object.

This seems to me to be basically true, yet men are as Other to us as we are to them. We still have not answered the question as to why, in the mists of pre-recorded time did we, as women, become Object, the Other of the human species, while men became Subject, Absolute, Man, Mankind. As de Beauvoir says, "There has come to be an absolute human type and it is masculine." Aristotle stated that the female is a female by virtue of a certain lack of qualities. "We should," he said, "regard the female nature as afflicted with a natural defectiveness." And de Beauvoir describes her own experience. "In the midst of an abstract discussion it is vexing to hear a man say 'You think thus and so because you are a women', but I know my only defense is to reply, 'I think thus and so because it is true', thereby removing my subjective self from the argument. It would be out of the question to reply, 'and you think the contrary because you are a man', for it is understood that the fact of being a man is no peculiarity."

In searching for an answer as to why duality came to mean inequality and inferiority for women, I think we must accept that, until the present, biology largely has been destiny. Women are, with the odd exception, less strong physically than men. In primitive societies, this handicap was reinforced by the debilitating effects of menstruation, pregnancy and child-bearing. These,



while vital to the survival of the species or group are natural functions, providing little affirmation of individual existence as such. They happen, as we know only too well, in spite of ourselves. They also made the woman the logical choice for domestic labours that would have been more stationary and less demanding in strength. The contribution of the male was to support the group, which meant as far as we can tell, hunting. In doing so, he faced a challenge outside or beyond himself. When he was victorious, he found a new sense of self-realization and identity. So that, whereas it has been the lot of the female to repeat life in order that it may continue, the male in his activities came to experience transcendence and in doing so created values. In de Beauvoir's words, "Man's design is not to repeat himself in time — it is to take hold of the instant and mold the future. It is male activity that in creating values has made of existence itself a value; this activity has prevailed over the confused forces of life; it has subdued Nature and Woman." The essence of the male, then, has come to mean transcendence, while the essence of the female, permanently embedded in the natural world, has come to mean immanence. Here for me are the glimmerings of a comprehensible explanation as to how duality and difference expanded to mean subjugation. From here it is easy to construct a theory — or a variety of them. Another of de Beauvoir's important supportive points of the above theory is that as the female became aware of her inferior status she tended toward complicity. It is easy, even pleasant, to be cared for and thereby avoid the struggle of undertaking an authentic existence. Then the way to passive acceptance of dependence is straight.

The order of things thus established is speculated to have endured for the nomadic period and strengthened with the beginnings of agriculture. With land to work and settle, more value was placed on children as workers and heirs. Woman's fecundity was likened to the earth itself and revered. Still woman remained Other, often feared as she was worshipped, but as her power was mysterious — beyond human control — she remained outside the realm of human affairs. Levi-Strauss has said that "Public or simply social authority has always belonged to men." So, even when the great goddesses Ishtar, Astarte and Isis ruled lesser male deities, women never set up a group on their own account against the male grouping. They have never entered into a direct and autonomous relation with men. When men learned to fashion tools, they were able further to transcend experience and the male principle was more firmly entrenched. Man, the tool-maker, could begin to dominate and even-

MUTATION

Brand-new
one katydid adds
its leaf to a branch
unfolds its green deception
and floors its neighbors with its find:
a perfect dewdrop
etched on each wing
illusory and dry
as a dead painter's
canvas.
Framed.
Sure to be famous

as peacocks
lungfish
or the child
emerging from our dark yard
holding a lightning bug
to feel the explosion
in her hand.

—Meredith Fuller-Luyton

tually control Nature. Needless to add, his awe of woman, at the same time, was correspondingly lessened, "and the great god Pan begins to fade when the first hammer blows resound and the reign of man begins."

While we are still immersed in prehistory and in the solely speculative stage of the evolution of the race, I should like to introduce the subject of one of my favorite books. It was written by Elaine Morgan and is called *The Descent of Woman.* It could be described as a rerun of some of the evolutionary tours of the last decade or so, in which social historians have cast an appalled look at the present human situation and fumbled for an explanation. Like Desmond Morris and Robert Ardrey, she returns us to the trees and tries to trace it all from there.

