# THE DEVELOPMENT OF AQUACULTURE: AN ECOSYSTEMS PERSPECTIVE

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# INTRODUCTION

CARVINGS OF FISH found in caves inhabited by our early ancestors and piles of shells discarded by ancient coastal inhabitants attest to the important role that aquatic animals have played in the lives of humankind. These animals are equally important today. Fish, shellfish, and crustaceans are the major source of animal protein consumed by people in many areas of the world. Aquatic animals are among the most widely traded and transported food commodities. Recreational fishing is a multi-billion dollar industry in North America, and the aquatic animal "pet" industry is valued at several hundred million dollars.

Throughout most of history, humans have harvested aquatic animals from streams, lakes, bays, and oceans. In contrast to terrestrial animals, there was almost no domestication of aquatic creatures. As the human population increased in size, people simply harvested more. When they reduced the number of animals available inshore, they devised improved nets and traps and increased the rate of exploitation still further. When harvest was reduced to a point of unacceptable diminished returns, they developed fishing boats to be used in harvesting aquatic animals offshore.

The relationship between an increasing human population and increasing harvest persisted generally throughout history until the 1970s. At that point, a rapidly growing world population coupled with an increase in the consumption of fish per person and a leveling off of the increase in the amount of animals harvested from natural waters led to a reduction in the quantity of fish available per person. From that time onward, the harvest of fish from wild populations could no longer keep pace with growing demand, and it has been estimated that worldwide demand will exceed supply by 20 million metric tons at the beginning of the 21st century (Neal, 1987).

Most fishery scientists agree that the harvest of aquatic animals from natural systems cannot be increased substantially. While there will be some increases in the harvest of under-utilized species, this increase will only offset the reduction in harvest of some over-utilized species. With this perspective, it is apparent that significant increases in the supply of aquatic animals can be achieved only by direct intervention in the production process or through aquaculture.

I noted previously that aquaculture had contributed relatively little to the supply of aquatic animals historically. This situation began to change in the years following World War II, and then changed even more rapidly in the 1960s and 1970s. At present, aquaculture provides some 10-12 percent of the supply of aquatic animals worldwide, and the rate of increase is spiralling upward. It is now estimated that aquaculture will contribute as much as 20 percent of the supply by the end of this century.

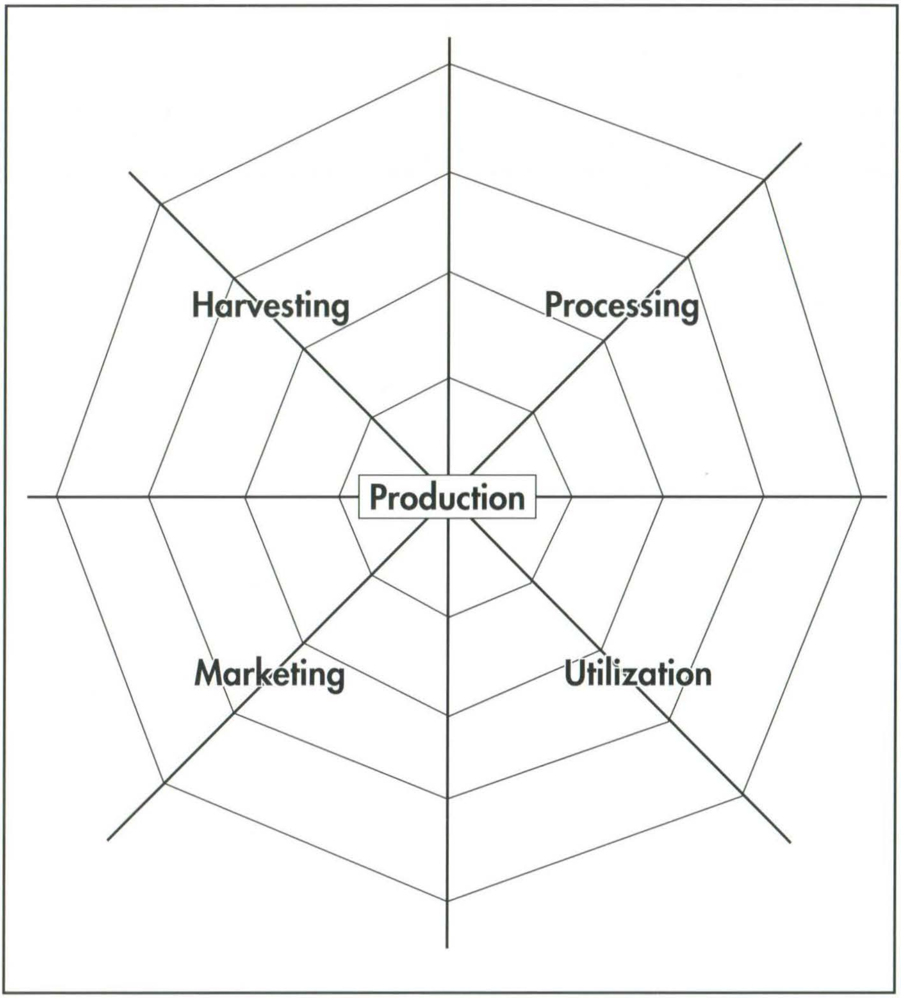
Meeting the demands expected to be placed on aquaculture this decade and in the next century will be a formidable task. Providing the necessary inputs (ponds, seed, water, information, processing, marketing, etc.) will require an enormous worldwide investment. Deploying those inputs on such a large scale will require an extremely effective planning process and implementation strategy. It is the primary purpose of this book to detail the inputs required and discuss the deployment of those inputs to advance aquaculture worldwide. I propose to examine the nature of aquaculture as it affects development and to expand on the importance of advancing aquaculture. Then I propose to discuss various aspects of aquacultural development using the general development process in biological systems as a model. With this perspective, I will consider the planning of a development strategy and its implementation. It is not practical in a book such as this to attempt to describe how the development of aquaculture might be accomplished in every location where the production of aquatic animals is or might be feasible. Instead, I propose to define a general philosophical base for development that can be used as a model in a variety of environments. Throughout the book, it is my intent to present aquaculture as a dynamic ecosystem, a "web" or matrix of interconnected and interdependent physical, chemical, biological, psychological, sociological, economic, and political processes. I will describe the development of aquaculture from this perspective.

# PART 1
# THE NATURE OF AQUACULTURE

THE SO-CALLED "CAPTURE" FISHERIES -- the harvesting, processing, marketing, and utilization of aquatic animals produced in the world's streams, reservoirs, bays, and oceans -- provide approximately 90 percent of the 90-100 million metric tons harvested each year. This process of production and utilization of aquatic animals can be roughly divided into five steps: (1) production, (2) harvesting, (3) processing, (4) marketing, and (5) utilization. People must be involved in steps two to five, but not in step one -- production. Aquatic animal production is a naturally occurring process that proceeds without human intervention. If people do become purposefully involved (intervene) in the production step as well, the process becomes aquaculture instead of capture fisheries (Food and Agriculture Organization of the United Nations, 1990). As part of this general definition of aquaculture, it is assumed that any intervention in the production process is planned. With this perspective, I will use the following definition of aquaculture for discussions in this book:

*Aquaculture is the planned or purposeful intervention in the production of aquatic animals.*

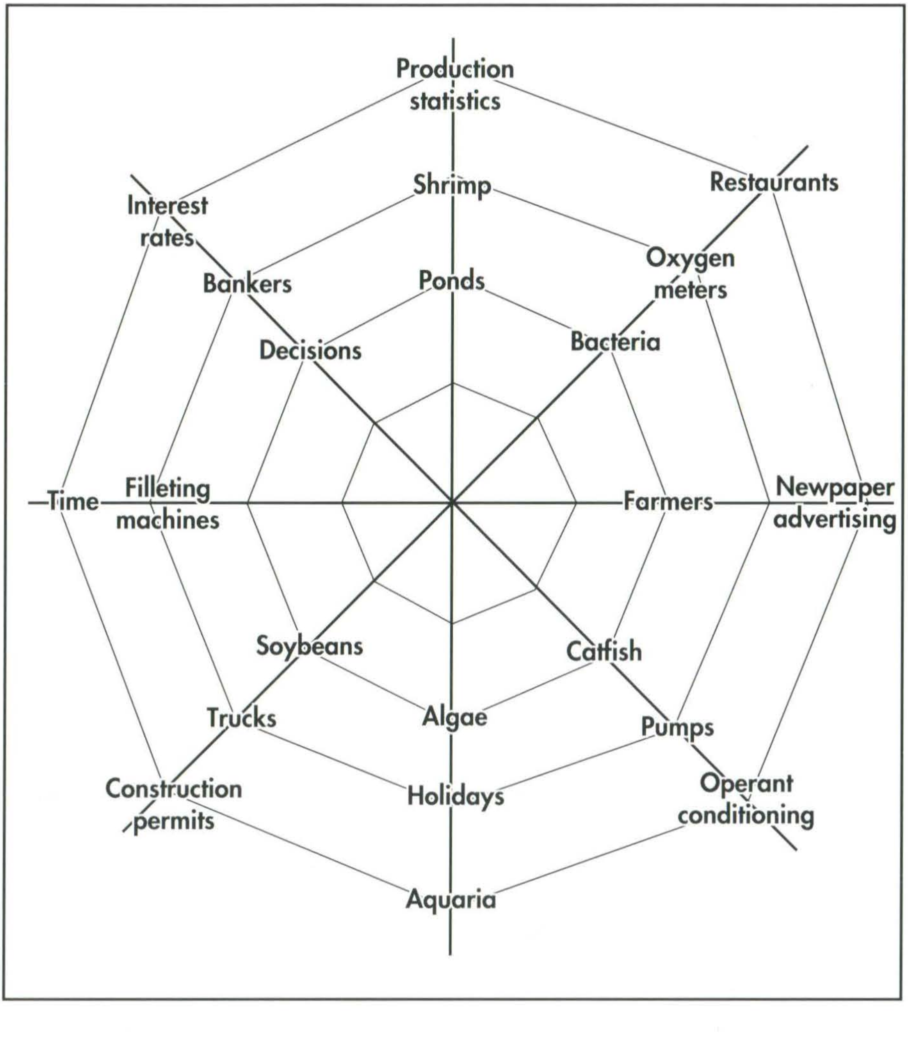
The production and harvest of aquatic animals is a widely occurring, natural process in ponds, streams, and oceans. In the process, energy from the sun is trapped in the chemical bonds of complex carbohydrates through photosynthesis, primarily in single-celled plants (algae and diatoms) suspended in the water column. The plants are "grazed" by foraging microcrustaceans and/or insects. These small animals, in turn, are used as food by forage fish that may, in turn, be eaten by predatory fish. After death, the predators and forage fish become sources of raw materials and energy for "decomposers" (microorganisms). Because of the loss of energy between steps of the process (The Second Law of Thermodynamics), the quantity (weight) of organisms forms a so-called pyramid with the algae at the base and the predatory fish at the apex. This is a simplified description for a complex process that in reality is an ecosystem or "web" of interconnected, interdependent processes (Odum, 1983; Cowley, 1988).




**Figures 1a., 1b. (facing page). The aquacultural ecosystem shown as a web.**

The interconnected physical, chemical, and biological processes that characterize aquatic productivity are complex; yet they represent only a fraction of the complexity of the entire aquaculture ecosystem that also includes harvesting, processing, marketing, and utilization. In this larger ecosystem, the chloroplasts in algal cells are "connected" with decomposing bacteria, fish and crustaceans, feed manufacturers, bankers, legislators, grocers, and European families celebrating Christmas with a carp for dinner. This ecosystem can be represented by a multidimensional matrix or web where each component is connected and interdependent with all other components either directly or indirectly. Defining the characteristics of this total system and coping with its complexity in the development of aquaculture will be a primary thrust of this book.

