11. SOME OTHER ANIMALS FOR URBAN BACKYARDS

Aquaculture

Advantages of Backyard Aquaculture

1. High quality, tasty protein is produced in small increments.

2. Household wastes can be converted to human food. The energy by which this food is produced would have been lost as heat if the wastes were composted.

3. Macronutrients—especially nitrogen and phosphorus, present in fish excretions—as well as many micronutrients are available for garden plants if pond water is used for watering.

4. Aquatic plants can be grown for human and livestock food.

5. Invertebrate food animals can be cultured with wastes in very limited space and used as aquaculture feed or sold at premium prices in the aquarium pet trade.

6. Aquaculture animals are quiet and do not create odors when alive.

7. With good design aquaculture ponds can be very pleasing aesthetically, and can make a significant contribution to the human use of the backyard space.

8. With proper attention fish can be raised which are much less polluted than those sold in the market.

9. Good quality feed plus extreme freshness make for remarkably good flavor in backyard pond fish as compared with those otherwise available in the city.

10. Raising aquatic animals is extremely interesting to some people and is an excellent way to learn biological and ecological principles.

Aquaculture ponds have enjoyed increased attention in recent years and are naively included in numerous fantasies of the integral homestead. The extent to which such systems can contribute to the human diet in an urban situation is actually more restricted than some imagine. The main limiting factor in small-scale aquaculture is the accumulation of toxins and growth-inhibiting wastes and metabolites in the water. Terrestrial husbandry systems largely avoid this problem, because wastes are either carried off in the air, absorbed into the soil, or can be easily removed mechanically. When water quality problems are solved, the next limiting factor is the territorial behavior of the animals raised. Trophic (feeding level) limitations constitute the third factor.

The trophic limitations are a matter of ecosystem dynamics. Only 1 percent of the sun's energy falling upon typical vegetables is generally fixed as tissue under field situations, although higher efficiencies have been achieved with other plants under laboratory conditions (see the earlier discussion of the photosynthetic efficiency rate, page 28). Another way of expressing this rate is to say that 1000 kilocalories of light energy can produce ten kilocalories (2.5 grams) of plant matter. Animals eating those plants (in this instance, fish) can obtain only 10 percent of the energy originally utilized by the plants. And animals eating those animals (humans eating fish) can obtain only 1 percent of the energy originally utilized by the plants.

With these facts at our disposal, some aspects of aquaculture quickly become obvious. For example, one could get the most food energy (calories) out of a given pond area by eating the plants, not animals, grown in it directly. In fact, there are edible species of algae that can be consumed directly, such as *Chlorella* sp. Next best is to raise a plant-eating fish and eat that. The least amount of energy in a pond system would be derived from the raising of carnivorous fish exclusively. Figure 11-1 shows that by the time catfish, the carnivorous fish, are harvested, only 67 kcals per day of food energy would be derived from a daily algae production of 2700 kcal.

Significant losses of usable energy are sustained in the conversion of algae to zooplankton and then zooplankton to catfish.

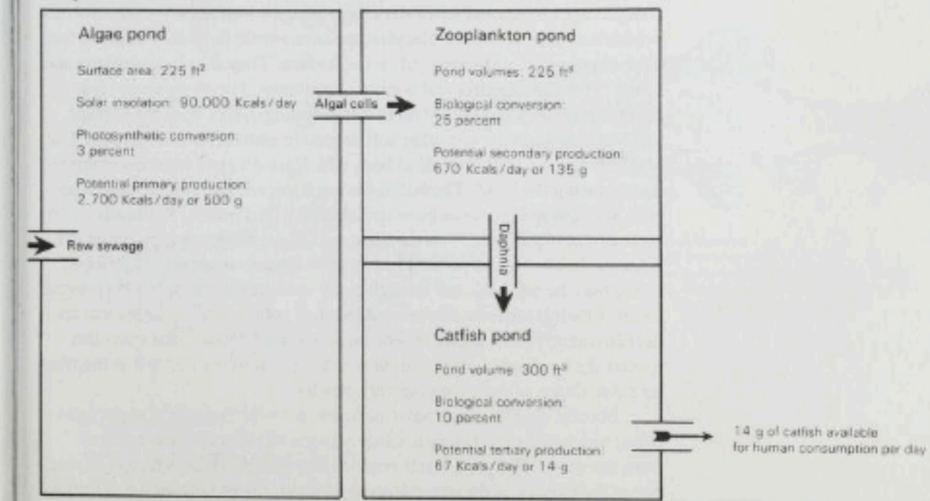
Aquaculture systems, especially backyard ones, do not exactly fit the trophic model in Figure 11-1, however, because feed, kitchen wastes, and weeds from outside the pond can be used as food for the fish, or feed animals can be cultured from them. The backyard fish pond can thus be part of a detritivore system in which a very rich food source (garbage) supports several trophic levels. Here too each level receives 10 percent of the energy of the preceding level.

Nevertheless, number of calories alone is not the only reason for wanting to include animal protein such as fish in the diet. Fish protein is a high-*quality* protein, meaning that the number and balance of amino acids corresponds closely to that required in human nutrition. Most aquaculture animals are smaller than other livestock, which means that they can be conveniently harvested in increments proportional to the daily need for animal protein in the human diet.

Furthermore, fish or crayfish provide variety in the diet, an important factor if the household is subsisting on home-raised vegetables supplemented by grains. Such fare can grow monotonous for some, even when dairy products and eggs are added. And there is a certain fascination in raising aquatic animals, so maintaining an aquaculture system for the purposes of recreation alone and the information one can learn about biological systems should not be discounted. However, the reader is warned that such systems are complex and may take a great deal of attention.

The advantages and disadvantages of maintaining backyard aquaculture systems are summarized in the margins.

