TECHNICAL PAPER # 52

UNDERSTANDING AQUACULTURE

By
Ira J. Somerset

Technical Reviewers
Marilyn S. Chakroff
Robert Bettaso
Martin Vincent

VITA

Published By
VOLUNTEERS IN TECHNICAL ASSISTANCE
1600 Wilson Boulevard, Suite 500, Arlington, Virginia 22209 USA
Telephone: (703) 276-1800, Fax: (703) 243-1865
Telex 440192 VITAUI, Cable: VITAINC
Internet vita@gmuvax.gmu.edu, Bitnet: vita@gmuvax

PREFACE

This paper is one of a series published by Volunteers in Technical Assistance (VITA) to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteers technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Margaret Crouch as Executive Editor, Suzanne Brooks handling typesetting, layout, and graphics, and James Butty as technical writer/editor.

The author of this paper, VITA Volunteer Ira J. Somerset, is a sanitary engineer working for the US Food and Drug Administration as an evaluator of shellfish sanitation programs in the northeast states. The reviewers are also VITA Volunteers. Marilyn S. Chakroff, a technical writer and fishery trainer, is the author of Fresh Water Fish Pond Culture and Management, published by VITA; Robert Bettaso is an agricultural scientist with specialty in fish culture; and Martin Vincent is a self-employed fisheries

expert.

VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry service, a specialized documentation center, and a computerized roster of volunteer technical consultants; managers long-term field projects; and publishes a variety of technical manuals and papers.

UNDERSTANDING AQUACULTURE

By VITA Volunteer Ira J. Somerset

I. INTRODUCTION

Aquaculture is the production of protein-rich foods through the controlled cultivation and harvest of aquatic plants and animals. Using inexpensive equipment and simple techniques, aquaculture can supply more protein than normally produced through conventional agriculture such as dairy, poultry, and cattle farming; and traditional fishing.

Aquaculture is not new. More than 2,500 years ago the sticky eggs of some fish were collected on mats and bundles of reeds or wood attached to posts in streams. Oyster and clam eggs were also collected and transferred to other waters to hatch. This was the first form of aquaculture.

In the 11th and 12th centuries, pond culture developed. Carp were moved through a series of ponds where they reared young fish and grew to harvest size. Later, other fish were cultured in a similar manner. Today, several types of fish and shellfish are grown in high density aquaculture operations throughout the world.

The techniques of animal husbandry improve the chances of survival of the plants and animals being raised and speed up their growth so that the food yield is quick and large. Almost any type of aquatic organism can be raised from its youth to a healthy, marketable adult. However, this paper in restricted to fish and shellfish culture. The reader is presented with only general considerations and approaches to aquaculture, since it requires specialization to address each possible cultural species.

ADVANTAGES AND DISADVANTAGES OF AQUACULTURE

Systematic aquaculture operations have a number of advantages over fishing for the production of protein foods. Some of these are:

o Economics (employment, new industry and support services, and increased foreign and domestic ex change);

o No need for expensive fishing craft and gear;

o Low operating and maintenance costs;

o Low capital investment (unless Ponds must be constructed;

o Reasonably predictable yields;

o Less time lost due to bad weather or breakdowns;

o Fewer equipment malfunctions and injuries;

o Reduced health risks to consumers.

Aquaculture operations do have drawbacks, however. These include:

o Water is necessary, in predictable quantity and quality;

o Large land area on which to construct ponds or access to large shallow area of water is required;

o Knowledge of culture conditions may not be generally available.

TYPES OF AQUACULTURE

There are five major types of aquaculture:

1. Transplantation: The movement of a species to a suitable location. This method in also used to introduce species into new environments.

2. Hatchery and Stocking: The spawning, hatching, and rearing of a cultural species that will be transplanted to suitable or desirable areas. This method is used to supplement or replace the natural stock, or for transplantation.

3. Enbayment Culture: The use of enclosures, such as ponds, cages, baskets, and strings, for aqua culture in natural waters.

4. Ponds with Supplemental Feed and Fertilizer: Aquaculture in natural or artificial ponds with food and fertilizer provided to maintain algae and species at desirable levels. In some systems, animal manures are used to provide fertilizer and some food.

5. Ponds without Supplemental Feed and Fertilizer: Aquaculture in natural or artificial ponds with the cultured species subsisting an natural available food in the pond water. This requires a high rate of exchange of water for high growth rates.

As can be seen, the basic theory of aquaculture is to obtain small animals and provide them with an environment that allows for their rapid, healthy growth. A desirable-sized fish can be harvested in a short period of time.

II. CULTIVATION REQUIREMENTS

The most commonly cultivated species of fish are carp and tilapia. Shellfish such as oysters and mussels, which are low on the food chain, are also farmed extensively. While culture techniques must be adapted to the needs of specific species and to local needs and conditions, some general rules apply:

1. The species must be Suitable for cultivation under the proposed conditions.

2. The program must develop the best method of cultivating the identified species from physiological, geographical, and market points of view.

3. Adequate support must be available. This includes changing and aerating the water, feeding the fish, maintaining equipment, marketing, and so on. Experimentation is often necessary to improve yields substantially.

4. Predators must be controlled.

5. Cannibalism must be controlled.

6. The species life cycle must be understood, and good, inexpensive feed must be available.

A dense population of animals demands abundant food and oxygen and a means of removing metabolic wastes. There is a limit to the size of the biological community that can be supported before growth is limited by competition for food, oxygen, and space. The high density of cultured animals makes them susceptible to disease and predation. To prevent juveniles from being attacked by these diseases, drained ponds must be thoroughly dried to destroy parasites and disease-causing organisms. The water and stocking animals should be free of parasites and disease-causing organisms. Feed and feed supplements should not introduce parasites or disease-causing organisms.

On the positive side, the fertile fish and shellfish wastes can be used in the production of leaf crops requiring nitrogen. Shellfish wastes are best used on fruit trees.

OVERALL OPERATION AND MAINTENANCE

Aquaculture systems can be operated and maintained in three ways:

1. Communal: This is subsistence cultivation that is some times publicly funded. The conditions are often mediocre, and production is poor because duties are attended randomly.

2. Family: This can range from subsistence cultivation to a very sophisticated operation, depending on the skill and energy of the owners. Under the worst of conditions, it can be more variable than communal; at its best, it can

exceed the standards of a dedicated system. The key to a successful operation is the family's commitment to putting forth the effort necessary to produce a quality product.

3. Dedicated: This operation is designed to produce food for market, and is usually well-regulated with high yields.

Each of these types of operation can be run as extensive or intensive culture.

Extensive Culture provides little or no control over the environment. Placing shellfish on a site and allowing them to grow on their own, or trapping fish and invertebrates in special enclosures and holding them until they reach market size, are examples of extensive culture. In extensive culture, the fish depend upon the natural food supply in the water. Only 20 to 50 percent of the stocked animals survive in this uncontrolled environment.

Intensive Culture on the other hand provides full control, over the environment. An indoor culture of shellfish, in which temperature, salinity (salt/water ratio), flow rate, feed type, amount of feed, and light are fully controlled, is an example of intensive culture.

No matter which type of operation or which method of culture is selected, sufficient food and oxygen must be provided. Oxygen levels of 4 to 5 milligrams per liter (parts per million) are satisfactory. Water can be aerated by spraying it out at least 0.6m (2 feet) in droplet form. Food requirements are discussed in a later section.