I have chosen to represent the interconnected, interdependent processes comprising the aquaculture ecosystem as the web of a spider (Figures 1a., 1b.); however, it is not intended that this analogy be overdrawn. I chose to use the visual impact of the suspended web to emphasize the fact that one part of the structure cannot be displaced without displacing to some degree every other part. A primary goal of this book is to encourage everyone involved in any aspect of the development of aquaculture to be aware of the interdependent nature of the various processes and to plan and implement development efforts from this perspective.



# CHAPTER 1
# AQUACULTURE REDUCES UNCERTAINTY

THE PRODUCTION OF AQUATIC ANIMALS in natural systems is an uncertain and unpredictable phenomenon. Production from one year to the next is the result of a number of density-independent factors, such as the weather, and density-dependent factors, such as predation and competition for food (Odum, 1983). Harvest and utilization of the production from natural systems by man also is an uncertain and unpredictable process, as evidenced by the wide fluctuations in the catch of the Peruvian anchoveta and many other species over time (Comte, Hendry, and Thomas, 1984A; Miller and Francis, 1989). Also, any angler can attest to the wide fluctuation in catch per unit of effort from hour to hour or from one year to the next.

It is possible to intervene in the harvesting, processing, marketing, and utilization steps in capture fisheries and reduce the level of uncertainty somewhat. By utilizing improved technology, such as better boats and nets, electronic fish locators, and better angling equipment, the catch per unit of effort can be increased and the certainty of harvest improved. The use of new technology can have a similar effect on processing, marketing, and utilization as well.

However, to realize a significant reduction in overall uncertainty, intervention in production is essential. Aquaculture, or intervention in the production process, reduces the uncertainty. As the degree of intervention (organization) increases, the level of uncertainty decreases (Figure 2). There is less disorder, and the loss of energy is minimized. As the degree of intervention increases, there also are increased opportunities for realizing economies of scale. Unfortunately, there is no free lunch; as the degree of intervention increases, complexity also increases. Along with increased complexity, the demand for energy increases. At some point, the increased certainty realized is less than the energy cost of the intervention. Then the aquaculture reaches a point where there are diseconomies of scale.

There is another important effect of increased intervention in the aquacultural ecosystem. As the level of intervention increases, the size of the ecosystem ("web") also tends to increase almost exponentially (Figure 3). The size of a simple subsistence ecosystem is much reduced compared to the size of an ecosystem that provides fish for an export market to a developed country. The importance of this relationship will be covered in a following section.

In the development of aquaculture, there is a strong pressure to increase the level of intervention and reduce the level of uncertainty. Subsistence aquaculture requires a limited amount of intervention in the production process, and the results obtained are relatively unpredictable. Consequently, it is likely that farmers will increase the level of intervention in an attempt to further reduce uncertainty. One of the major driving forces in human development has been the effort to seek ways to reduce uncertainties in the food supply. This was an obvious reason for domesticating plants and animals some 10,000 to 15,000 years ago (Lewin, 1988A).

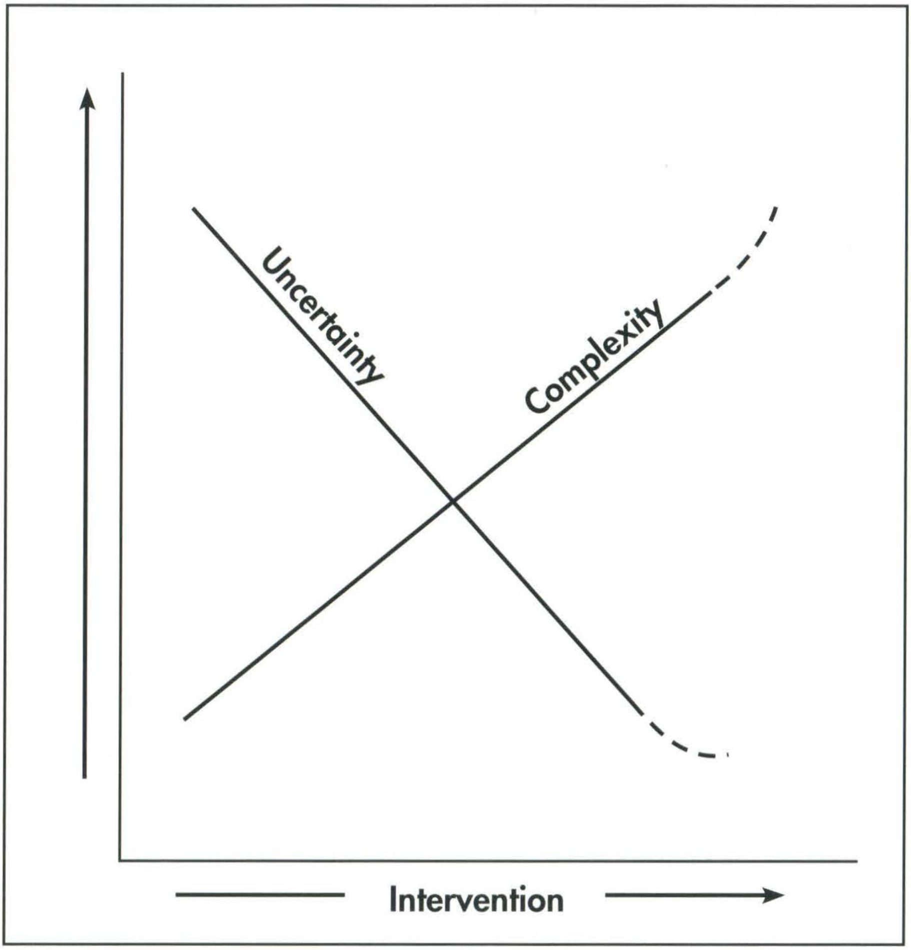



**Figure 2. General relationship between the level of intervention in the production of aquatic animals and uncertainty and complexity.**

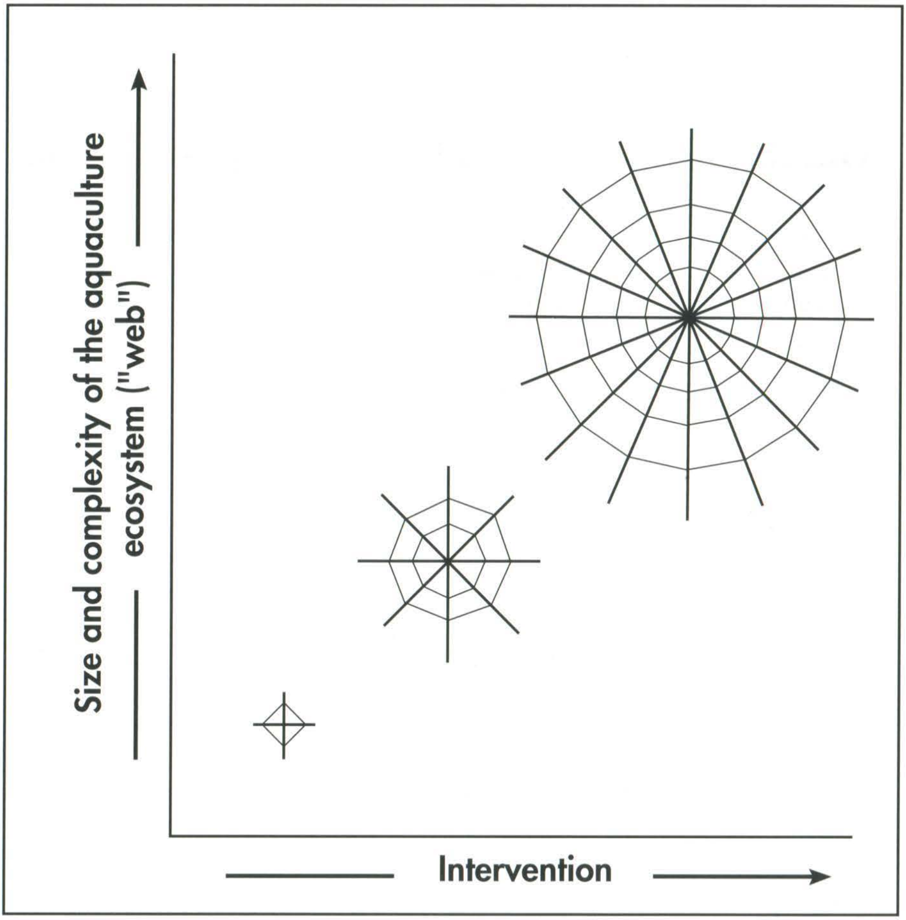



Figure 3. Relationship between levels of intervention and aquacultural ecosytem (web) dimensions and complexity.

# CHAPTER 2
# THE RANGE OF INTERVENTION IN AQUACULTURE

THE CONCEPT THAT ECONOMIC DEVELOPMENT occurs in sequential stages from simple to complex apparently originated in the 19th century. Hayami and Ruttan (1985) discussed the contributions of Friedrich List and Karl Marx to the theory of stages in economic development. List proposed a five-stage classification based on shifts in occupational distribution, including savage, pastoral, agricultural, agricultural-manufacturing, and agricultural-manufacturing-commercial. Marx also included five stages based on changes in production technology and associated changes in property rights: primitive communism, ancient slavery, medieval feudalism, industrial capitalism, and socialism. Robertson (1987) provided a fascinating discussion of the sequence of changes that has taken place in societies over time. He defines these changes as "sociocultural evolution," or the tendency of social structures and cultures to grow more complex over time. He also concluded that there have been five stages (societies) in this process: hunting and gathering, pastoral, horticultural, agricultural, industrial, and postindustrial societies.

The wide range of aquacultural practices indicating different levels of intervention and demonstrating the sequential nature of the development of the farming of aquatic animals will be briefly discussed in the following sections. These sections are not intended to describe in detail aquacultures found around the world. Rather, the purpose of the material is to call attention to the increase in the complexity of the aquacultural system as the level of intervention in the process (production, harvesting, processing, marketing, and utilization) increases. In presenting the material in this manner, I am suggesting that the level of intervention is indicative of the stage of the development of aquaculture.

Schmittou et al. (1985) recognized the concept of the stages of growth in aquaculture. They based their classification on the quality and quantity of nutrients utilized by aquaculturists as being indicative of the stage of development. Their classification includes seven levels: extensive (no nutrients added), extensive fertilization, intensive fertilization, extensive feeding, intensive feeding, hyperintensive feeding, and ultrahyperintensive feeding. While they based their classification on nutrient inputs, they suggested that the levels are really based on the magnitude of modification of the original aquacultural environment and the magnitude of control exerted over that environment.

Stickney (1986) suggests that the types (levels) of aquacultural systems are distributed along a continuum in which lightly stocked farm ponds are at one end and systems utilizing closed recirculating culture technology are at the other. Between the two extremes are heavily stocked ponds, cages, linear raceways, circular tanks, and closed systems.

Shang (1981) suggested that aquaculture could be classified according to several criteria: purpose of culture, nature of enclosure, sources of fry, level of management intensity, number of species stocked, water salinity, water movement, water temperature, food habits, and combination with agricultural production. For example, under his criterion for "purpose of culture," he listed the following six classifications:

1. *Human food.*
2. *Improvement of natural stock.*
3. *Sports and recreation.*
4. *Ornamental fish.*
5. *Bait.*
6. *Industrial products.*

I will take a more general approach to the classification of different stages of aquaculture than either Schmittou, Shang, or Stickney. I prefer to utilize levels of intervention (limited, intermediate, and high) instead. These levels of intervention lead to the development of lower, intermediate, and higher stages of aquaculture.