Figure 11-1. **Aquacultured Food Chain, Showing Trophic Levels**



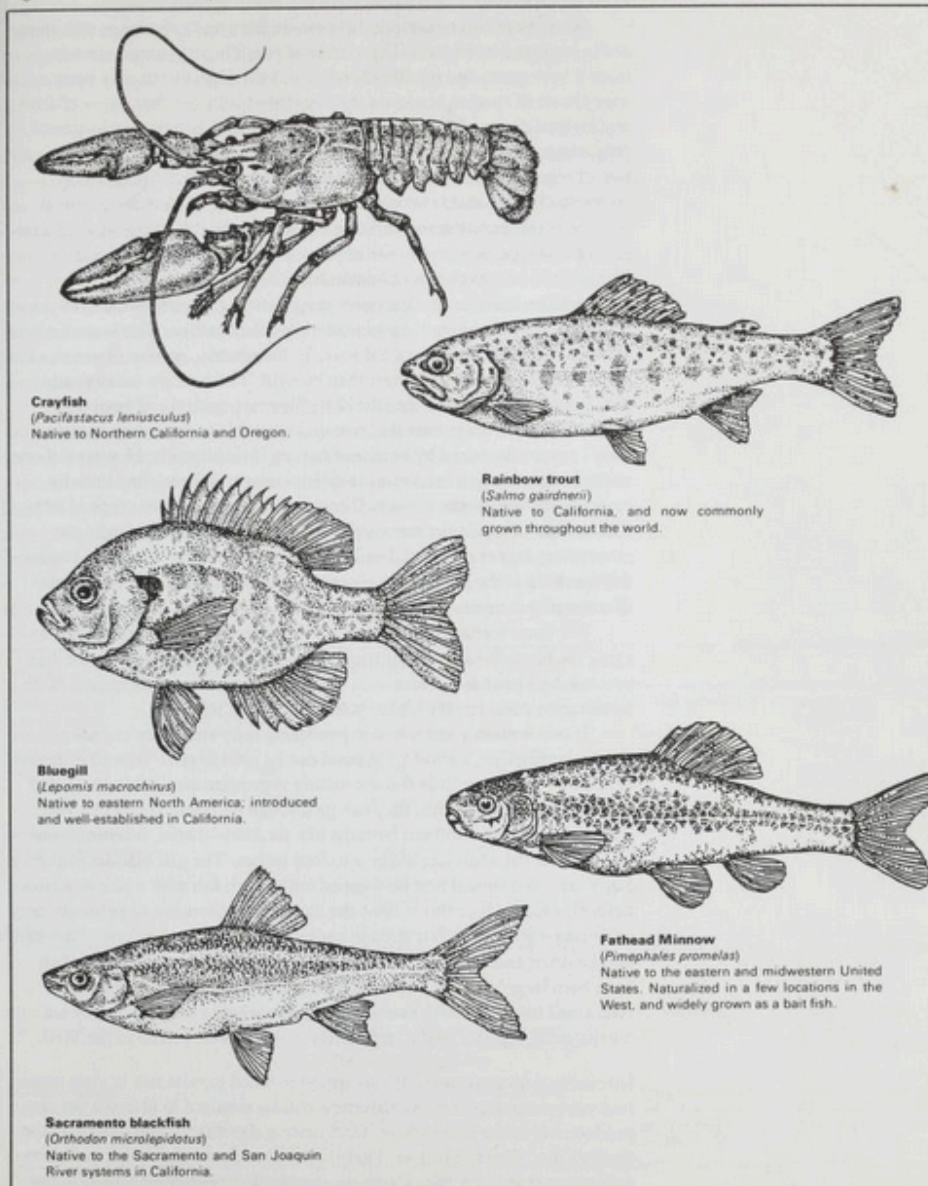
Polyculture in the Pond: Aquaculture has considerable theoretical appeal for those planning to implement the integral house concept. However, actually making a backyard system productive requires extensive knowledge of the biology and behavior of the species raised as well as the artful use of ecological principles in the design of the system. There is no valid cookbook formula for an aquacultural system that will work anywhere. One must always begin by carefully considering the local conditions, designing a system that has the possibility of meeting one's needs, and choosing species that fit that system and each other.

One way to increase the efficiency of backyard fishponds is by using the notion of polyculture skillfully, that is, simulating the development of a natural aquatic community by choosing species whose feeding modes and preferences differ in ways that are complementary. Better use is thus made of food inputs to the pond and, because less food is left over to promote the growth of bacteria and fungi, water quality is improved. At the experimental backyard pond at the Integral Urban House we have found several species combinations which appear to work in this way. For example, in the cooler season we grow *Pacifastacus* crayfish (Figure 11-2) together with rainbow trout. The trout are voracious omnivores that feed at all levels in the water, and the crayfish are bottom scavengers and detritivores. Both species have the same preferred temperature range. The crayfish eat whatever food is missed by the trout as well as coarse plant material that the trout do not eat, and they also consume the trout excrement, which would otherwise accumulate on the bottom. As detritivores, they live in large part on bacteria growing on decayed matter. Both trout and crayfish grow rapidly under these conditions, and water quality is much better than if the trout are raised alone.

In the warm season, from May to October, we have been using a combination of bluegills, black bullhead catfish, and Sacramento blackfish. The bluegills are surface and midwater omnivores, the bullheads are omnivorous bottom scavengers, and the blackfish are omnivorous feeders. The latter feed on the bottom, in midwater, and on the surface. They are phytoplankton and zooplankton filter feeders and bottom detritivores. The bluegills are fed redworms (from a culture fed on rabbit droppings), flies from the flytraps, and fresh corn kernels and other soft vegetable matter from the garden. The bluegills also get numerous dead bees, which are dropped from hives immediately facing the pond. The bullheads eat whatever fare gets past the bluegills, and also receive some commercial catfish feed pellets. Bullheads and to some extent bluegills feed on the filamentous green algae that grows on the sides and bottom of the pond. The blackfish feed on whatever of the food tossed into the pond is small enough to get into their mouths, but they spend much of their time vertically oriented as they gobble detritus or browse on the filamentous green algae. In feeding on the excrement of the other fish species the blackfish occupy a niche similar to that of the crayfish in the winter polyculture, and are growing very rapidly.

About a quarter of the pond surface is covered by a raft of water hyacinth, which gives the bluegills shady refuge and takes up some nutrients from the water. The pond water remains surprisingly clear, which is in part due to the efficacy of the polyculture association (judging from the previous

Figure 11-2. **Some Species for a Polycultural Fish Pond**



year when biological filter and hyacinths were present as now but blackfish were raised alone).

We present these examples because we have had experience with them under backyard conditions. The variety of possible polyculture combinations is very great, and the likelihood of success depends not only upon a wise choice of species, but upon stocking ratios, size of fishes, types of food input, pond design, and other physical conditions. The most sophisticated polyculture described in the literature is the classical Chinese pond cultivation of several carp species with differing feeding niches. Another polyculture technique that is widely used is the stocking of a predatory fish to prevent overpopulation and stunting of the primary fish being raised. Examples of this approach are the use of pike or brown trout in carp ponds in Europe, and of snakeheads in Southeast Asian polyculture.

A more familiar application of this predator principle is the stocking of farm ponds with a bluegill-largemouth bass combination. The intention is to provide bluegill as forage for the bass. Unfortunately, sportsmen are much more interested in catching bass than bluegill. The bass are usually soon fished out, with the result that the bluegills overpopulate and become stunted. The few large bass that remain are unable to reproduce because their eggs are devoured by hordes of hungry little bluegills. However, if one harvests only bluegills and returns all bass caught, a farm pond initially stocked with the proper ratios will continue to produce good crops of large, edible-sized bluegills for many years with no supplementary feeding or other management required. Fertilization of the water will increase productivity as long as the pond is not overeutrophied (in which case microorganisms would compete with fish for oxygen).

For those fortunate enough to have a farm pond, this method of managing the bluegill-bass combination allows an annual harvest of more than two hundred pounds per acre with virtually no maintenance expense. With fertilization considerably higher yields can be realized.

If one is mainly interested in producing tasty and cheap animal protein for the human diet, a small farm pond can be used to grow fathead minnows (Figure 11-2). These little fish are mainly vegetarian (see Table 11-1), and increase very rapidly since they can go through two generations in a year. They are soft-rayed and can be eaten like sardines—bones, intestines, and all—even at the adult size of three to four inches. The gall bladder imparts a bitter taste and should best be snipped out of each fish with a pair of scissors, before cooking. Once this is done the fathead minnows are surprisingly tasty and make a good breakfast fried in patties or put into an omelette. They can also be dried and stored easily. The culinary properties of these little fish have been largely ignored because we think of them as bait minnows. In Asia small fishes are often eaten. Because the whole fish is eaten they are nutritionally superior to the large fillets of fish muscle prized in the West.