I shall try to resist too much of a detour which, although fascinating, is off the main track. No woman can help but be drawn to such a statement as, "The longer I went on reading his (i. e., Men's) books about himself, the more I longed to find a volume that would read: When the first ancestor of the human race descended from the trees, she had not yet developed the mighty brain that was to distinguish her from all other species." As Ms. Morgan goes on to say, "Of course, she was no more the first ancestor than he was — but she was no less either."

Her theories on human evolution are based on those of Sir Alister Hardy F. R. S. and very briefly go like this. There lived long ago, back in the mild Miocene, a generalized vegetarian, prehominid, hairy ape. She got her food from the trees and slept in their branches. When the scorching heat of the Pliocene reduced the forests, she was forced to try life on the ground, and it is here that Ms. Morgan inserts her own chapter in our evolutionary history. A four-legged vegetarian was ill-adapted to life on an open plain. The generally accepted theory goes that in this crisis, our ape rose to its feet the better to flee an attacker or pursue a quarry, thereby freeing a foreleg for carrying a weapon, which it rapidly learned to aim and to hurl with efficiency at passing game. Thus we learned to survive on the treeless savannah.

Ms. Morgan would not dispute that this indeed probably did happen, but not without an intermediate phase. It is likely that the dwindling forests remained longest along riverbeds and that our forebears remained as long as possible in their arboreal homes. Their reluctant descent was most likely to have been in the vicinity of a riverbed which would have led eventually to the sea. And so, between our final descent from the trees and the millennia on the savannah which gave rise to man-the-hunter, woman-the-subordinate and all that that entails, she postulates ten million or so years — on the beach. I guess, for readers of T. S. Eliot or Neville Shute, there is a grim bit of irony here, but anyone who has spent as many shamelessly idle and happy summer days on the beach with her children as I have is at once drawn to the idea. Ms. Morgan offers considerable evidence in support of her thesis, including a long list of physical features from our hairless hides to our layer of subcutaneous fat. To go on would involve wandering well off the main topic. The point of this diversion has been to offer the happy thought that there may have been a ten million or so year period when humanity lived on the beaches, inlets and lagoons, and women, having less need for physical protection and some access to their own food, enjoyed something of a reprieve from domination and subordination.

I'm not sure how much any of this matters now. No matter how or why, we have for all history been "other", "object", and "secondary." All that is beginning to change now. Not fast enough or far-reaching enough, but with an increasing momentum and, in comparison to the ages of oppression, with breath-taking speed, a revolution in feminine consciousness is taking place.

Of primary importance to me is the question of the direction of change. Elaine Morgan deals with the issue of what women want with typical largesse. "Freud, toward the end of his life," she says, "bewailed the fact that even after spending years trying to pinpoint it, he had never succeeded in finding

out 'what women want.' " She goes on "It's a rather silly question. If anyone had assembled a string of names of well-known human beings — say, Albert Schweitzer, Attila the Hun, Casanova, Gandhi, Al Capone, Einstein, Henry Ford, Peter the Hermit, Gauguin, Elvis Presley — and asked him to encapsulate an answer to the question, "What do men want?", he would not have found that too easy, either. Any answer that he came up with that holds true for that list would be so abstract and general that it would also hold true for all women.

"But many people have a subconscious idea that women are an altogether less complex species, more like, shall we say, rhododendrons, or beans, so that somewhere just around the corner is a simple answer on the lines of 'they need plenty of phosphates', and that once this secret has been discovered, life will be simpler. Women can be given what they want and they will then keep quiet, thus enabling the time and attention of real (i. e., male) people to be devoted to the important and difficult business of conducting their relations with other real people."

The answer may not be phosphates but the idea of women as other with different parameters for their lives than men seems almost universal.

I want to turn later to the changes that must come about and the demands we must make if we are to achieve equality. Fundamental to our liberation as a sex, and beyond that, to human liberation is that we begin to exist for ourselves — to cease to be other and to become, for ourselves, subject. Perhaps this is self-evident, but it is still not the norm of popular consciousness or myth. In my childhood, the old maid was pitied, the object of mild derision. Not so the bachelor. He chose freely. When I was in university, it was felt to be a humiliation not to be engaged by graduation. The chorus of a popular song which went:

"A man without a woman
Is like a rag upon the sand.
There's only one thing worse in the universe
And that's a woman without a man."

seemed to reflect a certain tacit understanding that was prevalent at least then in society. I know that many women, mostly younger than I, are far less hampered by such vestigial assumptions, but they haunt us as a sex yet — one look at the popular culture from television to magazines tells you that to live at all you must please a man.