## *Limited Intervention Culture Systems*

On the coast of South America, there are numerous tidal streams and tidal swamps. These streams and swamps fill and drain with the ebb and flow of the tides. They usually contain the various species of mangroves plus a number of vines and shrubs.

In and around the roots of the mangroves and in the mangrove pools live an assortment of fish, crustaceans, and mollusks. Larger fish and crustaceans may come and go with the tides. Local fishermen hunt and gather aquatic animals from this productive environment. They place nets in narrow channels to catch these animals as they move out with the receding tide. On occasion, a few mangroves or shrubs may be removed to provide easier seining or trapping. Mangrove swamps are extremely productive ecosystems, but they are relatively unreliable as a source of food. The availability of fish and crustaceans changes with the tides and seasons. While the swamps are an important source of food for local fishermen, their lack of reliability makes them of questionable value as human population density increases in adjacent areas.

Several years ago, I visited a 1,500-acre tidal swamp on the West Coast of Berbice in Guyana (Shell, 1969). Channels from the ocean supply water to the swamp through tidal action. Fishermen using the swamp worked together to construct earthen dams on some of the saltwater stream channels, creating impoundments that trapped the water along with fish and crustaceans (Figure 4). After a period of time the fishermen used a variety of nets and traps to remove the animals (Figure 5).

Figure 4. A dammed tidal stream on the west coast of Berbice, Guyana (above).
Figure 5. Harvesting fish and crustaceans from a dammed, tidal stream container (below).

Impounding the brackishwater and animals represents a low level of intervention in the production-utilization process. These saltwater impoundments were little more than traps that held the fish and crustaceans until they could be removed, yet aquaculture was being practiced. Some production took place in those impoundments. There was at least some growth in some of the animals between the time they were trapped and the time they were harvested. Also, as a result of this extra growth, the swamp probably contained a larger weight of animals.

This dammed, natural watercourse-based ecosystem is one of the lowest stages of aquaculture, yet it contains all of the components of higher stages -- production, harvesting, processing, marketing, and utilization. In this example, there is minimal intervention or change in the natural system. The level of control placed on the system is extremely low, but the fishermen-farmers do exert some control by impounding a volume of water and a population of animals that will be allowed to increase in biomass before being harvested. Furthermore, there is some decrease in the level of uncertainty compared to hunting and gathering in the same area of tidal swamp.

Intervention in the processing, marketing, and utilization was similar to the levels of intervention in production and harvesting. Processing was essentially limited to heading, gutting, scaling, and peeling in preparation for cooking. Most of the utilization was by the fishermen-farmer families, although when there was a particularly good harvest, the excess beyond extended family needs was sold or bartered to neighbors or other community members. In these cases, there was virtually no processing prior to marketing.

It is questionable whether the fishermen-farmers have increased the production of the described area by converting from hunting and gathering to culture. If they had continued to harvest each day as the tides brought new fish and crustaceans into the area, their total catch summed over the culture period might be similar to the harvest when the container is drained. While total catch may or may not be greater, the effort (energy) required to produce a given quantity of fish is likely reduced substantially by utilizing culture rather than hunting and gathering. Even considering the energy cost of building and maintaining dams, the production per unit of energy expended is probably greater for the culture system. The return on investment probably was greater also. Certainly, the results are more predictable, which is of value. While many fishing trips to the swamps result in little or no catch, draining and harvesting the pond results in a generally predictable catch.

This simple culture system probably meets the needs of local human communities better than the hunting and gathering system, but there are numerous problems with it. The simple dams tend to leak as the water level outside the pond recedes on low tide. The pond can be filled completely only during the monthly high tide, making water control difficult. Also, stocking the pond is qualitatively and quantitatively unpredictable. If there is a large quantity of small fish and crustaceans in the volume of water impounded, then stocking is successful. If the quantity is low, the pond will be poorly stocked. There is little control over the species (quality) stocked. In some cases, the captured water will include a number of predatory fish. These predators grow rapidly, consuming smaller fish and crustaceans before they can be harvested. When the pond is drained, there may be only a few large predators remaining. Because of the loss of energy in converting prey species to predators (the "pyramid" effect), total production is low. Furthermore, water depth is variable; the culture container is filled with brush, trees, snags, and stumps; and the irregular shoreline offers few places to use a seine or even a cast net. The pond must be drained to harvest a reasonable percentage of the animals.

## *Intermediate Intervention Culture Systems*

Channel catfish culture as practiced in Mississippi is an example of increased intervention and reduced uncertainty in aquaculture (Huner and Dupree, 1984A, B; Foulke, 1989). In this culture system, two separate and distinct production cycles are involved. Fingerlings (seed) are produced in one cycle, and food fish are produced in another. Because spawning success, hatching, and early survival and growth are so unpredictable, these stages must be separated from the final grow-out phase.

Brood fish spawn in containers placed in holding ponds in late May through mid-July. Eggs are removed to a hatchery where they hatch in four to five days. They are kept in troughs in flowing water until the yolk sac is absorbed and they begin to actively seek and accept finely ground feed. Then they are transferred to fingerling production ponds. While in the production ponds, the small fish receive a high-quality feed daily. After a grow-out period of six to eight months, those fish are removed and readied for stocking in the food fish grow-out ponds. At this point, the uncertainty that was associated with spawning, hatching, and early survival is no longer a problem. Generally, these six- to eight-month-old fingerlings will survive well and grow at a predictable rate when stocked.

The grow-out ponds are the levee-type (Figure 6) constructed in a similar manner to the ponds utilized in shrimp aquaculture in South America. The ponds are filled by pumping high-quality water from a large aquifer approximately 10 meters below the surface. Once filled, these ponds are stocked with 4,000 to 6,000

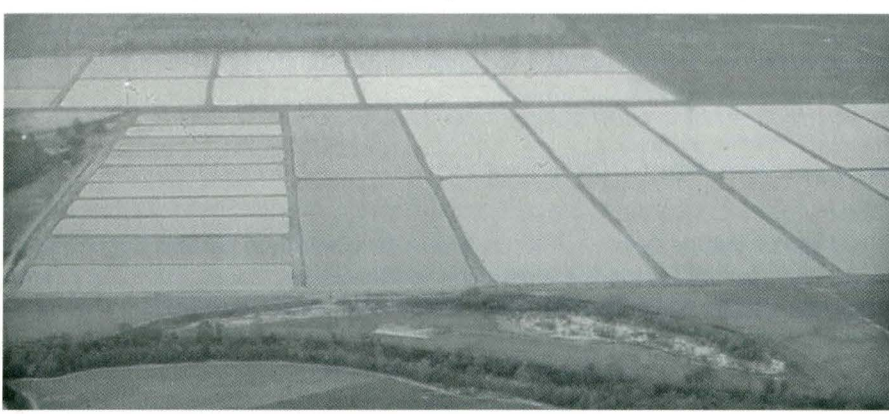


**Figure 6. Typical catfish farm with levee containers in the Mississippi Delta, U.S.A.**

fingerlings per acre, each three to five inches long. The fish are fed daily with a high-quality feed for six to eight months or until they reach marketable size.

Intervention in all aspects of the catfish farming system is at a higher level than for the dammed, tidal swamp culture system in Guyana. There is significant intervention in all aspects of the production process, including container construction, water management, "seed" procurement, and the addition of nutrients to the system. Harvesting is more predictable and efficient, and there is a highly structured processing system. Processing is managed to produce a high-quality product consistently.

Production of channel catfish in Mississippi is on such a large scale that it exceeds the capacity of markets in the local area, state, and region. A significant portion of the fish must be marketed in the north central and eastern regions of the United States.

Channel catfish command a relatively high price in the marketplace. Generally, the price is so high that catfish are not used as a staple food item in the way that poultry is used. Catfish is utilized as a specialty food. A significant percentage of the fish is purchased in restaurants.

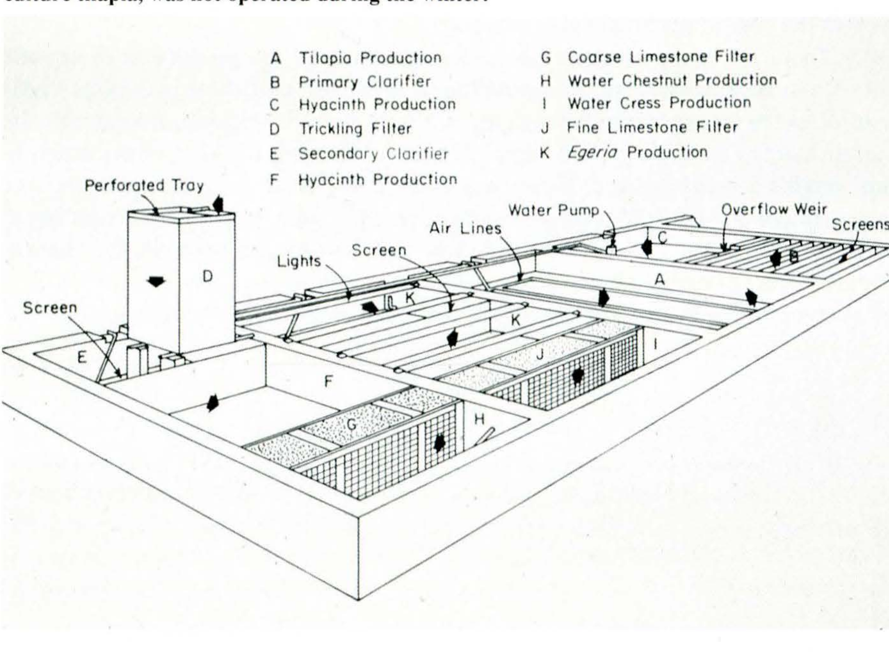
Channel catfish farming in Mississippi reduces the uncertainties of production compared to aquaculture in a flooded swamp in South America, and production may be higher. However, the system still has problems. Even if there is a good source of water in a nearby aquifer, it is expensive to pump enough of it to fill a fish pond and maintain the water level. Also, the level of the aquifer is pumped down rather rapidly (Fentress, 1987), further increasing the cost of water. Under certain conditions in the grow-out ponds, fish consume oxygen through respiration faster than algae can produce it through photosynthesis, possibly causing the dissolved oxygen concentration to fall to dangerously low levels. These conditions are more common when farmers have stocked at a high rate and when they must feed at a high rate to obtain satisfactory growth of the stocked fish. Under these conditions, it is necessary to begin mechanical aeration of the pond water. Finally, there is no practical way to maintain the water temperature so that a satisfactory growth rate can be maintained during cold weather. Even in Mississippi, the water is cold enough during the winter to severely restrict the rate of growth.

## *High Intervention Culture Systems*

In some culture systems, intervention in the production process is much more intense than in channel catfish production in Mississippi (Jones, 1988). A culture system for tilapia, which demonstrates a moderately high level of intervention, is shown in Figures 7a. and 7b.

McCoy (1986, 1987) described the characteristics and operation of a system with an even higher level of intervention — a system developed to culture the marine shrimp, *Penaeus vannamei*. It was developed hundreds of miles from the nearest

Figures 7a., 7b. A high intervention culture system. Although a biological filter and water circulation were used, there was no effort to control water temperature. This system, used to culture tilapia, was not operated during the winter.



marine environment in a large midwestern United States city, where there would be little transportation involved in getting the product to markets. The culture containers consisted of 20 stacked raceways. Flat-bottomed raceways varied from 20 to 60 feet long and were six feet wide. They were constructed of wood and lined with polyethylene. The raceways were held in a warehouse, where water temperature could be maintained with natural gas-fired heaters. Artificial marine water made with a commercial mix was used in the system. Water was recirculated continuously through the raceways. Waste was removed by passing the water through two large commercial filters with bio-disks. Approximately 12 percent of the water was replaced each day.