There is one other general consideration in aquaculture that is extremely important: The size of the animals. The animals stocked in the aquaculture system must be large enough to grow to market size in the desired time. Some preliminary experimentation is needed to determine the minimum desirable size. only healthy animals should be chosen for stocking the aquaculture system.

SITE SELECTION

An aquaculture system can be operated on a shore, in an intertidal region (zone between the high and low tides levels), in a sub-tidal region (zone below the low tide level), on a water surface, in mid-water, or on a seabed. Certain culture systems are better-suited to certain sites. A shore facility is usually used for fish and shrimp production. Full control (intensive culture) of the environment is characteristic of shore sites, and pumps may be needed to provide the water supply.

Controlled Pond Facilities

These are either man-made or natural areas that can be isolated from the water source. Water flows by gravity into the pond or is pumped in. Ponds are suitable for such fish as tilapia or carp, or even game fish such as salmon.

Intertidal Facilities

Intertidal facilities take advantage of the movement of the tides to replenish food and water. They are used for shellfish culture and spat (larval shellfish) collection and can be controlled if properly constructed. The incoming high tides are let into an area that can then be closed off. The high water, with its load of baby fish or shellfish, is dammed off and is held until the fish reach marketable size. Pumps may be necessary to provide the water supply.

Subtidal Facilities

Subtidal facilities have extensive culture (little environmental control) characteristics. No water pumps are needed, but detailed water quality analysis in required to ensure adequate circulation. Fouling organisms must be regularly removed from your stock and equipment.

Surface Floating Facilities

In this case, floating cages and rafts are used, which can be moved to protected areas if necessary. This is extensive culture and usually does not require pumping of water. However, fouling organisms may restrict the flow of water, creating supply and feeding problems. Supplemental feeding may be necessary, and fouling organisms must be removed regularly.

Mid-Water Culture Facilities

Mid-water culture facilities consist of strings of mollusks (shellfish) suspended through the water column. Since this is extensive culture, restricted flow may create fooding problems. Fouling organisms must be removed periodically.

Seabed Culture Facilities

These are also extensive culture sites and may be subject to fouling organisms that restrict water flow and cause feeding problems. Because of natural flow restrictions along the bottom, oxygen and food supply may be reduced.

For all of those sites, you must evaluate the exposure to pollution from land runoff (pesticides or siltation), and f rom sewage and industrial wastes. Ways of protecting a site from high winds and waves must also be evaluated.

MATERIALS

Enclosures are needed to keep predators away and to prevent the loss of stock through sluice gates and other outlets. Materials used in aquaculture must:

1. Have a long visible life.
2. Be resistant to fouling.
3. Be easily cleaned.
4. Be nontoxic.

Structures supporting enclosures within the intertidal zone must be rigid to allow for the rise and fall of the tide. Floating rafts, nets, and cages must be anchored to allow for wind and waves. Wind and waves cause wear and abrasion of the materials. The structure may also need fine-mesh nets for protection from predators and coarse-mesh nets for protection from trash and floating objects.

Surface floating units, consisting of a timber structure on floatation barrels or floats, require much maintenance. The condition of the floatation and framework should be checked often, especially when used in salt water. Before using any material in water, especially salt water, the effects of marine predators on the material should be evaluated by installing test pieces for at least one growing season.

Organisms growth on equipment and shellfish can be removed by brushing, hand picking, or high-velocity water jet. Growth may be prevented in some cases by periodically removing the material from the water. In removing growth, care must be exercised to ensure that the underlying material (rope, net, and shell) is not damaged.

FOODS AND FEEDING

Fish or shellfish cultured must be limited in number so that each animal can obtain enough food to grow. Insufficient food will result in slow growth, or even shrinkage, small animals (dwarfism),

and a high potential for disease. Harvest has been found to increase as much as 1,000 percent when animals are fed regularly. Figure 1 shows how the growth rate can be graphed.

ua1x7y.gif (540x540)

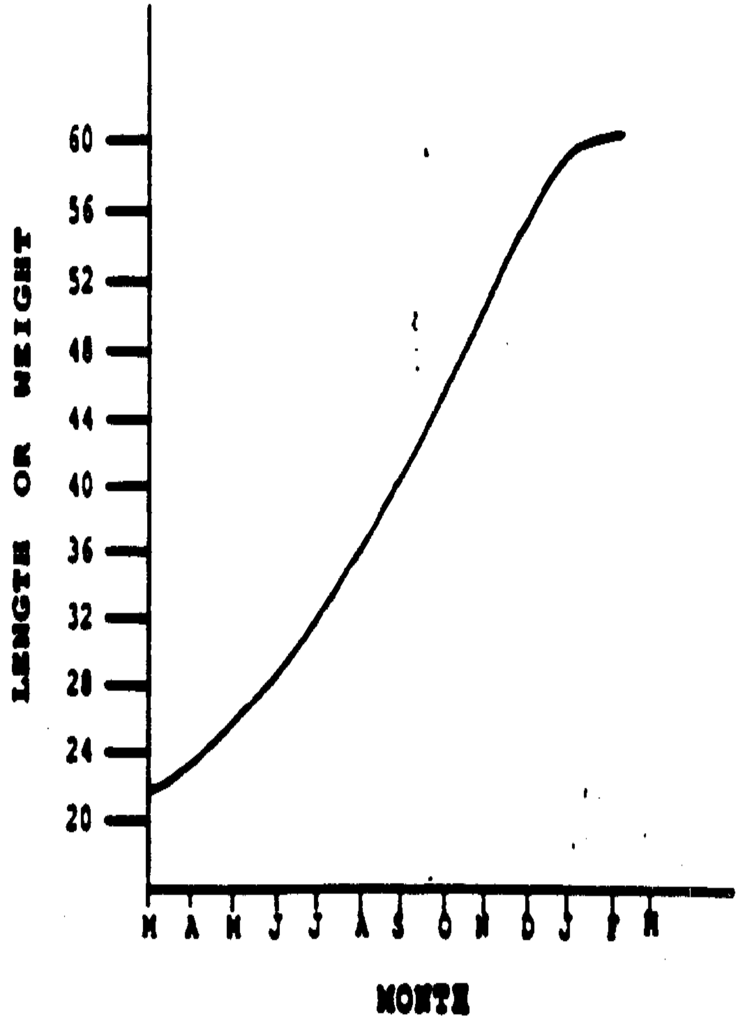

Figure 1. Growth-Time Relationship (Hypothetical)

The conversion rate from feed to flesh varies with fish species, food type, temperature, individual fish, and food availability. Generally, it in between 10 to 1 and 20 to 1. Cultured fist and shellfish should not be overfed, since unconsumed feed sinks to the bottom, decays, and aids the development of algae growth, while reducing oxygen levels through the decomposition process. Although some of this fertilization is good, too much growth creates low oxygen levels. Fish should be fed 6 days a week at the same time and place each day, ideally, 2 to 3 hours after sunrise or before sunset. To empty the digestive tract and produce better-quality fish, don't feed them on the day before harvest.