Intensive Aquaculture: If you are determined to raise fish in your urban backyard some degree of intensiveness will be required to increase per area productivity to the point where it can make a significant contribution to the family's diet. The rewards are likely to be educational, symbolic, and gustatory rather than economic. However, if water from the pond is used in the

garden, the fertilizer equivalent of the nutrients supplied should be considered as an additional benefit. Since it will probably cost at least $100 to construct a 100 square foot pond and several hundred dollars more to build a pump and filter system, the initial costs are high, since if you can produce more than twenty-five pounds of fish a year from such a pond you will be in the forefront of America's backyard aquaculture innovators.

Intensive systems use artificial means to perform life-support functions that would be carried out by natural processes in more extensive systems. By the use of technological means of aeration, waste removal, and temperature control it is possible to reach truly phenomenal productivities, exceeding a pound of fish per cubic foot of water per year, but these techniques are extremely energy-intensive, and the cost of electricity keeps going up. Moreover, if one talks with people who have had experience in maintaining intensive aquaculture systems for several years, they will usually tell you about the time when they went away for the weekend and a power failure or some other mishap occurred, and when they came back on Monday all the fish were dead.

It is probably the course of wisdom for the backyard aquaculturalist to use artificial supports only to promote growth, not to sustain life. This means settling for a moderate degree of intensity and a moderate level of production. Wind- or solar-powered support systems are adequate for this level of intensity. Fish under conditions too severe to allow growth may survive for extended periods of time if they are not too crowded. In such intermittent situations a pond will fluctuate between maintenance and growth.

Although aeration may be critical for a backyard pond in extremely hot weather or when the water is eutrophic, the support function most in need of

Table 11-1. **Some Species for Polyculture***

Common and Scientific Name	*Preferred Temperature*	*Feeding Mode*	*Breeding Regime*	*Approximate Annual Yield*
Rainbow trout (*Salmo gairdneri*)	55–70°F (82°F lethal)	In nature, carnivorous (worms, insects, etc.); in culture, omnivorous (will eat wide variety of meat and grain preparations)	Hatchery spawning (artificial)	0.5 lb/ft² in intensive culture; 100 lb/acre in pond culture
Sacramento blackfish (*Orthodon microlepidotus*)	60–75°F	When under five inches long eats small aquatic animals; when larger, a bottom detritivore and filter-feeder on phytoplankton and zooplankton; also eats decaying weeds	Pond spawning in spring	800 lb/acre in pond culture
Fathead minnow (*Pimephales promelas*)	60–85°F (95°F lethal)	Omnivorous but primarily eats filamentous algae, decaying weeds, and small aquatic animals	Pond spawning in spring and summer	3000 lb/acre in pond culture w/supplemental feed; 1000 lb/acre without feed
Bluegill (*Lepomis macrochirus*)	60–77°F	Omnivorous, but primarily carnivorous; eats insects, isopods, amphipods, worms, etc., also filamentous algae and decaying weeds	Pond spawning in spring and summer	0.5 lb/ft² in intensive culture; 300 lb/acre in ponds
Pacific crayfish (*Pacifastacus leniusculus*)	60–72°F (inactive above 75°)	Omnivorous; eats wide variety of plant and animal matter and detritus	Winter spawning in fallow swimming pools or garden ponds	0.5 lb/ft² in intensive culture; 400 lb/acre in ponds

*Information courtesy of Sterling Bunnell, Farallones Institute, Berkeley, California assistance is waste removal. Most aquatic animals excrete nitrogen in the form of ammonia, which is quite toxic to them. In confined spaces it accumulates to levels that inhibit growth and then to slightly higher levels which cause death. Certain bacteria (*Nitrosomas*) oxidize ammonia (NH_3) to nitrite (NO_2), and other bacteria (*Nitrobacter*) oxidize nitrite to nitrate (NO_3). Since nitrate is hundreds of times less toxic to fish than ammonia, the aquaculturalist can greatly increase the carrying capacity and productivity of a recirculating aquatic system by promoting this conversion. This can be done by means of a biological filter. The water is pumped through a bed of gravel or other granular substance, such as crushed clam shells. The bacteria attach to the granular surfaces and to particles of detritus that accumulate in the interspaces. Water must pass through the filter bed uniformly and have sufficient dissolved oxygen, since the nitrifying bacteria require oxygen to do their work. With the energy derived from the oxidation of ammonia they convert carbon dioxide into carbohydrates for their own use. Nitrifying bacteria have been found to be 100 times more numerous in the filter bed than in the water of the tank.

Many species of freshwater fish secrete hormonelike substances that inhibit growth when they reach sufficient concentrations in the water. These substances are eventually broken down by bacteria. It seems likely that a biological filter may provide a substrate where breakdown of these substances could occur more rapidly, although this remains to be conclusively demonstrated.

If the supply of water is not limited to a certain slope, problems can be circumvented by use of a throughput system (a system which allows water to continuously enter and leave the pond at the same rate). With crowding-tolerant fish such as trout or catfish, extremely high productivities can be reached with intensive throughput systems.

Disadvantages of Backyard Aquaculture

1. Aquaculture is usually considerably more expensive than fishing. On the small backyard scale it is especially so.
2. Certain constraints to productivity, such as water quality and territoriality, are most critical for small-scale systems.
3. The limited pond space available in backyards mandates some degree of intensiveness in aquaculture. More attention and expertise is required to maintain intensive systems than extensive systems such as farm ponds.
4. Disease and parasites can spread rapidly through intensive ponds.
5. Intensive systems require high initial capital expenditures relative to the value of annual production.
6. A sufficient stock of young fish must be available. Breeding and caring for young often requires special conditions and expertise.
7. Aquacultural productivity is dependent on temperature.
8. Quality of available water may limit aquacultural possibilities.
9. Ponds can act as traps for airborne pollutants.
10. Damage to local natural ecosystems, often irreversible, can result from the escape or release of exotic aquaculture organisms.

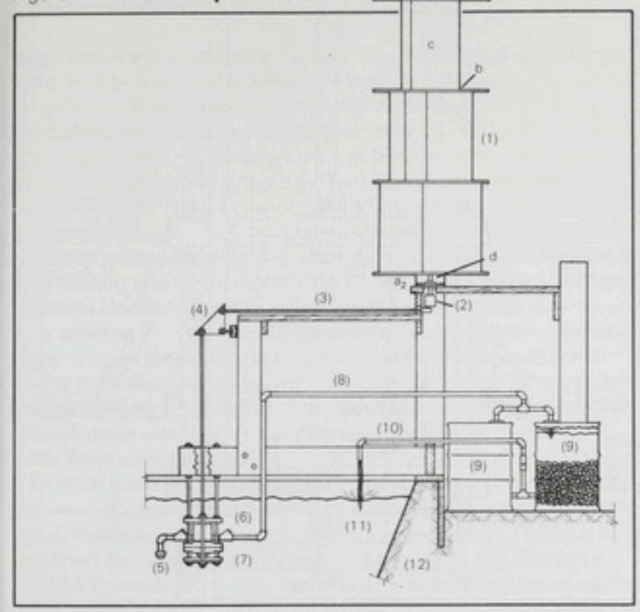
The Wind-Powered Pump and Filter: The following description of the wind-powered pump and biological filter at the Integral House in Berkeley is adapted from one written by Tom Fricke for the Farallones Institute 1978 Report. Fricke, together with Peter Holloway, built the system pictured in Figure 11-3, largely out of scavenged parts from various automobile graveyards and dump sites.