Total environmental control is of limited consequence in the husbandry of cattle, swine, sheep, or poultry because these warm-blooded animals have internal environments that remain relatively constant under a wide range of conditions. This more-or-less constant internal environment allows growth to continue all year with limited effects from a number of other environmental changes. High intervention aquaculture systems, such as the one described previously, attempt to compensate for the lack of control that fish, shrimp, and crabs have over their internal environments. Control of the external culture environment is substituted for internal control by the animals.

It would be difficult to achieve a higher level of intervention than was reached in that recirculating system developed for the culture of shrimp. Unfortunately the venture failed after approximately three years, apparently because of the problem of disposing of the total solid and soluble organic wastes generated in the system, as well as the cost of the artificial sea water.

There are many complex processes operating in the production of aquatic animals in natural systems. It is possible to bring some of these processes under control and to manage them through aquaculture. But it is difficult, at least with the current state of technology, to bring all of them under control. Also, when intervention begins, economic and social processes come into play, complicating the management of the whole system to a considerable degree. In a system consisting of some processes that are managed and some that are not (for example, the channel catfish culture system), it is possible to control the complexity. However, as the level of intervention increases, complexity tends to become difficult to manage.

# CHAPTER 3
# REQUIREMENTS FOR AQUACULTURE

CERTAIN ENVIRONMENTAL AND MANAGEMENT requirements must be met if the capabilities and possibilities of aquaculture are to be realized or if its full potential is to be reached. These requirements and associated inputs will be discussed in the following sections. Aquaculture, as noted previously, is a complex process which consists of a series of interrelated, interdependent sub-processes (production, harvesting, processing, marketing, and utilization) that take place in a well-defined order over a period of time. The order of the discussion of the requirements follows the general "flow" of the complete process as is indicated by the topics of the sections.

The first section describes various factors related to production, including needs assessment, product design, incentive, information, credit, labor, equipment, services, containers, water, seed, and nutrients. In the section on harvesting, I discuss concentrating the animals, removing them from containment, and transporting them. The third section, processing, is devoted to primary processing, or butchering; and secondary processing, which involves chemical or physical change. A section on marketing covers needs assessment, product design, price determination, promotion, and distribution. Finally, the fifth section concerns utilization, or consumption.

Stickney (1986) quotes James T. Davis in proposing a somewhat similar set of requirements for aquaculture. He calls them "considerations for prospective fish farmers." His requirements include financing, site, fish source, feeding, harvesting, marketing, and management. While his list is not as exhaustive as the one presented in this book, it nevertheless includes most of the essential requirements.

As the level of intervention increases in aquaculture, the process becomes more complicated, and the environmental requirements also become more complex. However, the actions or inputs listed above are required regardless of the stage of aquaculture involved. For example, credit, containers, seed, and equipment are required at all stages from the lowest to the highest. However, the level of intervention required of each increases as the stages of aquaculture advance. As an example, a flooded swamp container might suffice as a culture container at the lower stages but would not be adequate at the higher stages. The importance of maintaining a balance in the levels of intervention of the individual inputs will be discussed later. The changing characteristics of the inputs as the level of intervention increases also will be discussed in each section.

This list of requirements is neither exhaustive nor highly specific. It would be difficult to become involved in an aquacultural enterprise and be successful in it on the basis of this presentation alone. The purpose of presenting this material in this way is to show that in developing aquaculture, a broad range of physical, chemical, biological, social, and economic inputs are required. And while the same actions and inputs are required regardless of the stage of aquaculture practiced, the nature (level of intervention) of these requirements does change.

## *Production*

Production, harvesting, processing, marketing, and utilization are components of both capture fisheries and aquaculture. However, intervention in the process of production makes the difference between aquaculture and capture fisheries, and production is the primary component in aquaculture. In the following sections, the inputs required in the intervention will be discussed.

### *Needs Assessment*

Determining that there is a need for a cultured product is the first input in the process of aquaculture. Needs assessment per se is not a component of the production process. Rather, it is a component of marketing. In fact, it is the first of five distinct steps in marketing. However, needs assessment and the second step, product design, will be discussed as actions required before the production process begins. The remaining three steps will be discussed later. Although marketing in a physical sense cannot be done until the fish are produced and harvested, the total marketing process must be initiated before production begins. Without a positive response in the needs assessment process, production should not be initiated (Chaston, 1983).

Needs assessment is a complex phenomenon in aquaculture, because there is a limited specific demand for the products of aquaculture as opposed to the demand for products of capture fisheries. Wijkstrom and Jul-Larsen (1986) suggested that there is no such thing as a popular demand for aquacultural products distinct from capture fisheries. While this statement may not be true in all local situations, it certainly is true on the broader scale.

Shang (1981) suggests that local culture, religion, and tradition play an important role in determining the acceptability and need for cultured aquatic animals. He cites several examples: shellfish are generally not consumed by orthodox Jews; tilapia are generally not a popular fish in Vietnam; catfish are shunned by the Japanese; some African tribes have taboos against fish; and Hindus and Buddhists often are vegetarians.

The demand for fish is greater than supply throughout the world (Neal, 1987), not only for cultured fish but also for any kind of fish that can be obtained in dependable quantity and quality. The only specific demand for the products of aquaculture result from those cases in which certain species that are no longer available from the capture fisheries in sufficient quantity can be cultured (Food and Agriculture Organization of the United Nations, 1986). These species include channel catfish, marine shrimp, rainbow trout, and Atlantic salmon. Beyond a limited number of species, however, needs assessment becomes a matter of determining whether a culturable species can be substituted for another species that is in short supply and cannot be grown reliably under controlled conditions. For example, cod and haddock, two important species in capture fisheries, are in limited supply relative to demand, but neither can be cultured with existing technology. There obviously is a need, but it is not certain that aquaculture can produce a substitute. The redfish in the Gulf of Mexico is another example where there is an obvious need, but where there is not yet an effective culture alternative. The growing need for this species has sparked a massive effort to develop cultural techniques (Texas Agricultural Extension Service, 1986).

Because an aquaculturist makes a positive response in the needs assessment process does not mean that production and marketing efforts will be successful. Needs assessment should be done from the perspective of specific production units. This means that not only should prospective farmers determine that there is a general need for a product before they begin production, but they also should determine whether there is a need for their particular product. Even though there may be a need for cultured fish, in a given situation, an individual farmer may not be able to meet that need or even take part in meeting that need. For example, even when there has been a greater demand than supply of channel catfish in the larger cities of the southern United States, fish farmers in east Alabama generally have not been able to participate in those markets because there are no processing plants near their farms. Consequently, those farmers have had to market their fish locally, usually as live fish. For these small farms that are approximately 100 miles away from processing plants, needs assessment is a different problem than for the large farms in west-central Mississippi which are near the center of the catfish farming industry.

It is also important to realize that needs assessment is a continuing process. For example, shrimp have been considered to be a luxury product for many years. As a result, prices are relatively high. The high price and relatively limited supply provided incentives for early efforts to culture shrimp. These incentives were so powerful that they encouraged the flow of large amounts of capital to the coastal areas of Central and South America, China, and Southeast Asia for shrimp aquaculture. Production has increased so rapidly that shrimp are losing their reputation as a luxury food. Handley (1989) noted that "shrimp producers are seeing the transformation of shrimp from a luxury food to a relatively low-cost, steadily supplied commodity." Needs assessment must be carried out continually for farmers not only to cope with changes of this magnitude, but with changes of a less profound nature as well.

Needs assessment also must be related to the stages of aquaculture. Farmers operating at the lower stages must generally assess the needs of their immediate families, local people, and simple local markets. As the levels of intervention increase, local marketing generally is not adequate. Consequently, at the higher levels of intervention, needs assessment must be done in a much broader and more complex context.

### *Product Design*

Product design refers to the characteristics (species, size, shape, etc.) of an item desired by a consumer. Like needs assessment, product design is a component of marketing, but it should be dealt with before production begins. Even if there is a need for an aquacultural product, effective marketing will be difficult unless production is planned and organized to provide that specific item at the desired time, with the desired size and in the desired form (fillets, steaks, fresh, frozen, etc.). Product design in its broadest form should take into account the basic needs or motivations of consumers as defined by Bransom and Norvell (1983):

1. *To satisfy individual tastes and preferences.*
2. *To experience change.*
3. *To find dependable products.*
4. *To find safe products.*
5. *To improve health.*
6. *To save time in meal preparation.*
7. *To save money.*

Product design in aquaculture is not a particularly difficult problem in the current fish demand-supply situation. Virtually all of the species that are produced under cultural conditions are those that have been obtained for many years through capture fisheries. The rapidly growing channel catfish industry in the southern United States is a direct result of the failure of a capture fishery that probably existed along the major rivers from the time the American Indians came to this region. The catfish farming industry developed because the demand for the product could no longer be met through capture fisheries. Demand simply became greater than the natural system could provide on a sustainable basis. Product design for the channel catfish has become somewhat more flexible in the last decade, but when the culture of this species was begun, consumers demanded a farmed product that was identical to the captured product with respect to size and form. Similarly, the product design for marine shrimp, Atlantic salmon, and rainbow trout produced under cultural conditions is determined largely by customer preferences established over a long period by fish captured from the wild. Having product design determined from fish captured while "hunting" is not a unique phenomenon. The product design for virtually all of our foods initially was determined by animals, seeds, and tubers which were captured and gathered from the wild. Man's domesticated food bears a striking resemblance to his "wild" food.

While product design of cultured species largely has been determined by capture fisheries, there are developments taking place that will force major changes in this situation. Product design for cod, haddock, flounder, grouper, and snapper also were determined by capture fisheries, but capture fisheries no longer can meet the rapidly growing demand for those species. Unfortunately, methods for their culture have not been developed, and it probably will be many years before it will be possible to grow some of those species in sufficient quantity and at a reasonable price to meet even a small fraction of the demand. As a result of these developments, efforts are underway to find suitable substitutes that can be cultured and that can meet product design requirements.

For example, research is well underway to develop through selective breeding strains of the tilapias that resemble some of the snappers and certain other ocean fish. Tilapias generally have a dark grayish-blue or even darker color. As a result of breeding for red body color, these species may be more acceptable as substitutes or replacements for some of the ocean fish that are no longer available in adequate quantity (Galman et al., 1988).

In a similar manner, the culture of the channel catfish is changing to attempt to meet product design characteristics of some of the ocean species. When the industry first began, product design characteristics for the catfish required relatively small fish, usually 0.2 to 0.5 pound, that could be skinned, headed, and deep-fried in hot oil. A relatively small fish is required if it is to cook uniformly without absorbing excess oil. Also, most customers wanted a fish that would just span the diameter of a large dinner plate. Production of catfish initially was programmed to provide fish this size. However, because of the shortage of many of the species of ocean fish, catfish are now being grown to a larger size that can be filleted or steaked. These cuts can be processed into a form similar to those products usually developed from cod, haddock, or similar species. Because of the growing demand for fish relative to the availability, traditional product design is becoming much more plastic. Thus, there are opportunities for developing and marketing new products that can be produced through aquaculture. Chaston (1983) has discussed procedures that should be followed for new product development.

Product design is affected by customer behavior which, in turn, is a function of culture and of social characteristics. For example, Ed Reichel (personal communication) suggested, "People tend to eat with their eyes as much as with their mouths." With some foods, the appearance of the package may be as important as price in the consumer's decision to purchase it (Senauer, 1989). The purchase of farmed trout with "heads on" is likely a result of recreational or sport fishing for trout. It has been traditional that trout harvested by angling are cooked with heads on after gills and viscera are removed. In Thailand, the culture of *Pangasius sutchi*, a species of catfish, is influenced to a degree by a belief among certain ethnic groups that the flesh of this species has special powers. Eating it is supposed to guarantee that pregnant women will be able to carry the baby full-term (Wimol Jantrarotai, personal communication). Also, as noted earlier, the catfish farming industry was the result of Saturday night fish fries in river towns of the southern United States. Similarly, carp farming in central Europe probably was encouraged by meatless or fasting days (Dyk and Berka, 1988). Today, fish consumption in general in the United States is increasing rapidly because of a groundswell of interest in nutrition and health

(Rhodes, 1988). Obviously, this increased demand for fish has a major effect on product design in aquaculture.