Our goal for every woman must be a sense of completion; of destiny as a person, not as wife, mother or mistress, but as herself first, all other roles being secondary. This, of necessity, would include liberation from the feelings of guilt and inadequacy admitted or concealed that have been chronic to our history. With an end to our age-old crisis in confidence, we might well be ready for anything.

I am not naive enough to think that our freedom will be given us. We must take it. That is what the lib movement is all about. As de Beauvoir says, "the fact is that oppressors cannot be expected to make a move of gratuitous generosity." But I have every confidence that we are indeed coming closer to the self-realization we seek and that is why I want to turn now to the subject of women in relation to society, by which I mean western technological society, and hesitate for long enough to scan the horizon before deciding where to go from here.

In deliberating along a similar vein, many years ago Virginia Woolf in *Three Guineas* wrote "We are here on the bridge to ask ourselves certain questions and they are very important questions and we have very little time in which to answer them. The questions we have to ask and answer about that procession during this moment of transition are so important that they may well change the lives of all men and women forever. For we have to ask ourselves here and now, do we wish to join that procession or don't we? On what terms shall we join that procession? Above all where is it taking us, the procession of educated men?"

Perhaps we should enlarge the meaning of "procession of educated men" to that of western technological society (I hesitate to call it civilization) and take a critical look at it before answering that question.

The liberation of women is beginning, but it is, as yet, embryonic. Apart from political, social and economic inequalities, there remain the industries whose lives depend upon keeping woman as object. Where would they be if we ceased to deodorize our bodies, brighten our teeth, soften our hands, give body to our hair, remove inches from our hips and thighs and add glow to our lips? And what if we didn't spray/clean everything from our carpets to our hair? Perhaps most maddening are the slick Madison Avenue-types who co-opt the language of the movement and give us bra-less bra and "natural" make-up.

An article by John Kenneth Galbraith in a recent issue of *MS.* for me added an interesting dimension to our economic exploitation. He states that the decisive contribution of women in the developed industrial society is straightforward. "It is overwhelmingly to facilitate a continuing and more or less unlimited increase in consumption." A crowning insult really. For uninformed and uneducated women to be manipulated unwittingly is one thing. Surely the so-called educated woman could show less complicity. Galbraith continues "the lifework of such women is still, in the main, husband, home and family. A high income family sets the consumption patterns to which others aspire. That such families be supplied with intelligent, well-educated women capable of exceptional managerial competence is important, not only for the consumption involved, but also for its demonstration effect on the entire economy, making possible its infinite expansion."

All this offers a most unwelcome aspect to the view from the bridge. Looking beyond the consumerism of our own society we are confronted with a world threatened by terrifying dark shadows; over-population, famine, a heedless scramble for the last of the world's finite energy sources, the threat of war, possibly nuclear, from countries who have suffered our affluence too long, and the development of nuclear plants with the age-long radioactive wastes they will produce. Howard Odum, the well-known ecologist, postulates the return of chronic disease and epidemic as modern medicine based largely upon cheap, readily available fuels fails us. At best then, the view affords a future that is bleak, at worst, utterly hopeless. From our vantage point on the bridge that is beginning to crack beneath us, asking again the question, do we wish to join the procession of Armageddon-bound western technocracy? The answer can be, I think, only if we are highly resolved to try to alter its course.

This seems to lead to another question, equally difficult. Should we make the decision to join the mainstream of human affairs, is there any reason to believe that we could effect any change for the better? De Beauvoir says, "in truth, women have never set up female values in opposition to male values." And further, that "women have never as a sex sought to play a historic role." If this is the case then it would seem that the triumph of scientific rationalism could be attributed to the dominance of male thinking. So that, with regard to the question as to whether women might conceivably alter the path we are on, there is, as yet, no way of knowing. One wonders, though, if man with his transcendent quality has dominated nature and brought us to this point in history, is it possible that the immanental essence of women, rooted more firmly in the processes of nature, might find a way to shape a better world? Could we be more capable of a better understanding of what might be called human ecology?