The aquaculture system in the southwest corner of the Integral Urban House garden employs a unique device, called the Savonius Rotor, to prevent our pond from becoming stagnant and eutrophic. The rotor takes its name from J. Savonius, a Finnish engineer who studied the aerodynamic properties of S-shaped vertical (upright) axis turbines. The design is from the early 1930s.

The wind machine is constructed of three recycled 55-gallon drums that have been cut in half longitudinally. The halves are positioned on three tiers, clamped between plates of salvaged lumber, and offset at 60-degree angles around a 1-inch shaft of discarded steel.

The Savonius can catch winds from any direction, and a gust of seven-to eight-miles per hour will start the machine moving. Rotation will continue until the windspeed dies down to below 3 miles per hour, since the thrust bearings on which the mill is mounted are quite frictionless. Although

Figure 11-3. **Wind Aquaculture Unit**



high torques are achieved with this device due to its enormous size, the Savonius rarely achieves high rpms (rotations per minute). Mechanical energy conversion seems to be an ideal use of the wind energy rather than electrical energy, which requires both high wind speeds and rpms. With linkage improvised from scrap metal and spare parts, we converted the rotational force to vertical strokes which activate a homemade diaphragm pump, submerged in the pond (details of construction are shown in Figure 11-4).

The pump raises water to a biological filtration unit which is housed in another steel drum, the top of which is five feet above the surface of the water. Primary filtration of large particles is achieved by a felt bag located on top of the drum, and secondary filtration consists of a bed of crushed oyster shells that fills the drum. The toxic ammonia and growth-inhibiting hormones excreted by the fish are removed by bacteria lodged in the oyster shell bed of the filter. Filtered water passes through a faucet aerator to restore oxygen to the pond to complete the cycle.

We have estimated that in a 15-mile-per-hour wind, the Savonius can cycle 1.5 gallons of water per minute through the filter. Though seemingly not a great amount of pumping power, 8 hours of pumping will circulate nearly 750 gallons of water, or one third of the pond's volume, which is our optimum design consideration.

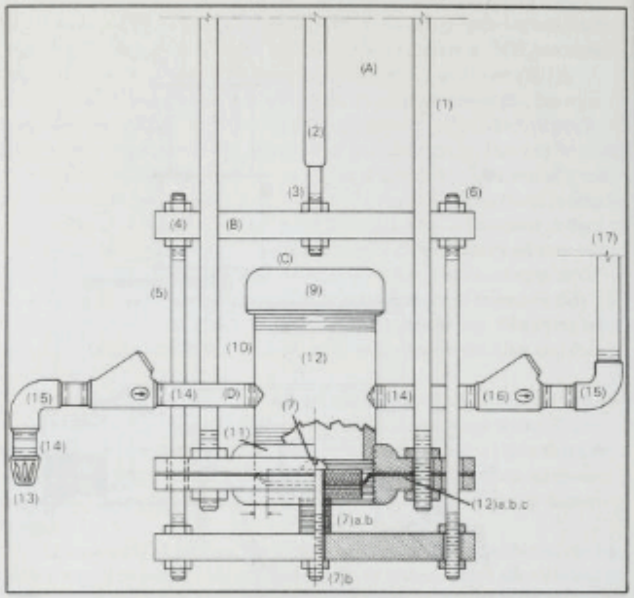
Pond Construction: The pond should be constructed so that it is easy to net the fish out when they are to be harvested or examined. If the water is at

Key to Wind Aquaculture Units

(1) Savonius rotor vertical axis wind turbine
 - (a_1) flange-mounted bearing
 - (a_2) flange-mounted thrust bearing
 - (b) plywood end-caps, with 1" flange for mounting axial shaft
 - (c) bisected oil-drum (or aluminum, fiberglass, etc., sheet) impellers, offset 60°, bracket mounted
 - (d) 1" rolled steel bar, axial shaft

(2) Eccentric-mounted bushing
(3) Lightweight scrap aluminum linkage, pump rods
(4) Triangular bell crank
(5) Inlet pipe with strainer
(6) Pump stirrups
(7) Handmade diaphragm pump
(8) 1" water pipe, for delivery from pump to filtration unit
(9) Oil-drum biological filtration unit (one drum is shown in section)
(10) Filtered water delivery pipe
(11) Fish pond, lined with Hypalon and formboards
(12) Tamped earth

Figure 11-4 **The Diaphragm Pump on the Aquaculture Unit**



Key to the Diaphragm Pump

(A) *Linkage and support connectors:*
- (1) threaded 3/4" bar, to connect entire pump from support members above pond to submerged level-bars inserted into four of six 4" flange holes.
- (2) lightweight aluminum pumprod, transfers vertical strokes from linkage to Savonius Rotor
- (3) adjustable mechanism
  - (a) threaded 1/2" bar, inserted into pumprod
  - (b) 1/2" machine nut

(B) *Stirrups:*
- (4) 3/4" × 1 1/4" aluminum stock, drilled as shown
- (5) 3/4" bar, threaded on both ends
- (6) 3/8" machine nuts
- (7) 3/8" machine bolt, approximately 3 1/4" long
  - (a) metal spacers
  - (b) 3/8" machine nut

(C) *Pump chamber:*
- (9) 4" threaded cap (metal or ABS plastic)
- (10) 4" double nipple, tapped and drilled on sides to receive 1" pipe nipples
- (11) 4" pipe flange
- (12) Rubber diaphragm, approximately 3/32" thick (from discarded truck tire tube)
  - (a) holes cut into the rubber at flange bolt holes
  - (b) fit snugly flat to insure that there are no leaks
  - (c) diaphragm, when flexed, during pump stroke

(D) *Delivery and supply pipe:*
- (13) simple strainer made of screen, affixed by crimped wire or hose clamp
- (14) 1" pipe nipples
- (15) 1" elbows
- (16) 1" nonreturn valves
- (17) supply pipe to filter

least two feet deep in the shallowest part, raccoons (which can be a problem even in cities) may be frustrated in their attempts to catch fish. If the deepest part goes down four feet there will be a certain amount of temperature stability if the weather should suddenly turn extreme. If the pump intake is placed near the bottom of the deepest point circulation within the pond will be optimized.

Finding the right lining material for the pond can be a problem. An earth bottom can be sealed with bentonite (a fine clay powder) but this remains rather "goopy," is hard to clean, and some creatures do not like it although others may find it satisfactory. Heavy polyethylene (5 or 6 mil) is relatively inexpensive but is subject to damage and disintegrates spontaneously after a few months due to the action of the ultraviolet frequencies in sunlight. Black polyethylene lasts somewhat longer than clear, but it too must be replaced after a season. Hypalon is quite durable and is said to be nontoxic, but it is expensive. Other plastic and vinyl lining materials are to be regarded with caution, as they often emit plasticizers and other toxic substances that can kill fish and may not be very good for the people who consume them either. Concrete or ferrocement makes an esthetic and durable coating for a fishpond. It should be leached with several changes of water over a week or so to remove excess alkalinity before fish are introduced. A nontoxic sealer may be required to prevent seepage through the concrete. Although initially more expensive, concrete will last for many years and can be much more interestingly designed than the other materials. Its main dis-

advantage is that it makes it harder to move your pond if you decide to rearrange your backyard.