The fast-food industry has had a major impact on fish consumption. The giant McDonald's restaurant chain is credited with helping create part of the current demand for seafood with its filet of fish sandwich. McDonald's is marketing a shrimp salad as part of its new line of salad products (Pierce, 1987). This fast-food giant purchases shrimp in the quantity required to meet the needs of its far-flung chain, and it has had a major impact on the shrimp market. This market was important because McDonald's purchases a smaller-sized shrimp, a move especially welcome to shrimp farmers.

Food fads that are a manifestation of a nation's culture also can have a major effect on product design. The Creole cooking fad, which originated in New Orleans primarily as a result of the 1985 World's Fair held in that city, swept across the United States carrying with it a skyrocketing demand for "blackened" redfish (Texas Agricultural Extension Service, 1986). This species previously was taken primarily by sport fishermen because of its size and "fighting" characteristics when hooked. It was not considered to be a high quality food fish until it was prepared using the Creole searing heat recipe. The catch has now increased to the point that alarmed recreational fishermen have banded together to force the curtailment of commercial fishing. This situation has resulted in major efforts to develop the technology for culturing redfish.

Food fads such as the blackened redfish wave often tend to become less distinct with distance from their origin and with time. Already several other species, including catfish and tuna, are being used in Creole recipes. While these fads finally dissipate, they usually leave a legacy. The Creole cooking fad seems to have convinced many Americans, slowly and somewhat reluctantly, that fish can be cooked without breading and frying (Pierce, 1987). These changes in consumer attitudes (product design) will have a long-lasting effect on aquaculture.

***Incentive***

Incentive is defined as something that "incites to action." Aquaculture is a relatively expensive enterprise because of the cost of the culture containers (ponds, raceways, and tanks) and because of the cost of water in some cases (Keenum and Waldrop, 1988). Consequently, it is not likely that individuals will invest scarce resources in aquaculture without some incentive to do so.

Both the private and public sectors commit scarce resources to the culture of aquatic animals. There are several incentives for individuals in the private sector to engage in aquaculture. These include:

*1. To produce food for their immediate families.*
*2. To produce aquatic animals for sale or barter as food or bait.*

*3. To produce ornamental fish for pets or for sale to others as pets.*
*4. To produce fish for their own recreation or for sale for the recreation of others.*

Considerable quantities of aquatic animals are produced for all of these purposes, but the profit motive (expressed in incentives 2, 3, and 4) is the major reason for aquaculture. Probably the least important in terms of quantity (weight) is the production of fish only for the consumption of the immediate family. Not many farmers grow fish only for use by their families where there is no barter or sale involved. There is an obvious reason for this. A family can consume only so many fish. Once that quantity is exceeded, the excess must either be sold or bartered in some manner where there is a return on investment.

Although the quantity of ornamental fish produced is relatively low, the value is extremely high. Winfree (1989) notes that the retail sale of aquarium "livestock" in the United States has been estimated to reach as high as $700 million annually, and that aquaria are found in approximately 7 percent of American households. The value of the ornamental fish industry in 1987 in the state of Florida was estimated to be in excess of $21.7 million (Harvey, 1988). Similarly, the acreage devoted to the culture of fish for recreational purposes in the United States is much greater than that devoted to food fish production. There is an estimated 2 million ponds (1 million acres) devoted to the culture of sportfish such as the bluegill sunfish and the largemouth black bass, but less than 200,000 acres devoted to catfish production.

There are two general groups of individuals involved in aquaculture with respect to the nature of their investment: those who invest personal resources and provide day-to-day care of the animals and those who invest resources but are not involved in day-to-day operations. The incentives required to get these two groups involved are quite different (Pillay, 1977). Investor farmers, who make up the first group, are usually somewhat resource limited, and aquaculture is only a part of their farming operations. These farmers generally will not engage in aquaculture primarily to earn all of their cash income, and they will produce aquatic animals only if they are convinced that investment of their time and resources in aquaculture will not jeopardize their established agricultural activities (Wijkstrom and Jul-Larsen, 1986). If they are to become involved in aquaculture, they must be assured beyond a reasonable doubt that they can launch a successful operation. Individuals of the second group -- those who have nothing to do with day-to-day operations -- invest in aquaculture only because of the opportunity to earn a profit on the financial resources they invest. They employ others to care for the animals. These people are extremely important to the development of aquaculture on the scale required to prevent a serious shortage of aquatic food animals throughout the world. The farmer investors of the first group often do not have access to the financial resources required for development of this magnitude.

The public sector has several incentives for becoming involved in aquaculture (Pillay, 1977):

*1. To provide food for poorer people.*
*2. To meet the increasing demand for highly valued species.*
*3. To replace the loss of an important species from natural sources.*
*4. To support export trade or import substitution.*
*5. To generate rural employment and prevent the drift of people to the cities.*

Generally, but not always, public involvement in aquaculture is limited to providing some input (credit, seed, information, etc.) that will encourage individuals to become involved. Seldom does the public sector supply all of the inputs required and become directly responsible for the production process on a day-to-day basis. The fact that the public sector does not become involved in the day-to-day production process results in a problem relating to incentive that is difficult to deal with. It is difficult for government to transfer its incentive for investing in aquaculture to the individuals who must actually care for the animals on a day-to-day basis. Governmental success in transferring incentive to individuals will determine the effectiveness of public effort to promote aquaculture in many situations.

Producing fish for food only for a farmer's family generally is limited to the lowest stages of aquaculture (lowest levels of intervention) where it is only a minor part of a farming operation. The total quantity produced usually is quite limited. Even in cases where fish farming is a minor part of the farming operation, production is often sufficient for at least some of the fish to be sold for profit. Kent (1986) cited a survey in Thailand of 159 rice farmers who also cultured fish. Of the total, 26 percent grew fish only for food for their families. Thirty-one percent grew fish for food and minor economic benefit, and 43 percent grew fish for significant economic benefit. In a study in Guatemala, 53 percent of 62 fish farmers surveyed said that having fish available for family consumption was the primary reason they constructed ponds for aquaculture (Tom Popma and Alex Bocek, personal communication). In the same study, it was found that a typical family disposed of fish they had grown in the following ways:

| *USE* | *PERCENTAGE* |
|---|---|
| *Consumed by family* | *48* |
| *Sold* | *40* |
| *Donated to neighbors* | *10* |
| *Used for restocking* | *2* |

At intermediate and higher levels of intervention, the primary incentive for aquaculture is the production of fish for profit. Because of the quantity of fish produced and/or the cost of inputs required, barter or sale is required.

This book will primarily focus on the incentive to culture aquatic animals to produce food for the family or for other people after barter or sale. Limiting the discussion in no way suggests that other incentives for aquaculture are not important. Many developing countries earn important foreign exchange as a result of their involvement in some aspects of the culture of ornamental fish. Similarly, the culture of fish for recreational purposes is an important economic consideration in many countries. Actually, there is not a great deal of difference in the culture systems. Most of the inputs are quite similar. The primary differences are in marketing and utilization.

***Information***

Information is an essential prerequisite and corequisite of aquaculture. Without some information on opportunity, inputs and outputs, and return on investment, aquaculture would not be attempted. The decision to commit scarce resources to culture at any stage would not be made without some information. Even the minimum level of intervention likely would not be carried out without information. Similarly, once the decision to commit resources is made, culture could not be carried out effectively without information about the inputs required and about their application. Information is the "glue" that holds the other components (containers, water, seed, nutrients, credit, etc.) together.

The quality of information available to farmers is important. Quality relates to each bit of information required in the aquacultural process and to how closely what is known approximates the truth. There is an old folk-saying appropriate to this point:

*It's not what I don't know that hurts me. It's what I know that's not true.*

It is safe to say that no one can know all there is to know about a culture system. The uncertainty principle (Platt, 1966) keeps us from studying anything to the level that we would like. The more diligently we seek to learn everything there is to know about a natural phenomenon, the more we change it so that it is no longer the same phenomenon. For example, if we wish to study in detail the daily growth response of fish in a pond to a particular feeding regime, it would be necessary to seine the fish each day to see how much they had grown. Unfortunately, if the fish are handled daily, they probably would not grow at all.

The number and species of shrimp in tidal streams that can be captured for stocking in a mangrove swamp pond is determined by the action of a large number of complex physical and biological factors and their interactions. We will never know enough about this complex system to predict with a high degree of certainty exactly how many and what kind of shrimp there will be in a given volume of tidal water at a given time. In the previously described system of producing shrimp and fish in No. 19 Swamp in Guyana, it is important to know when to fill the container with water containing the animals. The number of larval shrimp and the number of immature predatory fish vary with the time of year. Also, there is variation in the species composition, the salinity of the water, and the height of the tide. Considering all of these factors, their main effects and their interactions, there probably is an optimum time to fill the container. In most cases, those farmers never have available more than a fraction of the information needed to make correct decisions.

The closer available information approximates actual needs, the higher the quality. From observation, local people know some things about the system. Truth and error are wrapped in superstition to provide an information base that is marginally adequate to sustain the lowest stages of culture but little more. I am not suggesting that quality of information is unimportant at the lowest stage of aquaculture. It is important, but probably not as critical to success as is the case in more advanced stages.

The quality of information available for aquaculture is relatively poor regardless of the level of intervention. While aquaculture is an old art, it is a young science (Sasson, 1983). Significant efforts to establish and build a scientific information base for the development of aquaculture are little more than a half-century old and are largely confined to the last 20 years. The Institute of Fisheries and Hydrobiology was established at Vodnany, Czechoslovakia, in 1921 (Dyk and Berka, 1988), and the aquacultural research center at Auburn University, Alabama, in the United States was established in 1934. These are two of the older stations in the world established to conduct research on aquaculture. The relatively young age of these two institutions is to be compared with the almost 150 years involved in the production of information through research in agriculture. The agricultural experiment station at Rothamsted near London, England, was established in 1843 (Ruttan, 1982).

A high percentage of the investment for producing quality information for aquaculture has been for the intermediate levels of intervention. There has been relatively little investment for research to improve the quality of information at either the lowest or highest levels. Most of the effort to develop aquaculture is taking place at the intermediate levels. Consequently, there is a relatively high probability that lack of good information will cause failure of a culture system on low returns on investment at either extreme.

As aquaculture of a species is developed from one stage to another or as intervention increases, information availability also must change. For the simplest level, where fish are "corralled" in a flooded watercourse, information requirements are relatively minimal. The farmer need only know when to close the container in order to trap the most "seed" and how to construct the structure to guarantee that it will hold the water until time to harvest. Also, there would be some requirement for information on length of the waiting period until the fish had grown some. In this situation the farmer would need no source of information other than an older family member or an experienced neighbor to pass along information based on experience. At an intermediate stage of culture, the level of the various inputs also increases. While the inputs required (container, seed, food, etc.) are the same, the complexity of those inputs is at a higher level. For example, the container, the seed requirements, and the problems encountered are more numerous and complex. Generally, average farmers, especially the less experienced ones, would not have all of the information required. Similarly, it is not likely that other family members or neighbors would have it either. When this is the case, it is necessary to have available individuals who specialize in supplying information. In many countries, this need is met by the extension agent or change agent. A person is employed usually by government to make information available to farmers. Usually these agents make the same information available on relatively short notice to a large number of farmers. As aquaculture expands and as a support industry develops, the input supply companies (feed manufacturers, for example) may employ specialists to provide farmers with information, especially information as it relates to the use of specific products which those companies have for sale.