Feed only what will be eaten daily. If a floating feed is used, feed what in eaten in 10-15 minutes. Observe the response to feeding: If the fish do not appear hungry, there may be logical reasons (abundant natural food available, low dissolved oxygen, poisons, etc.) and feeding should be discontinued until the reason in found and corrected. If sinking food in used, check the feeding response by placing a 1.2m x 1.2m (4 feet x 4 feet) tray on the bottom in the feeding area. After 1 hour, raise the tray slowly and carefully. Look for feed on the tray. If the feed has not been completely consumed, reduce the amount of feed. Generally, fish will eat one tenth to one half their own weight per day.

Both natural and artificial foods say be used. Controlled fertilization of ponds in order to increase their productivity and providing more natural food to the cultured species are established practices. Artificial foods (those that will be consumed directly without conversion to algae) consist of plants, processed food, and certain industrial wastes. Examples of plant foods are the leaves of the cassava (tubers and peelings are not suitable), sweet potatoes, eddoes, banana, paw paw, maize, and canna plants. Processed foods include meal waste, cassava bran, flour, rice chips and balls, corn flour, and cotton and groundnut oil cakes. Industrial wastes such as decomposed fruit, brewery sediment, coffee pulp, and local beverage wastes have also been used successfully.

Fertilizer is added to a pond to ensure that there are minimum amounts of nitrogen, phosphorous, and potassium in the water to support algae growth. The requirements will vary with the water quality and fish population. Fertilizer should be added before the fish-growing season and repeated at ten-day intervals to produce the desired algae population, known as a bloom. After the bloom, add fertilizer as necessary to maintain a light bloom. The density of the bloom must be adjusted for different seasons, since too much algae will cause a reduction in the dissolved oxygen levels and could kill fish. A desirable bloom will shade out a bright object 0.3 - 0.5m (12-18 inches) below the surface. If 3 to 5 applications of fertilizer are made and a bloom is not observed, there may be other problems, such as filamentous algae or other plants using the fertilizer. These must be killed before phytoplankton algae can grow, unless the aquaculture system uses filamentous algae or large plants. If filamentous algae or larger plants are consistent problem, you should consider adding species of fish that can eat then, thus converting then into useful protein, rather than staying in a constant battle to remove them.

The pond can be fertilized in three ways: by spreading the fertilizer over the water surface; by placing perforated bags at intervals around the pond edge to allow the wave action to dissolve the fertilizer; or by placing the fertilizer on sub merged floating or stationary platforms off the bottom. That last method provides the best results with the least fertilizer. Although agricultural runoff may help by providing nitrogen and phosphorous from the fields, pesticide and herbicide residues may destroy all of the fish in the pond. The direct application of animal manure has been shown to be effective in producing algae bloom, but it does have two potential dangers. Oxygen may be used up and ammonium (a reduced form of nitrogen) may reach too high a level. Both of these problems can be avoided if manures are used in moderation or if they are held in a pretreatment aeration pond. In general, if used carefully, animal manures may be an excellent, inexpensive, source of fertilizer for the fish pond. The aquaculturist should, of course, be aware of any religious or cultural taboos against such use that may affect marketing. (If taboos exist, the fish can be hold in "clean" ponds, or use of the manure can be suspended, for a week or two prior to harvest.

III. CULTURAL METHODS

Fish can be grown in open ponds or in cages in ponds. Shellfish, on the other hand, often do better in what is called suspension culture. These three methods are described below.

POND FISH CULTURE

Types of Pond Culture

There are four general types of pond fish cultures: mixed age groups, temporary age group mixing, separated age groups, and controlled reproduction.

The Mixed Age Groups Method. This method produces all sizes of fish in great quantity. The level of production is maintained by catching some fish while the fish are growing. This may be done with a hook and line or a limited number of traps. At the end of the growth period, the pond is drained and all fish are harvested. Some are selected for restocking the pond when it is refilled. This method provides a high production rate if the fish are well-fed. Fish from a different source should be put if the pond periodically to improve the fish quality.

The Temporary Age Group Mixing. This culture produces a large portion of equal-sized fish. The pond in stocked with young fish of approximately the same size, which are fed and allowed to grow and reproduce once. When the largest of the fish spawned in the pond are large enough to use for restocking, the pond is drained and the fish harvested. All adults are sold or used for food; the smaller fish are used for restocking. In this method, the weight per fish is usually small. A mixed size fishery usually evolves from temporary size mixing.

Separated Age Groups Method. In this method, two ponds and heavy feeding are used to produce table or market-size fish as rapidly as possible. Adults of a single species are introduced into a reproduction pond. When the young spawned in the reproduction pond are large enough to survive in a larger growing pond, they are transferred to the larger pond.

The "Natural" Predation Method. This method attempts to balance the fish's growth and reproduction through the introduction of a predator. The results of this method are uncertain, since over-predation will reduce or even eliminate the population, leading to too many fish that are too small (dwarfing).

Controlled Reproduction Methods. These methods control the sizes and numbers of fish in the growth ponds by controlling reproduction within a laboratory. Fish stock in the ponds do not reproduce because conditions in the pond are not favorable for the species used or because something is done in the laboratory to prevent fertility. One method that has been used with some success if separation of fish by sex. Males and females are simply placed in separate ponds. However, this is a very difficult method to use, because a small number of males in the female pond (or vice-versa) will cause reproduction in the female pond (and in the male pond to a lesser extent).

Other methods include production of sterile hybrids, operating on fish to sexually denature them; or treating the fish to reduce fertility.

Construction and Operation of Fish Ponds

Once pond cultivation has been decided on, the technical considerations must be addressed. A suitable location with an adequate water supply must be chosen. The soil must be able to contain the water in the pond. The water quality must be adequate for the species, and the quantity must fill the pond in less than one month and replace losses due to seepage and evaporation.

Water Supply. There are several sources of water for pond culture, including rainfall, surface water, springs, and wells. Surface water often contains unwanted fish, pollution, parasites, and disease, and is the least desirable water source. It is often necessary to aerate to remove undesirable gazes and raise the

ua3x13.gif (600x600)