Requirements of the Species Grown: The psychological requirements of fish must be considered in designing a backyard pond. Some fish, such as bluegills, feed better if they have a secluded shelter from which to forage. Food falling within a certain radius of their hiding place is more likely to be taken. Rafts of water hyacinths provide a good shelter of this kind, under which many fish can take refuge at the same time. Trout tend to establish feeding territories in the open water, which they cruise actively. The dominant trout become so voracious and aggressive that less dominant ones are frequently prevented from feeding and so the trout in a pond tend to grow at quite differing rates. This imbalance can be compensated for by periodically harvesting the dominant fish so that the others have a chance to grow faster, or by crowding the trout until they lose much of their territoriality. Bullhead catfish are quite gregarious and will eat more when crowded because they stimulate one another into a feeding frenzy. The territoriality of crayfish appears to be mostly horizontal. Vertically oriented structures such as bundles of weeds or the roots of water hyacinths markedly decrease combat and losses due to cannibalism.

While it makes good sense from the trophic standpoint to raise animals that are at least partially vegetarian, most aquatic animals, especially when young, require at least some animal protein for good growth. The list of invertebrates that can be cultured for fish food is extensive. We have cultured *Daphnia*, ostracods, amphipods, chironomid larvae, mosquito larvae, mayfly larvae, tubifex worms, redworms, and isopods. All were grown on wastes and weeds. Redworms and isopods are good food for larger fish and can be grown with very little effort and attention, whereas the others are mainly for smaller fish and require more care if they are to remain highly productive throughout the year.

The optimum conditions for breeding and rearing young fish are different from those in which the most rapid growth to large size occurs. When fish become reproductive most of their energy goes into behavior rather than growth. Therefore, good breeding situations are not desirable in grow-out ponds. It is advisable to separate breeding ponds from grow-out ponds in urban aquaculture. The best use of most backyard ponds is as grow-out ponds, for which fingerlings are obtained which are of the right size to eat the foods usually available.

Species Selection: Each species of fish or other aquatic animal has a preferred temperature range within which growth occurs most rapidly. Beyond this optimum in either direction growth slows markedly and at either extreme death occurs. The aspiring aquaculturalist would do well to consider raising species that are adapted to the local climate. Much has been written about the aquacultural promise of tropical creatures such as *Tilapia* or the giant freshwater prawn *Macrobrachium*, and many persons living in the temperate zone have been tempted to try them. However, these animals die when the water temperatures drop into the low fifties Fahrenheit. Even when the pond is enclosed in a greenhouse, expensive heating systems are required to keep such species alive through a cold winter. Why not consider bluegills and crayfish, which occupy much the same niches but are adapted to a temperate climate?

The highest productivity can probably be obtained from backyard ponds by double-cropping—that is, growing cool-water species in the colder months and warm-water species in summer. Depending on local conditions, a portable greenhouse may be useful for moderating the climate during the cooler months.

Many state fish and game departments are justifiably concerned about enthusiastic aquaculturalists releasing exotic species into natural waters, and some species with aquacultural potential, such as grass carp, are banned from importation into some states. One need consider only the destruction wrought by the common carp, brought to America as "that most delicious of all fish" or more recently the *Clarias* catfish in Florida, to share their concern.

It is a good idea for aquaculturalists to look at their own region and, as much as possible, stock their ponds with native species or exotic species that are already harmoniously established in local waters. That way, if any individuals escape no great harm will be done. State fish and game departments can usually supply directories of breeders that have fingerling trout, warm-water game fish, and bait fish for sale. Permits from the same agency may be required to buy or transport them.

Keeping Bees in Urban Areas

The integral urban house concept can include beekeeping because of the pollination capabilities of bees and their production of honey and pollen. Beekeeping is one of those hobbies that can be self-supporting, at least to the degree that the household consumes home-produced honey instead of granulated cane or beet sugar bought at the store. Keeping hives in some metropolitan regions can be even more productive than in some rural locations because city people often maintain ornamental plants that bloom more frequently than farm crops, and thus provide nectar and pollen for a larger portion of the year. Although bees will travel a radius of two to five miles from their home seeking flowers, there is probably not enough pollen and nectar-producing foliage in the city to support a hive in every home. Still, it is unlikely that all households will want a beehive. We offer the following discussion for those who do.

The great importance of bees in pollinating crops is rarely understood by city dwellers, whose primary reaction to these insects is often fear of being stung. A number of cities have restrictive ordinances against beekeeping primarily to protect citizens from being stung. But the fact is, less than 1 percent of the population has an allergic reaction to insect stings. For people who do have extreme reactions, the best policy to follow is individual desensitization, a successful procedure available through allergy clinics and doctors who specialize in treating allergies. For the vast majority of people, the likelihood of being stung is slight, and the fear of the possibility is all out of proportion to the consequences.

Once, in our neighborhood, when a swarm of bees clustered on a shrub four feet above the sidewalk in front of a house near ours, a group of panicked housewives came over to ask advice, saying, "Please do something, because the young children will be stung." It is true that there are quite a few toddlers on the block as well as some rather mischievous kindergartners. We suggested to the mothers that they relax and not scare the children, but rather encourage them to appreciate this relatively rare and fascinating sight. If the children could be induced to stop and watch quietly, they might learn something.

Since the children took their clues from the warning noises of the insects and stayed at a respectful distance, all went well. We proposed making a sign—not for the children, who didn't need it, having enough sense to appreciate such a special happening, but for the insect-fearing adults who might be passing by. It read, "See our beautiful bees. Enjoy watching them. Do not disturb them and they will not bother you." All too soon the bees moved on, leaving a number of adults wondering why they had been so frightened.

Such opportunities to observe bees close up can be very valuable in helping people to overcome their fear of them and lead to further tolerance of beekeeping within urban areas. This in turn can result in increased fruit and vegetable yields in home gardens and more honey for the integral urban house table.

The honey bee, unlike hornets and wasps, loses its life when it stings, for it fatally injures itself internally trying to free its stinger. At the entrance to the hive there are a few guard bees whose job it is to come to the defense of the nest. It is these bees that first attack someone walking in front of a hive. Away from the hive, it is difficult to get honey bees to sting at all. They seem reluctant to sting in self-defense; self-defense, in this case, would mean death.

Other factors threaten bees' lives that are less in their control.

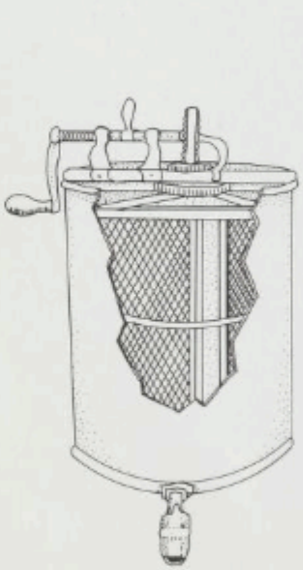
Many of the commonly used insecticides are highly toxic to bees. Unfortunately, a major use of these insecticides by home gardeners is directed toward producing a perfect rose or other flower, and the honeybee visiting the flower to obtain nectar is the unintended victim. In the revised edition of the classic *ABC and XYZ of Bee Culture,* A. I. Root states, "During the last twenty years . . . insect pollination of crops has become a more critical problem in the United States and in some other countries because . . . the use of insecticides is reducing the population of wild bees. . . . *Sevin* and the *arsenicals* are especially dangerous because they may be stored with pollen in the hive and later fed to the brood." Root's detailed chart on the effects of various poison sprays on bees rates pyrethrum as being low in toxicity in both laboratory and field trials.