At the most advanced stages of culture, the need for information is so great and so specialized that a source of information (the extension or change agent) which is shared by many farmers may no longer be adequate or be available when needed. For example, in recirculating culture systems, the system is in such a dynamic state that a large amount of complex information must be available almost continuously. In those situations, farmers may employ their own information sources or retain consultants who are available to provide the necessary information when it is needed.

Developing information (new technology) is extremely important in the development of aquaculture. This subject will be discussed in detail in a following section, but a few general comments are appropriate here. At the lowest stages of culture, the summed experiences of several generations of farmers would slowly improve the quality of information. Trial and error, though extremely slow, does result in information of improved quality (Shell, 1983; Myers, 1989). It should be noted that the only reliable method of improving the quality of information is through trial and error. Inductive and deductive logic certainly play a role, but only trying possible solutions to problems under actual conditions and discarding those that don't work can lead to significant improvements.

With intermediate stages of aquaculture, traditional trial and error is no longer appropriate. Investments are so large and the likelihood of loss so great that trial and error must be systematically applied. It must be institutionalized. Institutionalizing trial and error in the form of aquacultural research has become the province of government worldwide. Public agencies, utilizing funds derived primarily from taxing a broad segment of the population, now apply trial and error in a highly organized manner to improve the quality of information. Institutionalizing the process spreads the losses resulting from error over a much larger population. The cost of error can be catastrophic, and farmers are reluctant to try new solutions to any except the simplest problems.

In the highest stages of aquaculture, the institutionalized approach to improving the quality of information may not be entirely satisfactory. The traditional farmer-extension agent-research scientist linkage may not be sufficiently responsive. In those cases, the farmer might establish a private research organization to deal with specific problems. This approach has the advantage of providing highly specific information. This information also belongs to the farmer, and may be used to provide some advantage in competition with other farmers. This proprietary information might also be sold to other farmers for a profit.

### *Credit*

In economic terms, credit is defined as the acceptance of debt on the promise of payment at a later date. Almost all aquacultural production systems require credit. Debt is accrued in the form of inputs (seed, feed, labor, etc.) over a period of time before the fish can be harvested and marketed. Regardless of the simplicity or complexity of the culture system, some credit is usually required. Credit in aquaculture varies from the debt incurred in the expenditure of human muscle energy required to build an earthen dam to the cost of electrical energy, capital cost of pumps and filters, and cost of land and buildings that are required in a complex, recirculating culture system.

In a tidal swamp where a "trap-and-grow" container is constructed by building a dam across a natural water course on public land, little more is required than picks and shovels and the food energy required for the human muscle power to erect the dam and to open the gate periodically during high tide to allow additional water to flow in. Some money might be needed to purchase the tools and even timber, but relatively little would be required. Even if an individual owned the tools and did the labor, he would have to provide credit to the "system" until the crop is harvested and consumed and/or sold. At the other end of the scale, the credit needs are extremely high.

Table 1 includes information on the estimated investment required for the physical plant and equipment for three different sizes of catfish farms in the Mississippi Delta in 1988. These estimates range from $2,791 to $3,479 per acre of water farmed. This range of estimates suggests the economy of scale that can be realized in aquaculture. These estimates do not include any of the variable costs of production, such as the cost of fingerlings, feed, and labor. These vary widely depending on the intensity (level of intervention) of production. On Alabama fish farms these variable costs of production average approximately $1,500 per acre (John Jensen, personal communication).

Usually the more complex culture systems are constructed near or in a major center of trade because of the need for services (special consultants, equipment repair, spare parts, dependable transportation, and power). Land, buildings, and labor are expensive. Operation requires the continuous use of large amounts of electricity. Back-up generators and pumps must be available. Complex sensors and switching systems must be maintained. Also, the system is so complex that it usually requires an experienced technician to remain on the job continuously. Aquaculture utilizing

**Table 1. Estimated Capital Investment Required on Three Sizes of Catfish Farms in the Mississippi Delta in 1988[1]**

| Investment Category | Farm Size (Land Acres) | | |
|---|---|---|---|
| | *163a.* | *323a.* | *643a.* |
| Land | $130,400 | $258,400 | $514,400 |
| Pond Construction | $117,956 | $225,842 | $452,225 |
| Providing Water Supply | $30,720 | $61,440 | $122,880 |
| Feeding Equipment | $17,585 | $23,225 | $36,280 |
| Pest, Disease Control Equipment | $3,340 | $3,340 | $3,340 |
| Miscellaneous Equipment | $188,406 | $268,101 | $458,670 |
| Acres of Water Farmed | 140a. | 284a. | 569a. |
| Investment Per Acre of Water | $3,479 | $2,961 | $2,791 |

[1]Keenum and Waldrop, 1988.

these systems requires an extremely large amount of credit. Although the absolute need for credit increases with the level of intervention, the relative need probably does not change at the same rate. Credit needs for culture in a dammed, tidal stream container culture (Figure 4) are relatively small, but the amount of fish and shrimp likely to be harvested is also relatively small. At the other end of the scale in the highly intensive culture systems, the need for credit is extremely high, but production of aquatic animals also can be extremely high. The increased requirement for credit generally parallels the increased intervention in aquacultural production systems. At the same time, there also is a parallel change in the nature of creditors. At the lowest stages of aquaculture, a farmer may provide virtually all of his credit. However, as the level of intervention increases, second party creditors (banks) are usually involved. At the highest and most complex stages, venture capital investors may be involved. These complex credit schemes are seldom required in the lower stages.

An obvious consideration in obtaining credit for aquaculture is whether the debt can be repaid. This is a complex matter because the question must be answered before the culture begins. Whether or not the question was answered correctly cannot be determined until the fish are marketed, but a preliminary answer must be given at the beginning. Otherwise the culture should not be attempted. Making a preliminary decision as to whether a debt incurred in culture can be repaid is difficult because of the difference in credit-worthiness of the stages of aquaculture. In the first stages of aquaculture, the farmer has limited control of the system. Consequently, the amount of fish or shrimp produced is highly variable and unpredictable. The water captured in a tidal pond may contain relatively few or many fish and shrimp and few or many predators. The credit required is small, but the probability of not being able to repay the debt is relatively high. These systems have a relatively low level of credit-worthiness.

At the other end of the scale, the degree of control over the culture system is relatively high. However, because of the complexity of maintaining a constant environment, there is a considerable degree of uncertainty and commensurate lack of credit-worthiness. Furthermore, the cost of maintaining that level of control is also high. Consequently, even with the high level of production, it will be difficult to pay the debt unless production levels and prices received for the product are high. Thus, at the highest stages of culture, credit-worthiness also may be low.

Credit-worthiness probably tends to increase with the level of control that the farmer exerts over the system because the predictability of the system also increases. At some point, however, predictability seems to level off while the cost of providing additional units of control continues to increase. Beyond this point, the probability of repaying the debt (credit-worthiness) begins to decrease. Thus, credit-worthiness would seem to be low at both lowest and highest stages of aquaculture and highest at the intermediate stages assuming that the relative quality of management remains equal. Obviously this relationship is not firmly fixed. As more research is done and recirculating systems are made more dependable with lower costs, credit-worthiness will increase at the higher stages. However, even with considerable progress in the development of more reliable, lower cost systems, it is likely that credit-worthiness will always be somewhat depressed at the highest, more experimental stages of culture. Even at the intermediate stages, credit-worthiness is not guaranteed. Poor farmer knowledge or performance can depress credit-worthiness. Also, external forces, such as lost markets, general depression of food prices, increasing cost of inputs without an increase in market prices, and restrictive legislation or government controls, can affect credit-worthiness at any stage.

Even at the levels of intervention (stages of culture) where credit-worthiness is at its highest point, there still is some probability that a production cycle will fail and the debt cannot be repaid, and there must be some provision for paying it. There must be something set aside (collateral) to pay the debt if the crop fails. At the lowest stages of aquaculture, the collateral may be nothing more than having an alternative food supply available to repay the muscle energy used in constructing the tidal swamp dam if there are no fish or shrimp to be eaten. At the higher stages the need for collateral is more complex.

The collateral issue also is related to credit-worthiness. As credit-worthiness decreases, the importance of collateral increases. This relationship causes problems in the development of aquaculture. At the lowest stages of aquaculture, credit-worthiness is low, and availability of collateral also is low. Poor, subsistence farmers require relatively little credit, but they have almost no collateral or anything to set aside to pay the debt in the case of a crop failure. Usually some other person or group of persons (public sector) must provide the collateral. In this way the risk is shared by a large number of individuals. Public guarantee of repayment is often the only practical way to involve poor people in aquacultural production systems that require credit from a second party. While this is a commendable goal, it is not without problems. It is likely that a public guarantee against loss may result in deformities in credit-worthiness.

A somewhat comparable situation exists at the highest stages of aquaculture where credit-worthiness also may be low. Most of the recirculating culture systems are developed and operated by a group of investors who commit venture capital to the business with the anticipation of a high return on investment. In these situations, the risk also is shared by a number of individuals. At intermediate stages of aquaculture where credit-worthiness is high, it is customary for the individual farmer to provide his own collateral. In this case one or a few people are at risk.

Even under the best of conditions, credit for aquaculture can be difficult to obtain (Trosclair, 1987A, B; Water Farming Journal, 1987B). Many investors remember the failures of a number of aquacultural enterprises in the early 1970s (Huner and Dupree, 1984B; United Nations Development Programme, 1987). To investors, aquaculture continues to hold more promise than profit and is an expensive undertaking that often takes years to yield an adequate return on investment. These business failures, along with the perceived complexity of aquaculture compared to agriculture, are road blocks to creditor confidence. Also, the problem of inventory control is a major deterrent to creditor confidence (Mead, 1988). In most situations, the cultured animals are part of the collateral for the credit. Unfortunately, from the time the aquatic animals are stocked as seed until they are harvested, it is difficult to inventory them. Generally, the farmer does not know how many animals there are in the container until the water is drained away.

Fortunately there are indications that investor attitude is changing. The financial successes of shrimp farming in Central and South America and Asia, catfish farming in the southern tier of states in the United States, and the net pen culture of salmon in Canada and northern Europe have created a much more positive image for aquaculture.

While the investor/lender environment is improving, there is lingering concern. Requests for credit must be accompanied by rather complex business plans if they are to be approved. These plans must include information on the following areas (Water Farming Journal, 1987A):

1. *A technical report of the proposed operation.*
2. *A statement of purposes.*
3. *Project background.*
4. *History of the firm.*
5. *Permit requirements and industry regulations.*
6. *Progress already made in setting up the production operation.*
7. *Capital already raised and spent.*
8. *Future capital needs.*
9. *Competitors, including their sales.*
10. *Barriers and risks.*
11. *Management experience.*
12. *Spending plans.*
13. *Technology procedures.*

*14. Business background of company officers.*
*15. Techniques used in projecting production sales and profits.*
*16. Renumeration schedules for company personnel.*
*17. Audited financial statements.*
*18. Marketing plan and price schedule.*

Providing information on these aspects of an aquacultural operation requires a major planning effort on the part of the group requesting credit. If done correctly, it provides an excellent road map for developing a successful operation. At the same time, it builds confidence in potential creditors. Information developed regarding the business plan elements listed above probably would have to be more complex when obtaining credit through a public stock sale than when dealing with a local banker. However, the basic approach to the plan would be the same in both cases. In fact, a similar exercise in planning and "counting the cost" should be completed regardless of the stage of aquaculture involved. In any situation where credit is required, there should be a business plan. In the long term, such a plan would likely be of greater benefit to the farmer or group developing the operation than to the potential creditor.