We are about to reach the point where the tension between the subjects of women and ecology will be felt, but, prior to that, it would probably be useful to look very briefly at the concept of ecology *per se*. A common understanding of ecology is to consider that it is the study of the natural web of life. Paul Shepard, in his introduction to *"The Subversive Science, Essays Toward an Ecology of Man"* says, "The image of the web is too meagre and simple for the reality. A web is flat and finished and has the mortal frailty of the individual spider. Although elastic, it has insufficient depth. Ecology deals with organisms in an environment and with the processes that link organism and place. It must be a scope and a way of seeing." He goes on to say (and the use of the word man for all of us is his, not mine), "Man is in the world and his ecology is the nature of that inness. He is in the world as in a room, and in transcience, as in the belly of a tiger or in love. What does he do there in nature and what does nature do in him?" And he concludes, "affirmation of its own organic essence will be the ultimate test of the human mind."

This is the point at which the tenuous bridge between the subjects begins to suggest itself. Is it possible that the female mind might have less difficulty in making such an affirmation – in seeing through the glass a little less darkly? Since time began, our bodies have been rhythmically bonded to the moon. Unlike men, who at times have felt that they have transcended Nature, we are bound in her. Perhaps the time has come when women, by virtue of their immanence or "inness", albeit involuntary, will learn to listen to and trust themselves, and from there accept their responsibility in sharing in the guiding of the course of human history.

One thing I am very sure of is that the only way we can hope to rise to such a role is as liberated and self-actualized human beings. Diffident, inadequate or apologetic, no one will listen to us. We won't even listen to each other. This may well be the biggest hurdle – and we don't have much time.

Before formulating tentative first steps, it might be useful to inquire as to whether there is hope that even as free women we can hope to improve the world situation. It might be noted that at least three states which have granted equal or close to equal rights to women have not been known for their beneficent ways. These were Ancient Sparta, Nazi Germany and Soviet Russia. With women in many influential and professional fields, these states have been hostile, aggressive and warlike. Yet, for all their apparent equality in these states, women lived or are living in a masculine society, in a masculine-run state, and have adopted or been instilled with masculine values. From this we cannot judge conclusively that women cannot or will not make an impact upon the society in which they live. I find that I have assumed, rather smugly, in regarding the question of women's increased participation that it will, of course, be for the better. This, no doubt, stems from echoes of such outworn clichés as "behind every great man....." and "the hand that rocks the cradle.....", etc. Beyond a vicarious glow of self satisfaction, is there any basis to foresee potential improvement?

Lionel Tiger in *"Men in Groups"* states that the real, universal and indisputable difference between cohorts of males and groups of females is that the males are more aggressive and that this is true, in the main, for most species, particularly the primates. He goes on to say that male bonding is one of the functions of aggression. No doubt, a good deal of the variance in male/female levels of aggression can be

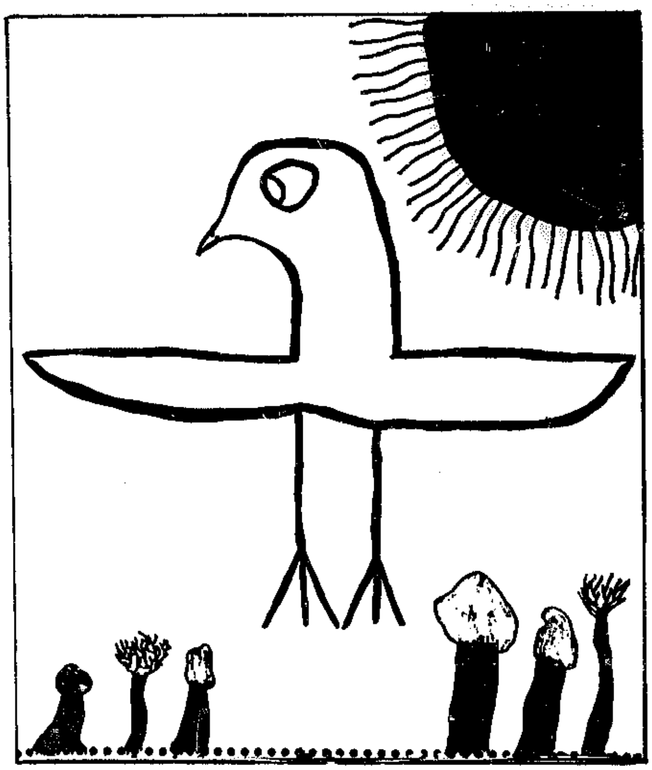
accounted for by conditioning. One of my close friends gives a well-attended course in assertive training for women, and it would be hard to accuse someone of being very aggressive if they are having to be encouraged to assert themselves. Elaine Morgan reports that "if you inject a female monkey with male hormone she will behave more aggressively; and if you inject a male monkey with female hormone he will behave less aggressively." She goes on to say that "anthropologists studying the cultures of different tribes have found almost no occupation which isn't somewhere or another considered to be 'women's work', and somewhere else considered to be 'men's work' whether it's pottery, or weaving, or agriculture, or cooking, or even caring for the children. The one exception is killing people. No one has found a primitive tribe where women are the warriors. War, like aggression, is a function of male bonding." Certainly, in the main, this has remained true, in spite of legends of Amazons and gory tales from the French Revolution and elsewhere, not to mention elements in the feminist movement who would have us demand equal participation in everything, however insane or immoral. If, then, aggression is an attribute found in larger doses in males and the stuff of male bonding, and these are surely two powerful elements current in the management of the business of the world, then it seems possible to postulate, at least, that if women were to have their say there might be less violence, even less war, and that we might be less inclined to wreak havoc upon the living world around us. This remains in the realm of hypothesis.