In spite of occasional prohibitory ordinances many people do keep bees in urban and suburban areas. These beekeepers quickly learn to make their hives inconspicuous by keeping them hidden or painting them unobtrusive colors. Gifts of honey or beeswax candles may help to make neighbors friendly, as gifts of fresh eggs may do in regard to raising chickens. When a town near us reviewed their laws prohibiting beekeeping recently, some thirty residents who were already keeping hives appeared before the city council and had all the legal constraints repealed. One of the arguments they used was that every town needs to have some responsible beekeepers who will capture the inevitable wild swarms for the public, as well as for their own benefit. We know several urban beekeepers who charge a fee for this service and each spring make a supplemental income at it.

Honey and Other Products of the Hive: Honey is the nectar and sugary exudate of plants that has been gathered, processed, and stored in the cells within the combs of the hive. The comb itself is a waxy substance constructed for the purpose of holding the honey, pollen, nectar, and the young larvae of bees while they develop. To produce honey, worker bees gather nectar, sucking it from the plant into their stomach. Here, various enzymes mix with the nectar. When the stomach is full, the bee flies back to the hive and deposits what is now the honey into cells allotted for that purpose in the combs. The hive boxes holding these honey-laden combs are usually high in the hive; the room below is used for rearing young. Once the honey is deposited, the worker bee goes out again to find additional food sources.

When the honey is first placed in the hive by the worker bee, it has a watery consistency and would probably ferment if no further processing occurred. Hive bees, however, take the honey back out and air drops of it in their mouth parts so that water evaporates. The dehydrated honey is then returned to a cell in the comb and a wax cap is placed over it. Finished honey has an average moisture content of 17.2 percent.

The beekeeper inspects the hive to see what proportion of cells are capped. Capping indicates that the honey has the proper moisture content for harvesting and storing. Frames with all capped cells can be stored away until it is convenient to take the honey out. Various devices can be used to remove honey, the most common of which is a centrifuge. The small beekeeper can use a hand-operated centrifuge, or a solar extractor that uses sunlight to heat the wax comb so that the honey runs out of it.



A hand-operated centrifuge is used to spin the honey-filled frames. The honey flows out of the gate at the bottom.

The "average American" eats somewhere in excess of one hundred pounds of sugar each year. While undoubtedly a good part of this annual amount is consumed without the person's knowledge as additives to restaurant meals or processed foods (breakfast cereals, baked goods, soft drinks, sauces, and so on), a considerable amount of sugar is consciously added to various dishes and drinks in the home. For the latter, honey is a splendid, fine-flavored substitute. It is actually sweeter than sucrose, the sugar derived from cane and beets, so you may even find yourself using less overall sugar. It makes a fine spread just as it is, either in syrup form or partially crystallized, for toast and pancakes. It can be used in canning and baking, but less by half is required than sugar (liquid contents should be reduced accordingly), since honey is more fluid. For an analysis of the mineral content of honey see Table 11-2.

One colony of bees can provide as much as one hundred pounds or more of honey per year. In addition to honey, which is a carbohydrate, protein can be harvested from a beehive as well. The two protein sources are pollen and the bees themselves. Pollen traps, whether purchased or constructed at home, make its collection easy. Advertisers in bee journals—for example, *American Bee Journal, Gleanings in Bee Culture*—sell such devices. Be cautioned, however, that since the bees also utilize pollen as a protein

source to develop their young, you need to learn how much pollen to harvest, so as not to damage the hive's reproductive potential.

Pure pollen also can be purchased in certain health food stores. Unheated honey, comb honey, or honey from cappings will have some intact pollen mixed in. It has been suggested these sources have an excellent effect in reducing certain allergies. Presumably they work by exposing the sufferer to steady, low doses of particular allergens; desensitization occurs after a long period of this sort of exposure. Pure pollen might possibly be used in the same fashion, but it should be tried first in very small amounts. Too much at once may cause a severe reaction.

Table 11-2 **The Mineral Content of Honey**

Mineral	*Ppm in Light Honey**	*Ppm in Dark Honey**
Potassium	205	1676
Chlorine	52	113
Sulfur	58	100
Calcium	49	51
Sodium	18	76
Phosphorus	35	47
Magnesium	19	35
Silica	22	36
Iron	2.4	9.4
Manganese	.3	4.1
Copper	.29	.60

Total ash .02–1.0 percent (average ash = .17 percent)

*Ppm is the abbreviation for parts per million; in this case, milligrams of mineral per kilogram of honey.

Note: If you compare honey and white sugar, you will notice that honey has small amounts of organic ingredients, and as the above shows, some inorganic minerals, while these have been removed from white sugar, in the process of "refining" it.

Source: *Beekeeping in the United States.*

Although beekeepers are known to eat larvae of developing bees as a sort of special treat on occasion, the possibility of regular harvesting of this protein source as a supplement to human or domestic animal diets is a potential and unexplored protein supply. The yeasty-tasting larvae are best offered to neophytes in a milkshake or a similar beverage, preferably after blending to destroy any resemblance to the original organisms. However, they can also be eaten directly. Still, eating queen larvae directly may be too much of a good thing. The taste is very strong.

In general, people are conservative about food. If they weren't exposed to something as edible when they were children they usually resist eating it later. When you do try a new food, it is wise to go slowly in any case. Each individual has a slightly different physiology to which he or she has adapted mature food habits. A gradual adjustment to something new is always wise.

At the Berkeley Integral Urban House, preliminary experiments showed that fish would eat dead bees. To make this fact useful, a beehive was mounted over a pond so that when bees died they fell into the pond and thus became a supplementary protein source for the animals within. This arrangement takes advantage of the normal process of bees dying. A strong hive of sixty thousand bees will have an average daily mortality rate of 1.5 percent during the periods of peak activity. This means that as many as a thousand bees per day can die in heavy honey-flow periods in the spring. This bee-fish combination exemplifies the integration principle by which systems that may be net losers from an energy, labor, or economic point of view, when combined can provide a net gain.

A way to use the dead bees without having to mount the hive above a pond is to employ a dead bee trap to collect all the dead bees as they are removed from the hive, or as they try to fly away from the hive with their last dying effort. Although additional research will undoubtedly turn up more ways to use dead bees, the underlying concept will most likely be to make use of the protein they contain.

Beeswax is probably one of the more important hive products, judging from its range of uses. However, in the future, honey converted into alcohol through fermentation may become important as a fuel for running vehicles. Beeswax can also be utilized as a heat source by burning, as in a paraffin heater; by extension, it could conceivably be used to fuel an engine of some sort directly. Of course, the most obvious use of beeswax is for producing high-quality candles, though one rarely encounters beeswax candles anymore. They are easy to make and are excellent gifts.

Propolis is a hive product that even beekeepers generally fail to recognize as a potential crop. It is the resinous plant product gathered and utilized by bees as a home sealer or caulking compound. The bees use propolis wherever a gap occurs in the hive, and in various other places as well. Propolis does have an export market, particularly from the United States to Japan, where it is used in various products, one of which is thought to be an aphrodisiac. The fragrance and water-repelling properties of propolis could make the material useful as a waterproofing compound, for example in basket-making. This product could become more important in the future, particularly if collection methods were well worked out. Presumably, a hive could be designed that would increase the amount of caulking done by the bees, or a strain of bees developed that would be especially adept at producing propolis.