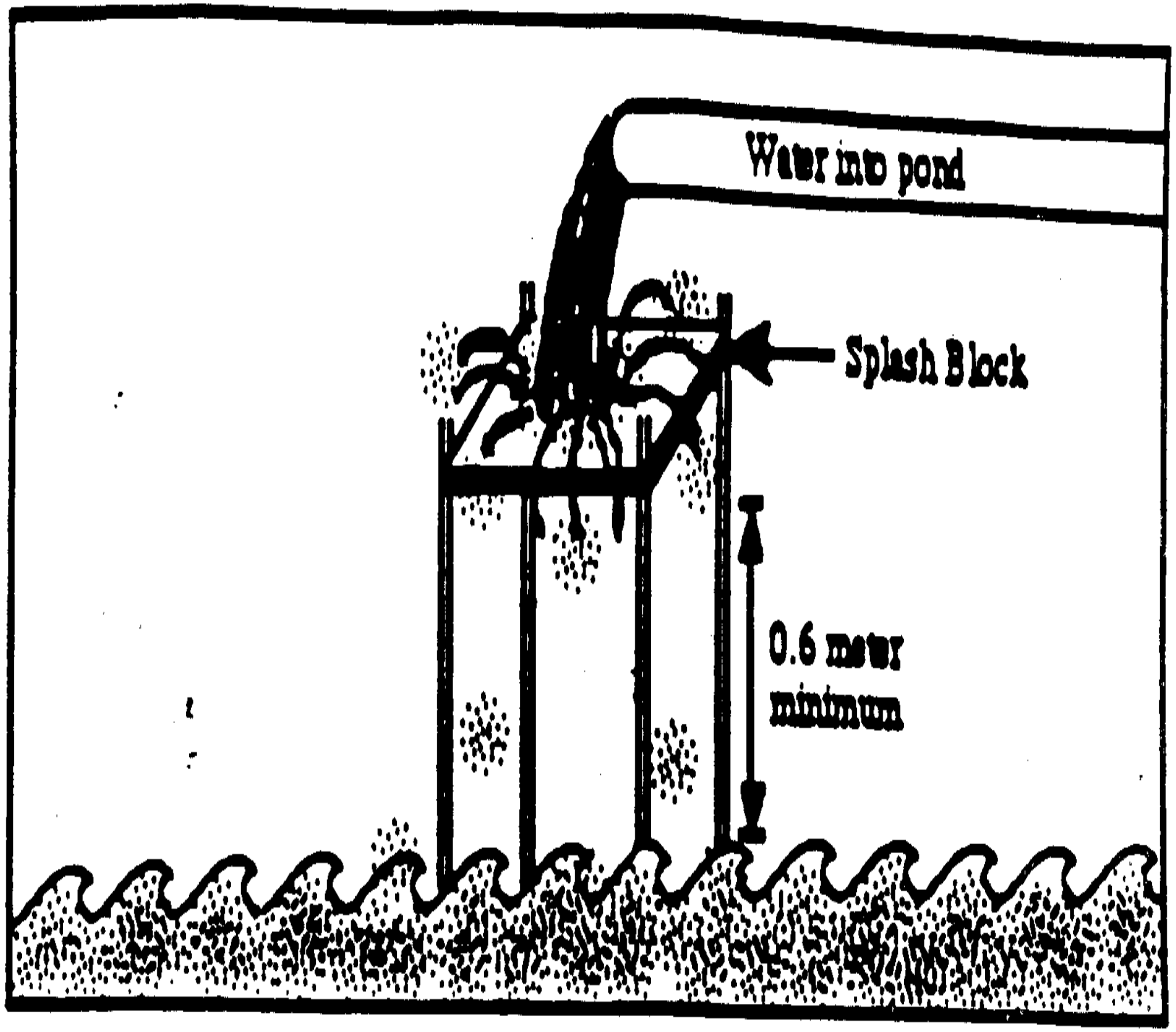

Figure 3. Gravity Aerator

oxygen level. Springs may also contain unwanted fish and can dry up at the time water is most needed. Rainfall may be even more undependable and low in nutrients. But it will generally be free of pollutants and high in oxygen.

Well water in usually the highest quality (especially when it comes from covered wells). It does not contain unwanted fish or suspended material, and is protected from flood water. But it also may need aeration to remove undesirable gases and raise the oxygen level. If the well's water source is of uncertain quantity or quality, test wells should be constructed first.

The minimum pond water depth depends on the air temperature, seepage rates, and the dependability of the water supply. In an area dependent on seasonal rains, the water should be at least 3m (10 feet) deep over at least 25 percent of the pond. In warm areas with low seepage or sufficient water supply, the minimum depth may be as little as 1m (3 feet). If the pond will be ice covered for one month or more, the pond will have to be at least 6m (20 feet) depth to prevent winter-kill.

Woods may grow in shallow water. Since this may be beneficial, removal will depend on whether the benefits outweigh the problems associated with the additional use of nutrients, loss of pond volume, and potential oxygen use when the plants decay. Shallow areas with weeds are favorite brooding areas for mosquitoes. It is recommended that the pond be not less than 12 (3 feet) deep to minimize weed and mosquito growth, or herbivorous fish, such as grass carp, should be among the species stacked in the pond.

Pond construction. The pond should be constructed with side slopes in a ratio of 2.5 to 1 and a gentle bottom slope of at

least 6.4cm per 30m (2 1/2 inches per 100 feet). (see Figure 2.)

ua2x11.gif (600x600)

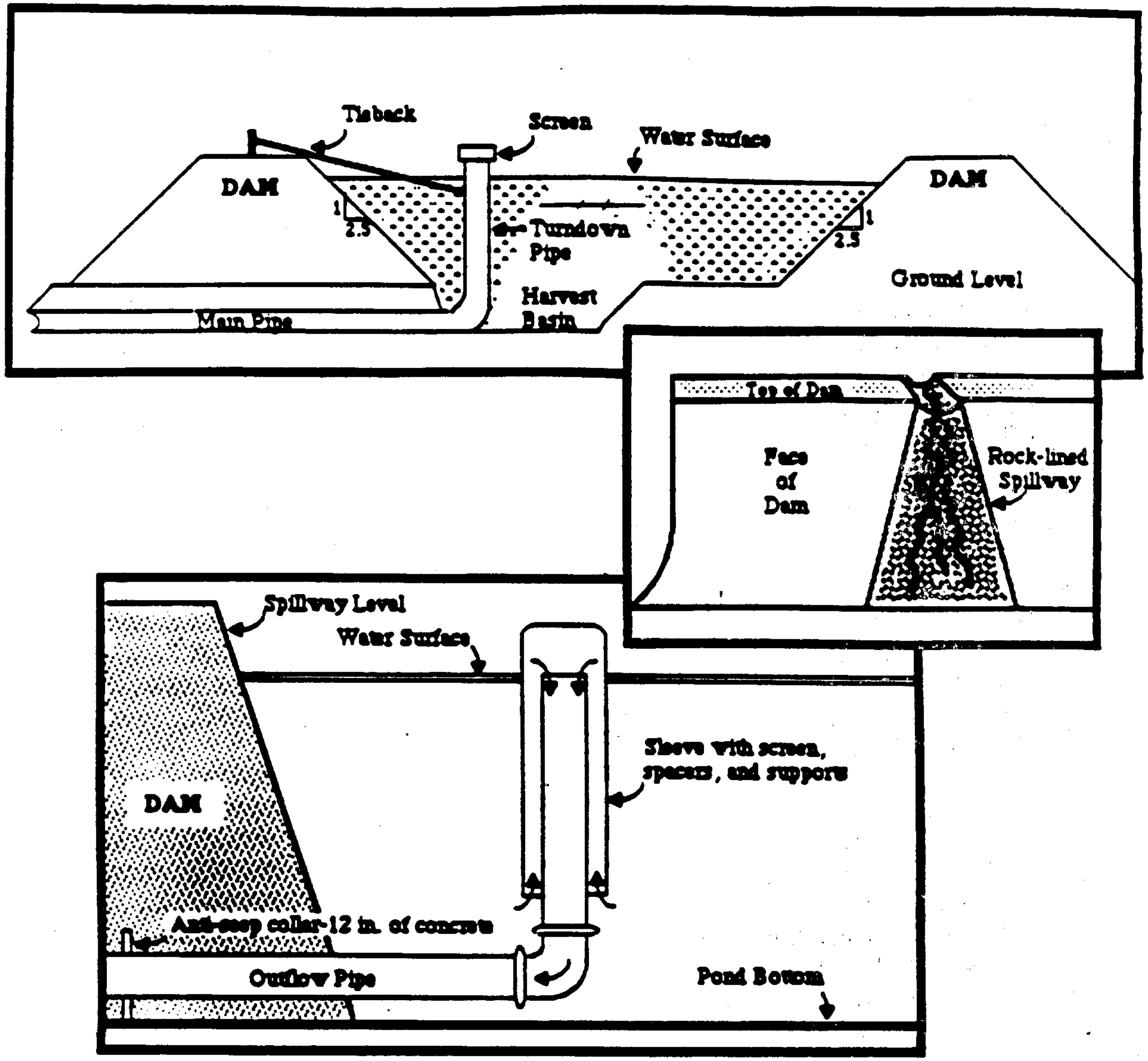

Figure 2. Pond Cross Section, with Details of Spillway and Turndown Pipe

To stabilize side slopes, grass should be planted as soon as possible after construction. If the bottom material consists of good stable soil, put in a drain well, or harvest basin. Although

most fish are harvested by netting, some will escape and be easily caught in the drain well. The drain should be approximately 1/10 of the size of the production area and 0.7m (2 feet) deeper than the surrounding area.