Murray Bookchin has written that "the very essence of the matricentric world is that it vitiates rule as such." He maintains that polarities cannot be found between patriarchy and matriarchy as two differing forms of rule; the comparison must be between rule and anarchy, between the presence and absence of domination. A world with less of the hierarchy that seems inherent to male society would be a far cry from the very structured one we now inhabit.

In the realm of the concrete, the point has come for us to ask, as John Platt did on contemplating the plight of the world several years ago, "what we must do." In this regard, it seems our approach should be two-pronged. We must keep in mind what must be done to improve the lot of women in particular and humanity in general within the present. At the same time, we must be creating and evolving and learning to make a transition to ways of living that are at one and not at odds with all other life — towards the day when we shall better understand how, in Gary Snyder's phrase, "to live lightly on the earth."

Within the context of the present and perhaps as a precondition to any fundamental social change, we must continue and intensify the struggle for liberation

Photo by Fritz Goro



Sven Atema

and self-actualization for women. I don't mean that this is important only for women. There can be no understanding of ecology, with its underlying wholistic conceptual basis, without people who have begun the search for heightened consciousness and self-awareness. We must find ways of reaching women trapped in their domestic and social rounds, often unaware of their exploitation. This does not imply that they will at once throw off their fetters and abandon home and children, as Germaine Greer has suggested, but that they may begin to know better who they are and to develop a full sense of their own identity. This is not easy to do. So many women are resistant, even hostile, to the idea of liberation. They are, of course, frightened. In these cases, I think the magazine *MS.* is doing an inestimable amount of good with its non-threatening, low-key approach. I think that it has been, so far, the most successful feminist vehicle for reaching more women than any other. After such an introduction, many women become ready for consciousness-raising which can be followed by a more active attitude in shaping the form and directions their lives will take. Subsequent steps within the social framework are best determined by the individual community – another instance of thinking in terms of the microcosm. In my area, as women emerged from consciousness-raising groups several years ago, there was a glaring need for a day care center and for some form of family planning and counselling. Both have been established since. In other areas, friends of mine have organized community gardens, craft co-ops, investigations of pollution practices, and environmental information centers.

Women interested in careers have a decisive role to play. There is so much useful work to be done and yet, in a society so permeated with false values, it is easy to be misled. We must constantly remind ourselves that the values of the society around us are male values and that we must guard against being tempted to win male recognition and approval. I saw a distressing letter to an editor a while ago. A girl wrote in, complaining about the fact that there had been no women in a certain beer commercial on television. In the same vein, we must refrain from basking in a reflected glow in the accomplishment of women who achieve the pinnacle on Madison Avenue. As the old saw goes, they are part of the problem. It was a blow to me when an acquaintance, a good student in biology, took to selling real estate. Such employment only furthers the status quo and offers nothing that would initiate the process of change.