There is a ready market for royal jelly (see below) and pollen. (In Berkeley, California, at this writing health food stores are selling royal jelly for $9.95 per 100 milligrams, or $74.00 per ounce, and pollen sells for about 50 cents per ounce.) A market also exists for workers, queens, hives and equipment. Another possible marketable product is bee venom. Bee venom therapy for arthritis utilizes the secretions of the poison glands as a way to alter the sufferer's immune system. For those interested in this form of therapy, consult the two articles and short note on the subject in issues of *American Bee Journal* listed in the bibliography at the end of the book. The articles describe how to use bees to sting arthritic joints and the beneficial results obtained. They also indicate that a method exists for harvesting the venom without killing the insects.

The Bees: One needs to know something about the biology of bees in order to manage them successfully. Table 11-3 shows the developmental period for the three different castes of *Apis mellifera,* the common domestic honey bee derived from European strains. (A caste is the name given by biologists to the respective hive groups: workers, drones, and queens. The word is useful because it designates that members are recruited into the group at birth.) A vigorous hive during its peak in the spring will have fifty to sixty thousand workers and about three thousand drones (males), but only one queen. A queen bee (larger than the others) and worker bees are shown in Figure 11-5.

Table 11-3. **The Development Period of the Three Hive Castes**

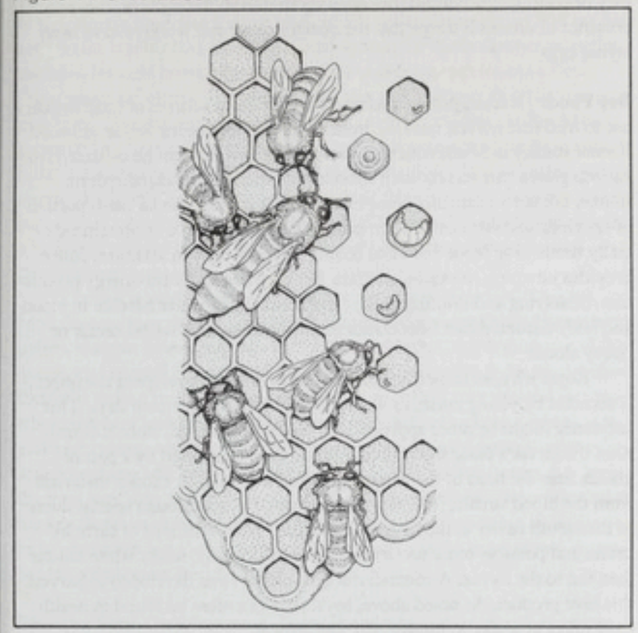
	Days		
	Queen	Worker	Drone
Egg	3	3	3
Larvae	5½	6	6.5
Pupa	7½	12	14.5

A young healthy queen can lay up to two thousand eggs per day, and live up to five years. The average life-span of the worker bee varies with the season—about six weeks in the active spring period and up to six months through the winter if it lives all the way to spring. Drones are fairly specialized creatures; they do no work except in nuptial flights. They need to be fed, as they do not forage for themselves, and they seldom live for more than four months. Near the season's end when less honey is available the drones are actually forced from the hive to die. Drones are easy to distinguish from the workers because they are much bigger than the other bees and have large eyes that almost entirely encompass the head. Also, they have so stinger. They are stouter than the queen, and their abdomens are less pointed.

The queen determines the sex of the developing grub or larvae by whether or not she fertilizes the eggs. Unfertilized eggs produce males through a genetic mechanism common throughout the Hymenoptera (the insect order that contains the bees, ants, wasps, and many parasitic natural enemies of other insects). The queen keeps a supply of sperm from her first and only mating, with which she inseminates all the fertilized eggs. How this feat is accomplished has attracted researchers who are interested in reducing the cost of sperm storage in artificial insemination programs.

The workers determine whether a fertilized egg will develop into a queen or a worker. They do this by selecting the food fed to the developing larvae. All young are fed royal jelly and "bee bread" (honey and pollen mixed together) for the first three days. The larva to become the queen continues to receive the royal jelly; those larvae that do not become the workers. Workers and drones are also fed more intermittently, and thus are really "incomplete queens," since queens take longer to develop. They are considered incomplete because they don't lay eggs. In extraordinary circum-

Figure 11-5. **A Queen and Workers in a Frame**



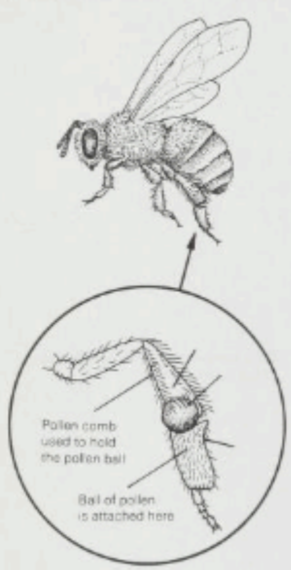
Note the size and shape differences of the bees.

stances, workers in queenless colonies *do* lay eggs. These being infertile, they develop into drones. If you open up an overwintering hive, the unusual presence of drones is a sign that the queen is gone and workers have been laying eggs.

Bee Food: Nectar, pollen, and water are the three sources of food workers use to feed themselves, queens, drones, and the developing larvae or brood. Recent studies in South America also indicate that fats can be collected from various plants that secrete such substances. Nectar is the carbohydrate source, but it also provides some minerals, some water, and a small portion of enzymes and vitamins. Pollen provides the only source of protein especially needed for brood food and colony reproduction. In addition, pollen provides vitamins, minerals, and fats. Bees require water for energy production, dissolving and diluting honey, and maintaining water balance in blood and body tissues. Adult bees do not require pollen, and live on nectar or honey alone.

Royal jelly, so named because of its key role in developing the queen, is secreted by young nurse, or worker, bees aged five to fifteen days. This substance might be more appropriately called brood food, since it constitutes the larvae's basic food supply. Brood food is secreted by a pair of glands near the head of the worker bees and these glands extract materials from the blood stream. The secretion is passed down through special ducts to the mouth cavity at the base of the tongue. With additions of carbohydrates and possibly other secretions, the thick, creamy, milky white fluid is then fed to the larvae. A commercial process has been developed to harvest this hive product. As noted above, royal jelly can often be found in health food stores as a special human diet supplement.

Figure 11-6. **The Pollen Basket and Comb**



Pollen is held on the lower part of the expanded tibial leg segment by means of the regularly spaced spiny hairs on the first tarsal segment.

The Seasonal Life of the Hive and Management Suggestions: The hive is basically a superorganism with the queen operating as a key control agent through chemical cues or phenomena. The queen produces a special chemical (9-oxo-dec-2-enoic acid) from her mandibular gland, and distributes it over her body during cleaning operations. Worker bees obtain it when licking the queen. This "queen substance" enables the bees to know when the queen is absent. As she gets older and produces less queen substance, the workers are stimulated to feed another developing larval queen. The workers who usually surround the queen distribute the queen substance to other bees in their normal process of sharing food.

In the winter, the queen stops laying eggs, and she places herself in the relative center of the hive, with a surrounding ball of workers as insulation and as a heat source. During this period, the bees live off the stored honey and pollen. This is one reason for leaving an ample supply of honey during harvesting operations. Otherwise, supplemental feeding will be needed to help the hive make it through the coldest periods.

Winter is a good time to plan the next year's activities and organize and construct new equipment. Spring is the period of greatest hive activity, for this the major period of nectar and pollen production.