It may be necessary to build a dam to trap the water for the pond. If so, assistance should be gained from a qualified engineer, as a break in the dam can have serious consequences. An emergency spillway that prevents water from flowing over the top of the dam should be constructed when the pond is created. The spillway must keep the flow shallow enough or must have a barrier so that large fish stay in the pond and unwanted fish cannot enter. A vertical overflow from the spillway of 0.7m to 1m, (2 to 3 feet), or a turndown pipe, will keep out unwanted fish.

A drainpipe large enough to drain the pond in less than five days should be placed in the bottom of the pond through the dam. A trickle tube--a small adjustable-height pipe that allows excess water to flow out without going over the spillway--may be connected to the drain pipe. The trickle tube should be small enough to prevent small fish from swimming out. It can also be used to regulate the depth of the water behind the dam.

To prevent decaying material from reducing the oxygen levels and to allow harvesting with nets, all trees, bushes, rocks, and stumps should be removed from the pond bottom and sides. Any trees within 9m (30 feet) of the edge of the pond may have to be cleared to reduce leaves, which can discolor the water and promote algae growth. Algae and decaying leaves cause oxygen

depletion, which may endanger the fish. On the other hand, both can be a source of food and might be desirable depending on the species chosen for culture.

Operation. Unwanted fish must be prevented from entering the pond wherever possible. Incoming water should be filtered and the pond located so that the overflow from streams does not enter. This will also exclude disease-carrying organisms and parasites. To keep birds from landing and taking off in the pond, you may have to stretch crossed wires across the pond.

It is critical in pond operation that an adequate amount of oxygen be dissolved from the air into the water. Without enough dissolved oxygen, the fish will die. To maintain adequate levels, do not make the pond too deep and provide a means to aerate the water if necessary (Figure 4). Unless there is good circulation

ua4x15.gif (540x540)

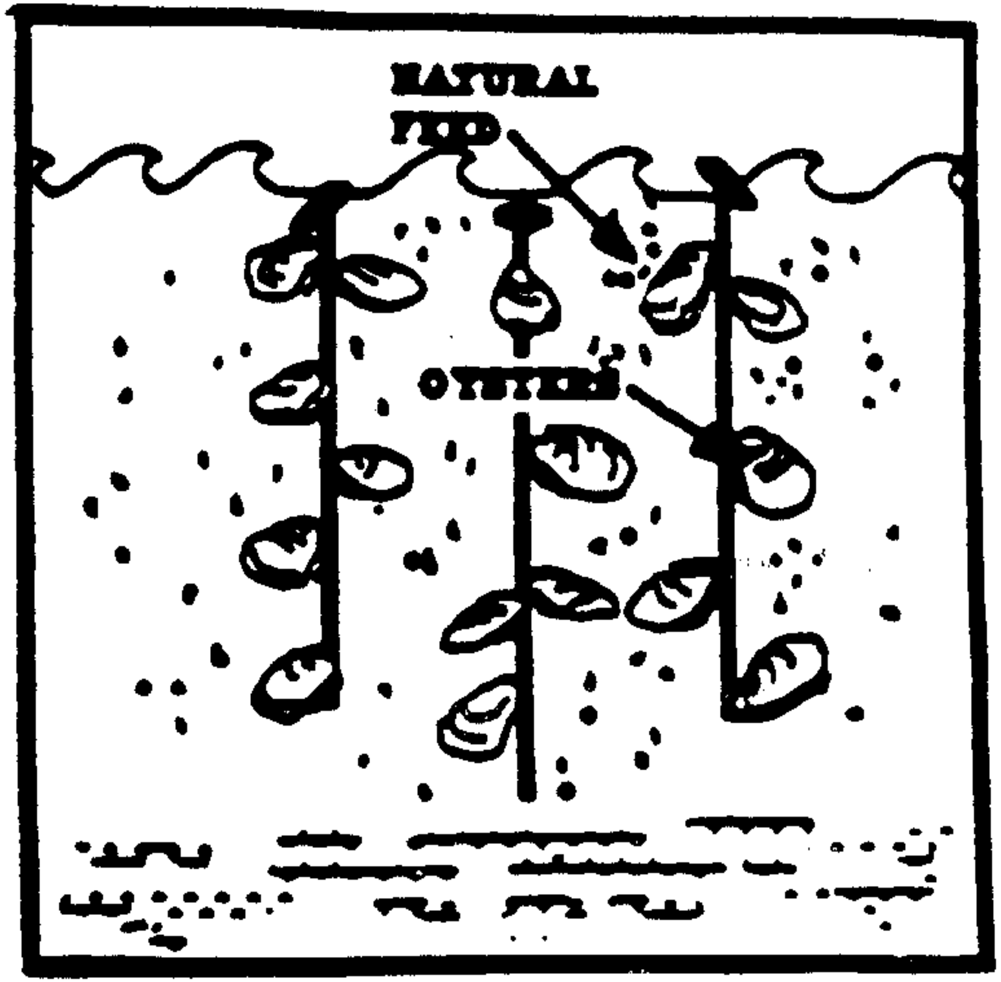

Figure 4. Suspension Culture

from the top to bottom, the bottom sediments will become anaerobic without oxygen) and produce hydrogen sulfide. This will interfere with the ability of fish to use the available oxygen, without which they may die. Decay from dead fish also requires oxygen, which reduces the oxygen available for the live fish, thus creating a deadly cycle. The pond must be filled with good water, ever-fertilization must be avoided, and dissolved oxygen levels should be checked frequently, especially at daybreak.