But we do need doctors. I do not mean to launch into horror stories of indignities suffered by women at the hands of male doctors, but they are countless. The same applies to lawyers. The need for women helping women in law is immediate. The list of fields where the demand is equally urgent is long. We must have women in psychiatry and psychology, in politics and government, in media and communication and in education. With sensitive teachers, little girls could be spared a great deal of confusion and pain in coming to know themselves. In addition to the service that they render directly, professional women provide models for others, particularly children, something that has long been needed. We need thousands more Bella Abzugs and Shirley Chisholms. The same can be said for the arts. The example of an independent – at least spiritually – artist struggling for her own fulfillment is one of the most compelling. We could go on and on. The essential point is that times are far too critical for us not to give our choices of career or occupation the most painstaking evaluation.

One idea that would seem well worth exploring for women with some free time would be the formation of some kind of consumer vigilante groups. These could be useful in a variety of ways, not the least being educational. I find, as a woman, that it is devastatingly insulting to have an economy structured around the fact that I am malleable and stupid enough to be manipulated into buying whatever I am told, in order to keep a small cog in the economic machine turning. Secondly, the machine itself is endlessly wasteful, unaesthetic, immoral and unecological. Perhaps study and research groups could be formed which could, among other things, separate

the wheat from the chaff as far as useful and totally superfluous or actually harmful products go. This could be applied to food, cosmetics, cleaning products, appliances and beyond. Based on such studies, committees to establish information services for the public could be set up or similar existing groups expanded. Conceivably this could lead to strong pressure groups which, armed with the threat of boycott, could begin to have some influence. Hopefully, there would be eventually congressional lobbies to voice opinions other than those of large corporations and manufacturing concerns. As women, we have few weapons in the struggle for a less destructive society. In this country, we do have buying power. It seems preposterous not to use it. To be cautioned that such actions could threaten the economy is rather like telling someone who is dying not to do something because it is bad for him.

I have only touched on practical, tangible steps, conceivable in our society as we know it at the present. There are our other occupations, which, while not political, are in themselves most fulfilling and well-adapted to both the needs and ground-rules of a more ecologically-oriented society. Within this context, motherhood seems well worth a second look. It is worth re-evaluating because it is rapidly becoming, for the first time in human history, largely voluntary. Reliable contraception, giving women the freedom to choose whether or not they will have children, has been called by a Jungian analyst, Irene Claremont de Castillejo, the "second apple." Given woman by technological

man, it offers hitherto undreamed-of possibilities of personal choice in shaping one's life. While not robbing us of our immanence, it offers the freedom that has until now been the prerogative of the male. Such a breakthrough at a time of dangerous over-population might be viewed as little short of providential.

Few occupations or roles, call it what you will, have raised as much ire in recent years as that of motherhood. It is held in the main in low regard in the feminist movement. In this case, Simone de Beauvoir seems typical. She begins her chapter entitled "The Mother" in "*The Second Sex*" with a long discussion of abortion. This hardly seems the most positive initial approach. Irene Claremont de Castillejo presents another pole of opinion when she says, "The woman with a newborn baby by a man she loves is as nearly in tune with nature as she ever can be." My favourite symbol for the feeling having children has had for me is the photograph of a black woman in "*The Family of Man.*" She stands lean and quiet with her children held against her. The caption reads "She is a tree of life to them." Given a society not so completely out of touch with natural rhythms, the role of a mother has too much love and joy and fierce pride to be the draining, demoralizing, second-rate occupation that it is currently considered to be.

Whatever one's inclination, it is cheering to know that we have at last come to the stage where those who want to have children may, and those who do not wish to need not; although, for all of us the spectre of over-population is peering over our shoulders. Even though women who have children do so voluntarily, it does not mean that society should not take greater responsibility for its young. Women should be independent economically. Perhaps this suggests some sort of family allowance during the time she has infants and very small children. There is, in addition, still a wide-spread need for well-run day care centers. Communities in general should take a

Photo by Fritz Goro

greater interest and joy in their children. And men should spend more time with them. It would be good for both of them.