The availability of good collateral and a generally good record of paying off crop loans likely was responsible to some degree for the rapid increase in catfish farming in the Mississippi Delta. Many of the farmers there owned large tracts of valuable land that could be used as collateral. Also, most had a long established history of borrowing and paying off crop production loans. In other areas of the southern United States with good prospects for catfish farming, obtaining credit has been more difficult.

Another characteristic of the need for credit in aquaculture is the dynamics of the credit load. At the lowest stage of aquaculture (a flooded man-made pond in a tidal swamp) after the building of the dam and trapping of the water, little additional credit may be required until additional water is added during the monthly high tide. Once the initial debt is incurred, it remains essentially constant until more water is added, at monthly intervals, until the time of harvest. At the other end of the scale (in the recirculating systems) the increase in credit required is continuous. Electricity, supervision, and other similar inputs, for example, are needed continuously. At the intermediate stages, credit tends to increase in a stair-step fashion. For example, in a catfish pond culture, additional feed and some supervision are required each day, but the amount of credit does not increase continuously.

***Labor***

Obviously, labor is required in aquaculture. Equipment can substitute for labor, but with the state of aquacultural technology, the degree of substitution is somewhat limited. As the level of technology improves there will be increased substitution. At least this is the path followed in agricultural development (Hayami and Ruttan, 1985).

At the lowest stage of aquaculture, there is a relatively large labor component in virtually every input from constructing the dam with shovel and pick to collecting the fish from potholes when the pond is drained. The requirement for labor on a time scale tends not to be continuous. Once the dam is completed and the water containing the seed animals fills the pond, there is relatively little additional labor required until the next time water is to be added, although some observation is required periodically to be sure there are no breaks in the dam. The labor required is not highly specialized, and the workers may be involved in a wide range of other activities unrelated to aquaculture (Wijkstrom and Jul-Larsen, 1986). Obviously, some knowledge on the best ways to build dams and the best times to collect seed is required, but the general requirement for informed labor (technical skill) is relatively low.

At this lower stage of aquaculture, there is little substitution of equipment (capital) for labor. Labor under these conditions often is relatively cheap and locally available. There is little pressure to replace it. Also, there are limited opportunities to do so. There would be very little equipment available that could replace labor. Even if there was equipment designed and manufactured for use at this stage, there would be little demand because of the cost relative to the return expected. Hayami and Ruttan (1985) provide an informative discussion of this phenomenon as it occurs in agriculture.

The labor requirement changes significantly for the intermediate stages of aquaculture. Labor is required for constructing the container, although there is generally more opportunity for equipment substitution than at the lower stages. The level of intervention involved requires more knowledge of fish farming. Generally, there are more problems to be dealt with at these stages because of the increased complexity. Even at this stage, the labor is not completely specialized. For example, most channel catfish production takes place on farms that produce a variety of other agricultural crops (cotton, corn, soybeans, cattle, hogs, etc.). The same labor is used for the production of all of these. Some labor is required almost every day in the year, but the requirement generally is not uniformly distributed within the day or the year. In the catfish industry, a major requirement of labor is for feeding, because fish in each pond must be fed one or two times per day. The most difficult requirement for labor at these stages, however, is for water quality monitoring in the early morning hours before daylight. If a serious dissolved oxygen depletion problem occurs in a pond, it will usually happen between midnight and sunrise. For this reason, dissolved oxygen concentrations must be monitored periodically during this time. This activity requires considerable specialized labor.

At the most advanced stages of aquaculture, labor is mainly limited to operating the production system. There is little opportunity to do anything else. There is so much equipment in service that constant attention is required. These systems usually involve a sequence of events that is cyclic and continuous in nature. If any one of these events does not take place at the proper time and in the correct manner, a major loss of fish can occur. The labor involved is usually highly specialized. The complexity and dynamics of the system and the interaction of the fish with the environment require that knowledgeable people be readily available for problem solving and troubleshooting.

There is considerable substitution of equipment for labor at the highest stage. Much of the work involved must be done with equipment. Because of the danger of an equipment failure, almost constant operator presence is required. The requirement for labor is essentially continuous.

### *Equipment*

Aquaculture would not be possible without equipment. Even at the lowest stages, shovels, picks, baskets, and tools for constructing an earthen dam or similar device for regulating water level in a tidal swamp are required. At this stage, there is virtually no specialized equipment required. John Moehl (personal communication) suggests that fish farming in Rwanda in Central Africa requires equipment no more specialized than a hoe, a machete, and a basket. The shovels, picks, carpentry tools, and baskets are used primarily for other purposes and only periodically for aquaculture.

As the level of intervention advances, the amount and complexity of equipment increases (Astatke, Bouning, and Anderson, 1986). Even at the intermediate stages of aquaculture, there is a need for many kinds of equipment that were not required at lower levels of intervention. For example, for catfish farming in levee ponds as it is practiced in Mississippi, earthmoving equipment is needed for pond construction (Figure 8). Large pumps with diesel engines are needed for filling the ponds. A wide

**Figure 8. Earth-moving equipment used in the construction of levee catfish production ponds. This equipment is fitted with a laser leveling instrument to allow precise placement of clay on the dam.**

**Figure 9. Truck fitted with an aluminum hauling container and liquid oxygen distribution system.**

variety of equipment is required for spawning, hatching, and growing the seed. Trucks with hauling tanks outfitted with aerators and oxygen supply lines are needed for hauling and stocking (Figure 9). Feed manufacturing requires many kinds of specialized equipment. Harvesting, processing, and marketing also require many different equipment items. At the intermediate stages, even though the same general inputs (containers, seed, water, etc.) are needed, the amount of equipment required is greater by at least an order of magnitude than for the lowest stages. Further, these items of equipment are essential for increased intervention. It is not possible to increase the level of control over the production process without increasing the use of equipment.

Even though the intermediate stages of intervention require much more equipment, relatively little of it is designed or manufactured primarily for aquaculture. There certainly is an increased proportion of specialized equipment compared to the lower stages, but much of it can be utilized for other purposes.

The increasing levels of intervention in the production process also carry with them an increased degree of the substitution of equipment (capital) for labor. The lowest level of intervention can be characterized as labor intensive. There is a relatively high labor component in each unit of fish or crustacean produced. At the intermediate stages, the labor component in each unit is considerably lower. Equipment is used to replace human labor. This is not meant to imply that less labor might be used on a channel catfish farm than on a tidal swamp farm. There actually is more labor in use on the catfish farm, but the ratio of labor used to fish produced is lower.

At the highest levels of intervention, the amount of equipment required is even greater. Generally, some of the same kinds of equipment are required for these stages as for the intermediate stages. In addition, controlling the quality of recirculating water requires a whole array of additional equipment (surveillance equipment, back-up equipment, switches, and filters) not required at the lower stages. Also, at those levels of intervention, a higher portion of specialized equipment is required. In fact, some of it is designed especially for the production of fish in recirculating systems. At the highest levels of intervention, the substitution of equipment for labor is even more pronounced than at the lower levels.

### *Services*

In economic terms, the inputs required for aquaculture are either goods or services. Goods are those tangible things required, such as containers, seed, equipment, or nutrients. Services are all forms of work done for others that do not result in the direct production of a tangible good. Information, credit, and harvesting are examples of specific services that are required in the production process.

There are other, more general, services that are not absolute requirements of aquaculture, but that may be needed if intervention in the production process is to function smoothly and efficiently. These include but are not limited to:

1. *Utilities (electricity, water, and gas).*
2. *Accommodations (hotels and restaurants).*
3. *Repair and maintenance.*
4. *Communications (telephone, radio, etc.).*
5. *Transportation (highways, airplanes, etc.).*
6. *Advertising.*

The need for these general services is positively related to the stages of aquaculture. As the level of intervention increases, the amount of services required also increases. Farmers culturing shrimp and fish for food for their families in tidal swamp ponds require few of these general services. At the intermediate stages, the general services are more important to the success of the farming venture. The farmer could produce and market a crop of fish without them, but not without increased risk of failure. Certainly the efficiency of production and marketing would be reduced in the absence of adequate transportation, utilities, repair, and maintenance.

These general services become much more important at the highest stages. Not only are the levels of services required extremely high, but also the level of integration of those inputs is high. The services not only must be available, they also must be available at the right time and in the correct amount. At these stages, because of the amount of equipment required, maintenance and repair are especially crucial. Breakdowns that last only a few minutes may result in the loss of the entire crop.

### *Containers*

Aquaculture requires that the farmer maintain some degree of control of the animals being cultured; animals must be "contained" if they are to be cultured. Also, aquatic organisms generally require water, and water must be contained. Because the water and fish are contained, I have chosen to use the term "container" at this point rather than ponds, raceways, or cages, although the more common terms will be used throughout much of the book. The term aquaculture implies the passage of time in which the biomass of the organism or organisms is increasing. During this period, the animals must be under someone's control or in someone's container. Otherwise, the wild fish of the oceans could be considered to be in a culture system.

There are three primary characteristics of containers that affect their use in aquaculture: (1) style of construction, (2) effectiveness as a container, and (3) harvestability.

**Style of Construction --** There is considerable variation in the style of construction used in aquacultural containers. The style varies from primitive to highly sophisticated. While there is some argument on the applicability of such a scale, it essentially reflects the degree of alteration (intervention) required of the natural containers (rivers, lakes, bays, oceans, etc.) in which the animals are usually encountered.

The most primitive containers, those utilized in the lower stages of culture, are constructed by placing a man-made "plug" or dam in a natural watercourse or channel creating a pool or pond. This primitive system requires little alteration of a natural land area to provide the containment. Many of the coastal shrimp ponds in use in the tropical world are of this type. These dammed watercourse ponds often are nothing more than tidal pools in which the natural channel is plugged with an earthen dam. Water is supplied to the pond from tidal flow. The ponds are most effective where there is a relatively high tidal range, otherwise the depth of water that can be trapped is relatively shallow. These ponds often have an ill-defined shoreline and variable water depth and contain both woody and herbaceous vegetation (Figure 4).

Many of the ponds utilized in catfish farming in the United States are of the more primitive type, the dammed watercourse (Boyd, 1985; Jensen, 1989). This is especially true in rolling-hill topography where there are numerous valleys. These valleys are the result of thousands of years of erosion. Many contain small, semi-permanent streams. A container is created by building an earthen plug (dam) across the valley damming the stream (Figure 10). The shoreline is irregular, the depth is variable, and there may be a considerable amount of vegetation. In more hilly terrain, the ponds may be deep relative to the area impounded. In order to impound three to five acres of water, for example, it may be necessary to construct a dam 15 to 18 feet high across the valley. These high dams are expensive to construct, and the deep pond usually stratifies thermally in the summer, resulting in the development of a large volume of water containing little or no oxygen (Tucker and Boyd, 1985). Water is supplied to the pond by the stream, which is usually dependent on localized rainfall and flood run-off. Water control is limited.

**Figure 10. Dammed water course containers used in catfish production in Alabama, U.S.A.**

The so-called levee ponds (formed containers) are more highly developed (Boyd, 1985). A dam or levee is constructed on four sides creating a rectangular pond (Figure 6) (Wellborn, 1989). These ponds are usually constructed on flat land so that the depth is uniform and the shoreline is regular. A large area can be impounded while maintaining a relatively shallow depth. Often, for this type of pond, water must be provided by pumping (Boyd, 1985). Many of the shrimp ponds constructed in the tropics in recent years are levee ponds (Figure 11). Water is supplied by pumping from a tidal stream (Figure 12).

Most of the catfish produced in the United States are grown in levee ponds. The ponds are constructed on the relatively flat delta soils along the Mississippi River. Water is pumped into these ponds from shallow, high-yield aquifers underlying those soils.