Harvesting

Harvesting the fish may be done by partially draining the pond

ua3x13.gif (600x600)

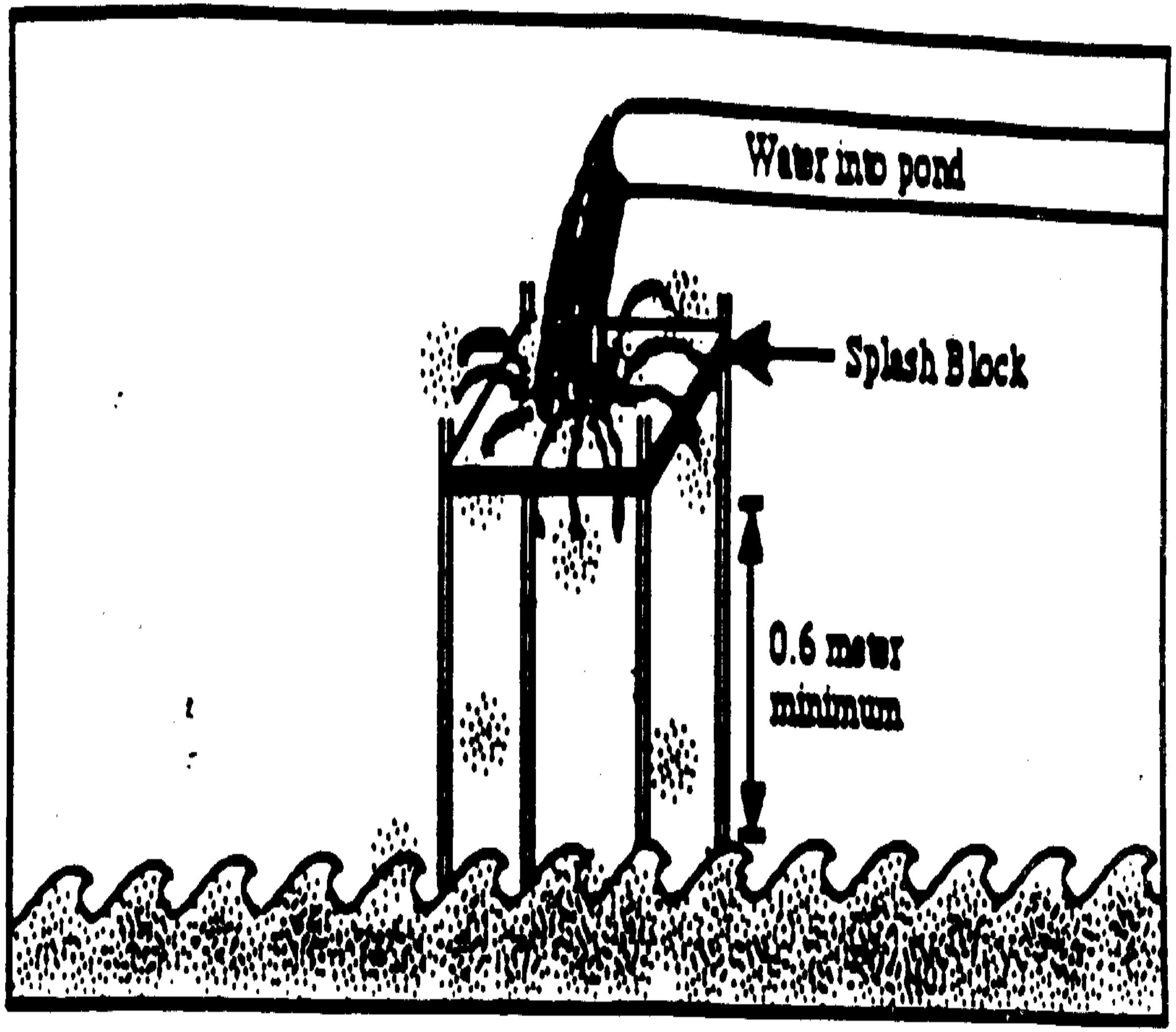

Figure 3. Gravity Aerator

and netting the fish. Make the not large enough to let undersized fish escape. Do not drain the pond down so far that the undersized fish are killed. The water level should be reduced slowly enough to allow the fish to move to deep water to prevent their death from stirred-up sediment and a lack of oxygen. Harvesting is best done in cool weather, but can be done at any time. After drying the pond and performing any necessary maintenance, refill and restock the pond.

Salt Water Ponds

Although most of the information in this section has related primarily to freshwater fish ponds, the same approach can be used to grow salt water fish in ponds. With a salt water pond, the tide circulates new water through the pond frequently enough to prevent low dissolved-oxygen levels. Predatory fish and crabs must be kept out of the pond. Crabs entering the pond can be trapped, but it is best to keep them out in the first place. Any starfish and crabs that are found in weekly inspections should be picked up and used for crop fertilizer, eaten, or grown in another pond and used for human or animal food.

CAGE FISH CULTURE

Fish can be confined to cages anchored in ponds, lakes, or salt water bodies. This method of growing fish is most often used when the desired species is not spawned in captivity, and the young can be caught in the wild and placed in cages to restrict their movement. They must be checked frequently for disease and parasites, but should be handled as little as Possible. Oxygen levels must be kept high enough for the fish Species. Regardless of which method of cage culture is Used, the water must have enough oxygen to prevent suffocation of the cultivated fish. Competing organisms must be removed with brushes, picks, or high-velocity water jets.

Cages

It has been found that unprotected metal cages rust quickly. Therefore, it is advisable to use plastic-coated metal whenever possible. Other materials, such as plastics and bamboo may be satisfactory. Cages should be anchored firmly, with the top of the cage high enough to retain food when the fish are being fed. The cage top should extend down about 20 cm (8 inches), and about 5-10cm (2 to 5 inches) below the water. Rigid or floating netting may be substituted for the top. At least 30cm (1 foot) must be left between the bottom of the cage and the bottom of the pond or ocean to keep predators from entering and to prevent wave action from bumping the cage on the ocean or pond bottom. Fish in cages must be fed if they are not plankton eaters. The outside of the cages must be cleaned periodically to remove fouling organisms and restore water flow through the cages.

Raceways

Raceways are long narrow artificial channels in which fish are raised. Water is usually recirculated in this type of system. The ends are secured to prevent the escape of the fish. A raceway system requires a water supply pond, a method of regulating the depth of the water in the channels, a settling basin to remove dirt and deposits, an auxiliary water supply, and a pump. This is a very complex, energy-using system.

Shrimp Ponds

Shrimp are often cultured in ponds where post-larval shrimps are washed into the ponds at high tide. Shrimp ponds must have a hard bottom consisting of sandy-silt, or the pond bottoms may become anaerobic. This is critical with shrimp, since they burrow, into the bottom of the pond during the day. Shrimp ponds are constructed with gates that allow the water and shrimp to enter at high tide when the gate is open. The opening in screened on the ebb tide to prevent the loss of the shrimp. Shrimp culture requires circulating water to keep the bottom oxygen levels high.

Shrimp are harvested by placing a not at the pond outflow at night on an ebb tide. Do not harvest shrimp by draining the pond as those in their borrows will be lost. The pond should be drained and baked in the sun for 3 or 4 days once a year.

SUSPENSION CULTURE

Oysters and other mollusks grow better with fewer deaths in suspended culture. Shellfish may be cultured on the bottom, on stakes or racks, in cages or nets, from rafts, or from long lines. They must be grown in the intertidal or subtidal zones.

Shellfish culture begins with the collection of the seed, called spat. Spat are the spawned animals that are ready to set on a hard object. Many shellfish do not move once they attach to something, so a proper material is essential. Collection units consist of shells on strings laid over or tied to racks, sticks, plastic disks, ceramic tiles, mesh bags of shells, or any other hard rough surface. Mussels prefer fibrous material such as coarse fiber ropes. These are placed in the water when shellfish are ready to attach at the time of spawning (to reduce fouling). After about one month, the collectors are moved to hardening racks where they are exposed only at low tide. They are raised gradually until they are exposed f or 4 to 5 hours per tidal cycle. This helps produce a thicker shell and stranger animal that can survive the first hibernation period (spawning usually occurs in the spring and fall). Mussels are transferred directly to the growing area and are placed on posts or strings to grow since they have the ability to reattach themselves once removed from a surface.