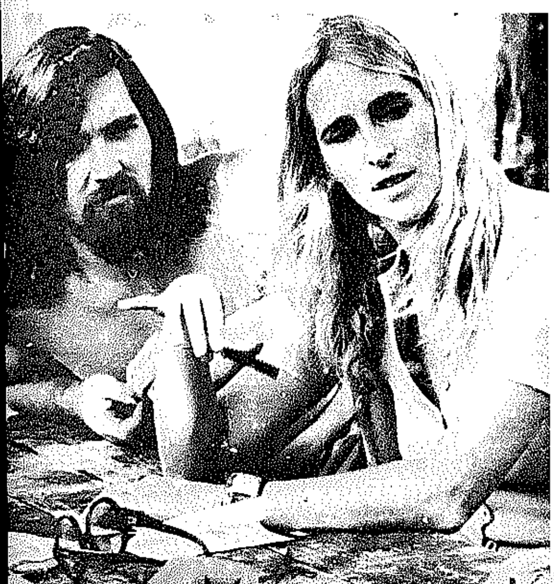
As for women who decide against having children, and many splendid women have, the field that is most in need of improvements is that of reliable, safe contraception. This burden must be shared more broadly by men. Perhaps there could be a male pill. Certainly a reversible vasectomy shouldn't be beyond neurosurgery. It would be cheering to see some of the stigma clouding the idea of vasectomy dissipate in cases of men who have had their children or do not plan to have them. Pursuing the subject of reproduction in a slightly different direction, there is one radical feminist idea to which I am unalterably opposed, and it is that of test tube babies. Besides being totally unecological, the concept with its science-fiction overtones is aberrant and potentially dangerous.

Elaine Morgan characteristically looks on the bright side of the whole child-bearing issue. Women who do not want to have children and would therefore likely have made indifferent mothers will not, thereby selecting themselves out. Those who then choose to raise children might be expected to make a better job of it. They might be inclined to be more selective in choosing father material as well. Ms. Morgan postulates that this for the first time could give woman "her finger on the genetic trigger." What will happen we cannot foresee, but Ms. Morgan expresses the hope that, in considering men to father their children, "extreme manifestations of the behaviour patterns of dominance and aggression will be evolutionarily at a discount."

Aside from, and often harmonious with, child-rearing, there exists the possibility of a host of earth-kindly skills. Some of these can provide for one's needs directly, others used for a source of income. Either way they are good for the soul. Gardening is high on this list. Apart from its obvious usefulness, it is endlessly interesting and rewarding. It is, perhaps, one of the most direct ways to study and form a bond with the earth, establishing a relationship that is profound, instructive, changing and changeless. Much of the drudgery and hard work, and admittedly it is hard work, can be relieved by working with friends — or is it that gardening together makes people friends? Pottery, carpentry, spinning, weaving, and making hand-crafted jewelry are other types of work that are at once satisfying and non-destructive. The study of herbal medicine, nutrition, and the care of animals are rewarding in themselves and engender a heightened awareness of the environment.

One possibility for exploring human potentialities, both male and female, is within the context of the small group. Countless communities, communes, coops and guilds have been and are being formed, perhaps to replace a sense of place and community

Photos by Fritz Goro



that has been lost in the impersonal mobility of society at large. People in them may be bound by a common idealism, a need to share their work or craft, or more simply a desire for companionship. Generally, they offer an accepting framework for personal change and transition. One such group, having a primarily ecological orientation, is the one with which I work, called New Alchemy.

It has been through working with New Alchemy that my understanding of ecology has moved from the theoretical toward some inkling of how the world works, in a biological sense. The philosophy behind the work of the group is wholistic, yet small-scale – to see only a small part of the world perhaps, but to view it in the complexity of its entirety. When one's primary sources of energy are the sun and wind, they play a greater part in one's life and one's awareness of them is markedly increased. To become involved in process develops a sense of stewardship, of interdependence between oneself and the land and its creatures, and wind and sun and water. The most concrete embodiment of our work that I can give is the greenhouse-aquaculture complex we call the Ark. Within the same structure, fish for food are grown in pools flanked by beds for the production of vegetables. The sun and the wind are the exclusive sources of energy and are transformed through biological processes into food. Living space will be the next concept to be incorporated. The fish feed mainly on algae which grows with them in the pond, and pond water irrigates and fertilizes the vegetable beds. It is a small, largely self-contained world in itself, and one cannot work with it without becoming a part of it.