It is instructive to observe bees as they pass into the hive at the landing board. Here, you can see the different-colored pollen balls attached to their

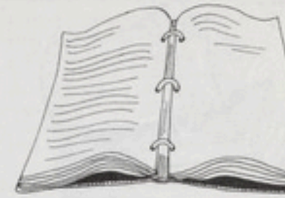
hind legs. If you can match the different colors with the predominant blooming flowers, you will know from which plants the bees are harvesting at a particular time. See Figure 11-6, which shows the so-called "pollen basket" on the worker bee. Spring is a busy season for the beekeeper as well as the bees, because harvesting and controlling swarms require extra time. (Swarms occur when a new queen and a group of workers fly off to start a new hive. This can reduce hive strength and productivity so it should be prevented.) These activities must be included in your schedule. Plan carefully and make regular assessments of hive conditions. In some areas, summer is like spring, and the bees will continue their foraging. In other places, summer may be drier and/or less flowers will bloom. You will have to learn which season is the busiest for your area and anticipate harvesting and swarm-control periods.

The fall period is highlighted by the expulsion of drones. This is a good time to open the hive and check out the remaining stores of honey and pollen, number of workers, age and amount of brood, egg-laying rate of the queen, and general condition of hive. One way to learn to judge for all these factors is to take out each frame (a frame is one of the nine vertical sections where the bees build their wax cells) and ask a helper to keep notes as you make percentage estimates for each one. By periodically making a thorough assessment you will begin to become sensitized to the key factors that keep the hive alive and thriving. In making the fall inspections, winter survival is the key factor to consider. Since it is difficult for the beginning beekeeper to judge if enough food will be available, either be sure to leave plenty or prepare to supplement the hive's food supply.

Starting Your Own System: Starting any new project requires motivation and resources as well as a general scheme. A design for developing a bee system for your home should be broken down into three phases: planning, construction, and management. During the planning process you may wish to educate yourself about bees and beekeeping from the extensive literature on the subject, and perhaps attend a class or make direct observations of beekeepers in action. Construction of the system requires assembling the materials (the hive and the bees). Management is the regular work of observing, operating, and readjusting the overall system.

Obtaining bees and equipment can be accomplished in several ways. It is possible to buy a full hive or a nucleus ("nuc"), which is a small hive with a few frames containing brood and a queen. Or you can purchase the components and assemble them yourself. When spring arrives, you then buy workers and queen(s) and watch the colony grow. The latter process is probably cheaper and will teach you more of the basics if you are starting alone. The former process is faster, and you will be a beekeeper as soon as the hives are yours. This kind of start may be a bit abrupt unless you are certain when you purchase your hive that a practicing beekeeper will advise you personally, and let you use equipment.

Starting with two or more hives is recommended. If you have only one and the queen dies, you will have lost everything. With more than one, dividing colonies and propagating from the other hives or combining two colonies becomes possible. Queenless colonies can be added to those with



Notebook for writing down records and special observations.

A veil is useful for keeping bees from stinging the face and neck.

Gloves are useful to prevent beestings on the hands.

A smoker is used to quiet the bees. They react to smoke by filling up on honey, and this makes them more docile.

A frame lifter is used to enable you to hold a frame with one hand. It is useful in finding the old queen bee when you replace her with a new queen.

A hive tool is used to pry up the cover and the hive boxes, which often are sealed together by the sticky resinous material called propolis that the bees harvest from trees.

queens by stacking the supers (hive sections that hold combs), with a paper sheet between. By the time the bees have eaten through the paper, the queen substances will have mingled enough so that no fighting will occur between the two formerly distinct populations.

Building your own equipment is a definite possibility, particularly if you are skilled at carpentry. Good plans for assembly of hives and honey extractors are available from Garden Way Publishing, Charlotte, Vermont 05445, or can be obtained from various published sources in local libraries or by letter to agricultural experiment stations.

Essential tools needed to start are a veil, hive tool, smoker, gloves, possibly overalls and a notebook. These items can be purchased from bee supply houses listed in bee journals, or if they are unavailable, mail order departments of Sears or Montgomery Ward. The latter mail order firms distribute equipment, bees, and tools, and you can learn from their catalog and use it to plan the cost of the adventure.

Setting up your initial hives with an ant excluder platform may help protect your hives against certain ant species. Such a stand can be used instead of a chlordane treatment, which is the common practice. Chlordane is a chlorinated hydrocarbon that accumulates in food chains and it should be avoided wherever possible.

A New Type of Hive: Don Simoni of San Francisco, California, has invented a new kind of beehive that can be used indoors and that reduces the possibility that the beekeeper might be stung. Such a hive may encourage many more people to become involved in beekeeping, particularly urban people, since the hive can be kept indoors, even in the kitchen where few onlookers will notice. This hive is outfitted with plastic look-in sides that allow easy observation. Thus it is possible to view many hive mysteries—egg laying, the waggle dance (see Box 11-1), and honey processing.

The queen and worker bees are placed into the bottom of this hive. There the queen lays her eggs. As the bee population increases the sliding gate between the two chambers is opened and the bees move up into the honey chamber. In a few months, when the bees fill the honey chamber with honey, the sliding gate is closed to prevent more bees from entering the chamber. In the honey chamber are devices for removing the bees and making honey harvesting easier. A passage off to one side allows the bees to travel out of the chamber through a one-way exit and down into the brood chamber. The majority of the bees as a part of their regular movements will leave the honey chamber within six hours of closing the passage, but a few will remain. To encourage these stragglers to leave, a smoking system built into the honey chamber burns incense cones. The smoke irritates the remaining bees enough to cause them to leave. A few hours after the smoker is used the honey chamber can be opened and the honey removed.

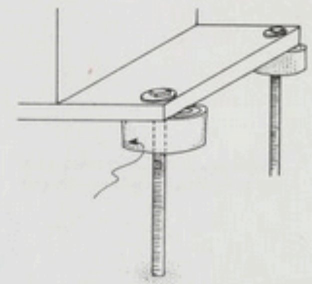
This observatory hive is designed to be kept indoors on a table or secured to the wall. Normal shelf brackets sold in hardware stores provide a solid base when attached to 2 × 4s in the wall. The most important consideration when placing the hive is to point the exit tube away from people or pet traffic. These exit tubes can be mounted in a window so the bees can come and go easily while you watch. Bees normally bother no one, but to be

Box 11-1. **The Bee Waggle Dance**

If you watch a bee land on the platform of an observation hive and move up into the hive you will notice that it is wagging its tail vigorously and rapidly circling. Other bees appear to be attracted to this dance. By ingenious studies, Karl von Frisch discovered the significance of this behavioral routine. He found that two types of information are conveyed by the dance: distance to a food source (by the dance tempo) and direction from the hive (the angular deviation from the vertical path of the dance indicates the angular deviation of the food source from the hive-sun axis). This complex dance has stirred apiculturists and behaviorists to long discussions about bee language and the evolution of language in these social insects. Recently, sound vibrations have also been shown to be involved in information dissemination in the hive.

safe you should place the entrance to the hive away from a frequented sidewall or the front or back door of the house.

If you are interested in this hive, write to Don Simoni, 177 Pixley Street, San Francisco, California 94123. He is continually experimenting with new designs. He is in the process of patenting this idea and sells handcrafted versions for $150 each. He cautions that the idea still requires further experimentation. If you want to join in, you may find yourself participating in a beekeeping revolution.



An Ant-Guard Hive Platform

Stickem (a brand name) is placed on the inside, where it is protected from rain, debris, and dust.

Figure 11-7. **The Indoor Observation Beehive**