Suspended culture of shellfish is practiced because it allows the use of all depths of water and helps control predators. Off-bottom culture provides a better quality product with no pearls, better meat yield, good meat color, and no foreign particles within the shell. The highest yields are obtained in the early spring, before the shellfish spawn, then again in late summer before the fall spawning.

The ABC's of Suspension Culture

ua4x15.gif (540x540)

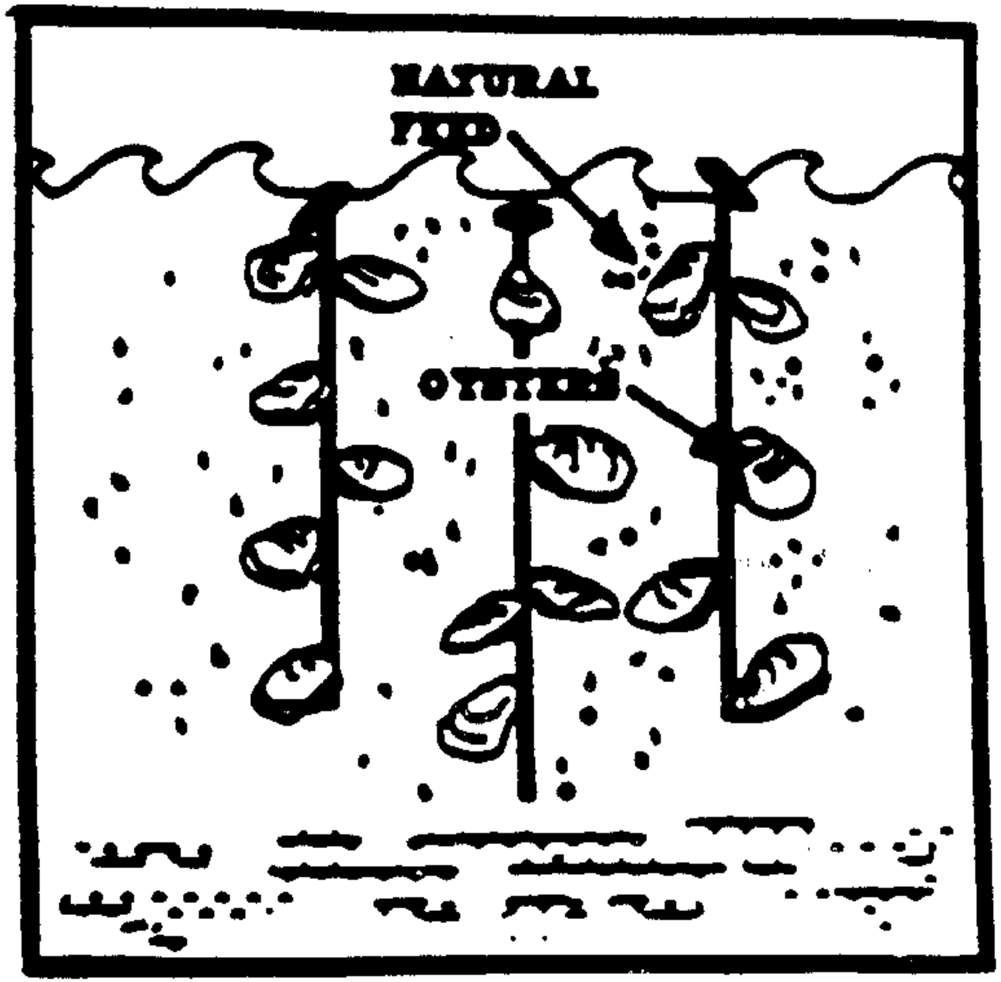

Figure 4. Suspension Culture

* Anchorage - making sure the shellfish stay where they are put.

* Buoyancy - keeping the strings from touching the bottom.

* Cultivation Materials - making sure the materials are sound.

Shellfish spat may be collected on racks in shallow water 2 to 4m (6 to 12 feet) at low tide. A rigid frame structure of poles planted vertically with horizontal ties are placed in the collection area. The collectors are arranged so there are 6 to 10 collector plates 20cm (8 inches) apart on strings 1.5m (5 feet) long. Twenty units are hung in every 3.3 sqare meters (10 square foot) area. Mussel collectors are best made from woven grasses, 1.5cm (3/4-inch) square wood pegs 25cm (10 inches) long are 40cm (2-foot) intervals.

Oysters are generally cultured by suspending them from rafts or long lines. Rafts are usually made of cedar or bamboo poles tied together in two perpendicular layers. Styrofoam cylinders, drums or floats are usually used for floatation. Additional floatation must be added as the shellfish grow. Rafts are usually 8 x 16m (26 by 50 feet), and contain 500 to 600 vertical strings of spat. Rafts are often tied together end to end and anchored at the ends of the row. They are placed in rows 102 (35 feet) apart. Production will vary depending on the amount of spat collected,

disease, predation, available food, and water temperature.

In long-line culture, lines about 70m (225 feet) long are buoyed by wood or styrofoam floats or glass balls. Floatation is initially 3m (9 feet) with more added as the shellfish grow. The lines are placed 10m (35 feet) apart and anchored at each and and in the center. Usually it is leas expensive to construct and maintain long lines, which withstand wind and waves better than do rafts. The vertical strings of spat are placed 45cm (18 inches) apart. They can be of any manageable length, but are usually in multiples of 5m (16 feet).

In areas where predators, waves, or winter storms are a concern, shellfish can be cultured in floating net cages. These are usually 10m (35 feet) square, 3 to 5m (9 to 16 feet) deep. They consist of floats, nets, and an anchored rectangular frame. These small rafts with the shellfish enclosed in cages can be moved to sheltered areas in winter, when storms approach, or for maintenance. Several cages can be Joined together to form a large raft.

It is extremely important to recognize that the strings and cages require maintenance to remove fouling organisms. The strings must be removed from the water periodically and washed with a high pressure spray. A barge-mounted crane will be necessary for raft or long line culture.

The large volume of waste produced by cultured shellfish creates special problems. A 60 square meter (600 square foot) bed can

produce between 1/2 and 1 ton (dry weight) of organic material. Decay of this material can cause anaerobic conditions close to the bottom, killing the shellfish on the bottom of the strings.

Monitoring Growth Rates

Shellfish have highly variable length-weight relationships that must be determined before the culturer can decide how long the shellfish must be grown and whether shellfish culture has a reasonable return for the time spent.

Probable growth can be determined by suspending about 25mm (1 inch) long shellfish in containers about 1m (3 feet) bellow the water surface. The container must have a good water circulation; the holes should be about 1cm (1/2 inch) in diameter. Inspect the shellfish monthly, brushing them clean, measuring them, and recording lengths and weights. Average the measurements and graph them, with the length (or weight) on one axis and the month on the other. This will provide a good guide to time of growth and feeding.

The shellfish cultures in the wild will suffer a higher mortality due to fouling organisms. The size at harvest should be deter mined by the use. Reference to the size-month chart will give the minimum length of time needed to culture the shellfish to that size. In practice, it is usual to allow one additional growing season for all shellfish to reach that size.