When we first began working together as a group, there was considerable resentment on the part of the women over the housekeeping and more domestic work which necessarily accompanies almost every effort. When we articulated our feelings, we discovered in our case, and this may not be in any way typical, that our domestic orientation had been largely the result of long-ingrained habits on our part as well as that of the men. As the men came to understand how we felt, the transition to sharing equally the work that we found to be most oppressive psychically was immediate. Group clean-ups usually resemble a brawl more closely than housework, but the results are adequate and the karma fine. Our other work is still somewhat divided along traditional sex lines. We don't have with us, at the moment, women with mechanical aptitude or engineering training, so our windmills and energy systems are largely in the hands of the men. But women do carpentry and rototilling and heavy garden work and carry their share of the physical burden. We still do more of the cooking, but the men do their share and like it. The kitchen staff is always bisexual and both sexes clean up.

The major advantage to working or living in something akin to a small group is the experience, being shared alike by both sexes, hopefully with minimal antagonism, of outgrowing and casting off sexist conditioning, and of learning that neither sex is bound by the limitations or inhibitions of traditional roles. This aff[illegible]s unusually free and affectionate environment where immanental feminine qualities and the transcendent aspects of the male can grow toward each other and toward a more androgynous type of mind. Such a possibility, like the alchemists' gold or the holy grail, has long been the object of human longing.

In 1928 Virginia Woolf told a story based on her fantasy of a sister of Shakespeare who apparently died very young and never wrote a word. Virginia Woolf goes on to say, "Now my belief is that this poet who never wrote a word and was buried at the crossroads still lives. She lives in you and in me, and in many other women who are not here tonight, for they are washing up the dishes and putting the children to bed. But she lives; for great poets do not die; they are continuing presences; they need only the opportunity to walk among us in the flesh. This opportunity, as I think, is now coming within your

power to give her. For my belief is that if we live another century or so – I am talking of the common life which is the real life and not of the little separate lives which we live as individuals; if we have the habit of freedom and the courage to write exactly what we think; if we escape a little from the common sitting room and see human beings not always in their relation to each other but in relation to reality; and the sky, too, and the trees or whatever it may be in themselves; if we face the fact, for it is a fact, that there is no arm to cling to, but that we go alone and that our relation is to the world of reality and not only to the world of men and women, then the opportunity will come and the dead poet who was Shakespeare's sister will put on the body which she has so often lain down. Drawing her life from the lives of the unknown who were her forerunners, as her brother did before, she will be born. As for her coming without that preparation, without that effort on our part, without that determination that when she is born again she shall find it possible to live and write her poetry, that we cannot expect, for that would be impossible. But I maintain that she would come if we worked for her, and that so to work, even in poverty and obscurity, is worth while."

I find this among the most moving statements of feminism, perhaps the more effective for the fact that it is in the form of a metaphor. With regard to women's hopes for personal fulfillment there is little one can add. But in relation to the potential influence women possess for the possibilities for drastic change in the course of human history, I found an encouraging statement from Irene Claremont de Castillejo. She wrote, "The deeply buried feminine in us whose concern is the unbroken connection of all things is in passionate revolt against the stultifying, life-destroying anonymous machine of the civilization we have built. She is consumed by an inner rage which is buried in a layer of the unconscious often too deep for us to recognize. She becomes destructive of anything and everything, sometimes violently but often by subtle passive obstruction.

"I believe it is often this inner protest which breaks out in neurotic illness in sensitive men as well as women, or turns destructive in places where it was not intended. With more consciousness feminine anger could be harnessed, to a creative end."

The reference to "more consciousness" surely justifies the countless hours so many of us have spent, in these times of rapid transition, in the search for identity and self definition. And surely "the deeply buried feminine in us whose concern is the unbroken connection of all things" is another way of defining feminine immanence and brings us back full circle to the question of our place in nature – to our own organic essence. For it would be a truly bitter irony were we to inherit the world just in time for its death throes. And it would be a poor world without dolphins and butterflies.

I should like to end with a story about women and ecology that took place around New Alchemy's compost pile, which seems a suitably earthy and symbolic place to close. A while ago, a group of us were turning the compost late one Saturday afternoon, an activity that has acquired the status of near ritual. As we shovelled, someone commented on the smell which was at that moment, as I remember, largely vintage cabbage. "Smell", said Hilde, who is our chief gardener and thinks well of compost. "That's the new perfume." To which one of the men, who has a voice which has been described accurately as stentorian tones, thundered, "If this is the new perfume, then women's liberation has gone far enough."

And Hilde said, "It's just beginning."

– Nancy Jack Todd

Photo by Alan Pearlman