Mussels are slightly different from oysters in that they will attach themselves to a secure place after being harvested and replanted. Mussel seed can be placed in very coarse cotton tubes and fastened in a spiral around ropes or thick poles driven into the ground. By the time the cotton has decayed, the mussels should be attached to the rope or pole. They can be harvested, cleaned, and graded with the smallest ones returned to the water in now tubes. They should be kept out of water for the shortest time possible.

To harvest mussels from strings, a collecting basket must be placed under the string when it in lifted to catch those mussels that drop off.

IV. DECISION MAKING FACTORS

The management of a high density aquaculture operation is complex, requires hard work, and is subject to the whims of nature. An difficult as it might appear, aquaculture has continued for thousands of years and is the source of food for many people today. Even though there will always be problems, the beginner aquaculturist is encouraged to start on a small scale, allowing the aquaculture operation to grow an the product does, in a controlled manner.

Researchers are working an improving aquaculture techniques. Specifically, they are working toward identifying additional species suitable for culture, producing industrial fish (for fish meal), and improving methods of managing various aspects of aquaculture such as seed supply availability and disease, predator, and water quality control. other areas of research include genetic improvement, manipulating water temperature, and treating fish with hormones to promote spawning, and identifying new protein sources (e.g., agriculture wastes and yeasts grown on petroleum products or wood pulp) to replace fish meal in feed formulations and to reduce the cost of feeding fish.

Some of the problem the aquaculturist will likely face include the effects of corrosion, fouling, weather, and climate. The aquaculturist will also encounter conflicting complaints and demands from those concerned about land and coastal areas, water use, and pollution. Aquaculture risks may be natural (adverse weather, disease), economic (price and market changes), or human improper care).

ECONOMICS

One major constraint on aquaculture development has been the limited supply and high cost of juvenile animals obtained from nursery areas. This can be solved locally by raising animals and producing juveniles, or by harvesting juveniles from their natural habitat. Once the basic problem of mating, spawning, and raising the juvenile stages have been solved, the hatchery production of large numbers of juveniles becomes routine and inexpensive. It does not require large or expensive facilities. By contrast, many variables make reliance on the harvest of wild juveniles a very risky long-term undertaking.

In evaluating the economics of aquaculture, it must be remembered that the price of the product is very important and will decrease as the fish supply increases. The price must exceed the cost if the project is to succeed. The cost of the right to use the property or the right of access to the culture area must be considered in addition to the equipment, maintenance, and labor costs.

MARKETING FACTORS

In marketing your aquaculture products, you need to:

o Develop a marketing system, including disseminating product information and identifying products that consumers will want to buy.

o Set or adhere to quality control standards.

o Consider transportation and marketing facilities.

o Preserve your fish products to prevent their spoilage before they can be sold.

SOCIAL FACTORS

Social factors that may affect your decision to pursue aquaculture include:

o The williness of your community to respond to changes in technology (e.g., from the technology of ocean fishing to that of aquaculture).

o Acceptance of your aquaculture products. For example, traditional food preferences and religious or cultural taboos may impede the acceptance of your products.

ENVIRONMENTAL FACTORS

Establishing an aquaculture operation may cause degradation of the environment through dredging and filling, pond effluent discharges, increased mosquito population, and exploitation of natural resources.

Care must be exercised when a new or foreign species is being considered for culture. A new species could escape into the wild and, without natural predators, multiply rapidly with disastrous consequences for the overall ecological balance.

LEGAL FACTORS

Consult your local authorities to find out whether there are any laws or regulations that may prohibit you from developing an aquaculture system or using an aquaculture area.

GLOSSARY

Anaerobic - Without free available oxygen

Aquaculture - The controlled cultivation and harvest of aquatic plants and animals.

Filter Feeders - Shellfish that food by filtering food particles from the water through their gills.

Food Chain - Transfer of food energy through a series of organisms with many stages of eating and being eaten.

Invertebrates - Lower animals, without backbones.

Larval Stage - An immature stage of an invertebrate animal. The animal in this stage is called larva (plural, larvae).

Mollusk - Invertebrate characterized usually by a hard, limy, one or more part shell that encloses a soft, unsegmented body.

Parasitic Organisms - Organisms growing on cultured organisms and competing for the available food and oxygen.

Predation - The act of an animal eating another animal, usually smaller and of a different species.

Spat - Young mollusks past the free-swimming stage and ready to settle and attach to a hard object.

BIBLIOGRAPHY

Burrill, G., and Lynch, K. An Evaluation of the Aquaculture Extension Project at Goddard College: Report to the ARCA Foundation. Bennington, Vermont: Goddard College, 1975.

Chakroff, M. Freshwater Fish Pond Culture and Management. Arlington, Virgina: Volunteers in Technical Assistance (VITA), 1976.

Conklin, D.E. "The State of Aquaculture," The professional Nutritionist, Vol. 8, 1976, pp. 3-7.

Cramer, D. L., Slabji, B.M., True, R.M. "Seasonal Effects on Yield, Proximate composition, and Quality of Blue Mussels, Mytilus Adults, Meats obtained from Cultivated and Natural Stock," Marine Fisheries Review (Volume 40, August 1978), pp. 18-23. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. Washington, D.C.

Cuyvers, L. Aquaculture 1980. Newark, Delaware: University of Delaware Sea Grant College Program, 1981.

Gates, J.M. "Aquaculture in Less Developed Nations, Some Economic Considerations." Presented at the Conference of the Marine Technical Society, Washington, D.C., 1971.

Grinzell, R.A.; Dillon, O.W., Jr.; and Sullivan, E.G. Catfish Farming. Farmers Bulletin, No. 2260. Washington, D.C.: U.S. Department of Agriculture, 1975.

Imai, T. Aquaculture in Shallow Seas: Progress in Shallow Sea Culture. Now Delhi, India: Amerind Publishing Co., 1971.

Jensen, J. Home-Grown Fish from Cages. Circular ANR-269. Auburn, Alabama: Alabama Cooperative Extension Service, Auburn University University, 1981.

Landis, R. C. A Technology Assessment Methodology. Mariculture (Sea Farming). McLean, Virginia: The Mitre Corporation, 1971.

Lutz, R.A, Bivalve Molluscan Mariculture: A Mytilus Perspective. Contribution No. 138. Walpole, Maine: Ira C. Darling Center, University of Maine, 1978

Meyers, E. The Husbandry of Mussels in a Maine Estuary: An Approach to a Commercial Enterprise (Publication No. UNH-SG-164). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, University of New Hampshire/University of Maine Sea Grant College Program. Washington, D.C. 1981.

Milne, P. H. Fish and Shellfish Farming in Coastal Waters. London, England: Fishing News Ltd., 1972.

Missouri Conservation Department. Fish Farming: What You Should Know. Jefferson City, Missouri: Missouri Conservation Department, 1981.

Ouasim, S.Z. "Sea Farming: An Appropriate Technology for

Generating Sea Food," Appropriate Technology, Volume 6, 1979, pp. 26-28.

Shapiro, S. Our Changing Fisheries. Washington, D.C.: U.S. Government Printing Office, 1971.

Tyther, J.H. "Mariculture: Potential Protein for the Third World," The Commercial Fish Farmer. Little Rock, Arkansas: Catfish Farmers of America.

U.S. Department of Agriculture. The Yearbook of Agriculture. Washington, D.C.: U.S. Department of Agriculture, 1978.

==

==