Actually, there is a sort of transition from the dam used to interrupt a watercourse to a levee pond. In some situations, one dam or levee will form a container. In others, two levees may be sufficient and in other situations, three or four dams or levees may be required to contain the water. Shoreline and depth uniformity and bottom contour generally improve with increases in the number of levees forming the container.

Raceways are a more highly developed container than any of the previous types described, although they also often are dependent on the damming of a watercourse.

Figure 11. Levee containers used in the production of shrimp in Honduras, South America.

Figure 12. Pumps used to lift water out of a tidal stream into ponds in Guatamala, South America.

Raceways are combinations of interrupted water courses and levee ponds (formed containers) (Piper et al., 1983; McLarney, 1984; Beleau, 1985). These containers are long, narrow, man-made watercourses with uniform width and depth (Figure 13). Usually they are supplied with water from a nearby stream or spring. Most often, raceways are constructed in areas where the streams have a relatively high gradient. A dam is placed across the stream, creating a small, interrupted watercourse container and raising its level high enough so that water can be diverted by gravity onto the stream bank where the raceways are constructed. The water flows rapidly through the container which contains a high density of fish and back into the stream. A high percentage of the trout produced throughout the world are grown in raceways.

Cages (Figure 14) are highly specialized containers (Beleau, 1985; Beveridge, 1987) which confine the movement of the cultured animals to provide a degree of control of the stock that would not be practical otherwise. Cage culture has an old and honored history in Southeast Asia where people living on river houseboats would keep catfish in slatted, bamboo cages. The fish were fed scraps from the table just as the penned-up pigs on shore. Cages have had their greatest use in the culture of salmon in the Pacific Northwest in the United States and in Europe (Fitzgerald, 1987; Lowe, 1988; Needham, 1988). Virtually all of the cultured salmon are grown in cages. Cages suspended in marine waters provide the salmon with the salinity and

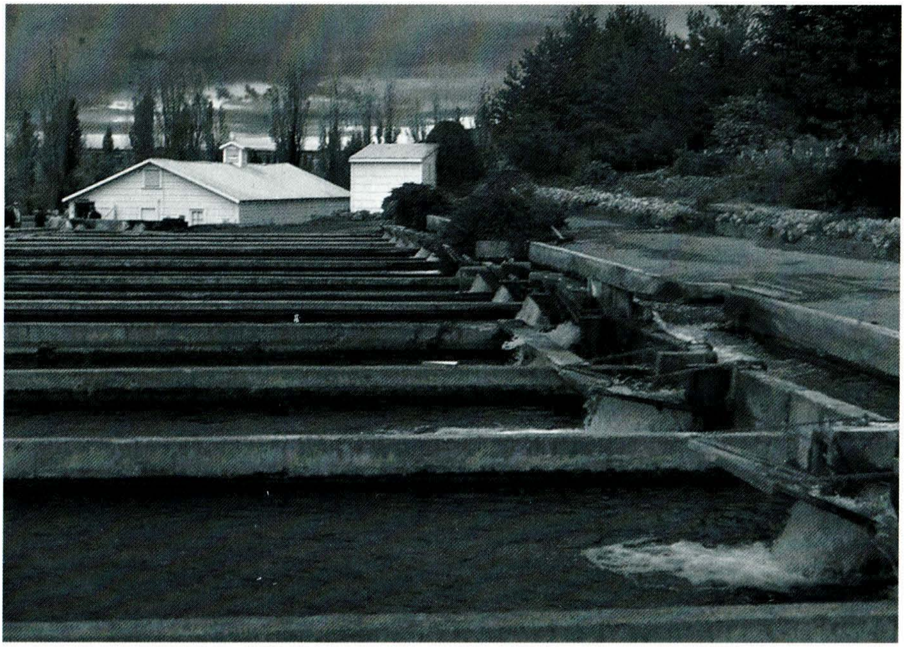


**Figure 13. Typical raceway containers used in trout production.**

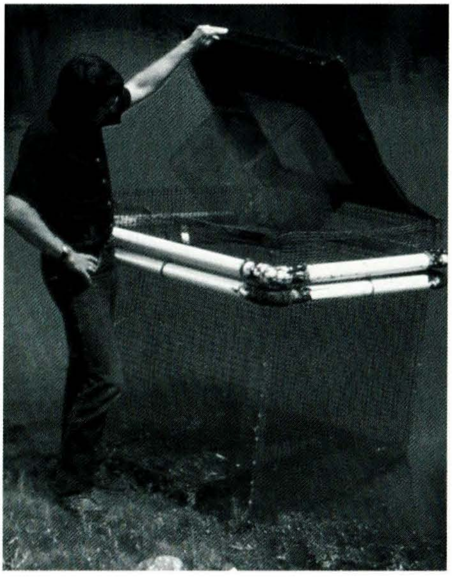


**Figure 14. A cage used in the culture of channel catfish in east-central Alabama.**

water quality required for rapid growth and, at the same time, provide the degree of stock control needed.

Some channel catfish are produced in cages in the United States. In Arkansas, cages are suspended in large freshwater reservoirs. Wind-induced water movement in those reservoirs causes a steady flow of freshwater through the cages; yet the fish are contained.

The net pens used in milkfish and tilapia production in the Philippines are a special application of cage culture (Guerrero, 1987). Large pens, which cover several hectares, are created by draping synthetic fiber netting on bamboo poles. Small milkfish are stocked in the enclosure where they feed on natural foods carried into the pens by water currents.

Recirculating systems also are a specialized type of container (Beleau, 1985; McCoy, 1986) (Figure 7). In reality, they are a type of raceway or formed container. The animals are contained in a tank. Water is pumped into one part of the tank and flows out in another. The container is part of a closed loop. After flowing into the culture container, water is partially stripped of oxygen by the fish, and it becomes contaminated with relatively high levels of carbon dioxide, along with other metabolic by-products, feces, and uneaten feed. Water then flows from the culture container into a settling basin where the suspended matter falls to the bottom and subsequently is flushed from the system. Then the water goes to a biological filter where the soluble nitrogenous metabolic by-products are removed. Finally, it is re-oxygenated and pumped back into the container. This system provides a high degree of water quality control.

Because of the cost of the operation and maintenance of this type of container, relatively few fish are being cultured in them on a commercial scale. These systems have a certain fascination because they provide a mechanism for controlling, to a considerable extent, the eccentricity of nature: flood and drought, cold and heat, day and night, and oxygen supersaturation and oxygen deficiency. Research and development on these containers will continue. With the improvements in engineering expected and with the development of sophisticated computer-aided monitoring systems, it is possible that they might be used in commercial aquaculture some day.

The most specialized type of container is not really a container at all (Sedgwick, 1982). In ocean ranching, salmon are placed in a "physiological container." The early life history stages of the fish become patterned to the chemical make-up of the water in the hatchery. Later, smolts are released to go into the ocean to feed. After several years, on reaching sexual maturity, they use their senses of taste or smell to follow the trail of the river and then the creek until they return to the same hatchery ponds where they were held in their early lives. Obviously, not all of those fish released actually return, but because of the unique nature of the container, cost of production per individual fish is relatively low. This approach to aquaculture can be profitable with even a relatively low return percentage.

**Effectiveness as a Container --** To be effective, an aquacultural container must contain both water and fish. Fortunately, with most types water containment is relatively effective. However, when it is lacking, an efficient aquaculture is extremely difficult. In the more primitive containers, such as the tidal pool, the pool level is essentially at the level of the water table, and the water table in tidal areas remains relatively stable. Seepage tends to be minimal. When there are problems, they usually are related to leakage around the man-made dam in the watercourse. Water loss can, however, be a serious problem in containers constructed in mangrove areas. Often soils utilized to build the dam contain large quantities of plant roots and other plant material. Seepage through levees or small dams containing this organic material can be quite high. This is especially true if the tidal range is relatively high so that the level of the water in the pond is higher than the water level in the surrounding area much of the time. The hydraulic pressure forces a large volume of water through the fibrous material in a relatively short time.

Water containment in most levee ponds usually is effective. Seepage can be a problem, although this is usually not the case. Land that is level enough to be used to construct levee ponds usually is associated with relatively high water tables, and the soil usually contains relatively high percentages of clay. Level land is usually the result of silt and clay settling out of static water in river valleys or deltas. These soils compact well in levee construction, and when the soils are wet, there is very little seepage. Levee ponds have one shortcoming related to water containment. While the fine clay usually found in flat lands resists seepage when formed into a levee, it is subject to erosion. With four levees surrounding most ponds, wind-driven water currents constantly move the fine particles from the shoreline to deeper water. As a result, the levees must be rebuilt after a time. This problem is further compounded by the lack of trees or windbreaks usually associated with levee pond construction.

The containment of water is effective in both raceways and in the tanks utilized in recirculating systems. Raceways are most often constructed of concrete to prevent erosion resulting from rapidly flowing water. Tanks used in recirculating systems may be constructed of sheet metal, aluminum, fiberglass, or plastic, and containment is extremely effective.

The containment of fish usually is directly related to the container's effectiveness as a water container. Any pond or tank that effectively contains water also will effectively contain fish under ordinary circumstances. Dammed watercourses are less secure because of the danger of flooding from high tides caused by storms or from excessive rainfall. The safety of the structure is usually directly related to the degree of intervention in modifying the natural system. Levee ponds are usually less subject to flooding and fish loss than dammed watercourses, although areas suitable for the construction of levee ponds often are in flood plains of major rivers. Although flooding is infrequent, it can be disastrous when it does occur. Raceways and recirculating tanks are even more safe.

**Harvestability --** This characteristic is related to the ease or difficulty of harvesting the crop once it is produced. Obviously, there is little return in producing fish or shrimp if they cannot be harvested when they have reached market size or when the market is available.

Harvestability usually is related to the degree of intervention involved in the style of construction. The harvest of a crop from containers constructed on tidal streams, for example, is usually difficult because of the uneven shoreline, variable depth, abundant vegetation, and lack of water control (Figure 5). To harvest the fish, it usually is necessary to completely drain the pond and catch the animals in nets as they pass through the "broken" dam with the water. Harvesting also is somewhat complicated because it is usually necessary to wait for the right stage of the tide before the water can be completely drained out.

Dammed watercourses in fresh water provide some improvement, because it usually is not necessary to wait until low tide to drain the water. However, irregular shorelines and variable depths still cause problems. In hilly areas, it usually is necessary to drain most of the water from the pond before the depth is shallow enough to remove the fish. Under these conditions, a large quantity of fish may be confined in a small volume of water before it is shallow enough to seine. Often the fish stir up anoxic muds and must be removed quickly or they will die. Even if the fish can be removed alive, carcass quality may be affected.

Levee ponds are much easier to harvest. The shoreline is usually regular, the bottom is smooth, and the change in depth is gradual. Consequently, it is necessary to drain off only a small amount of water, if any, before the fish can be removed by seining. Water quality remains good throughout the harvest.

Harvest is relatively simple in raceways and in tanks used in recirculating systems. Fish can be forced to one end with nets where they can be dipped out.

### *Water*

Water is one of the basic requirements of aquaculture. Water is important to aquatic animals for a number of reasons, but the most important is that respiration out of water is literally impossible. Without a constant supply of oxygen, most aquatic animals quickly die. Oxygen cannot pass across the gill or respiratory membrane into the circulatory system unless the membrane is wet. Without water, the membranes quickly dry and oxygen cannot pass through. Similarly, the metabolic waste product, carbon dioxide, cannot pass through a desiccated membrane.

At the lower stages of aquaculture, the natural food that cultured animals feed upon is produced in the same container where they live. The water serves as a matrix for an aquatic "pasture." These natural pastures are characterized as food pyramids in which the mass of the pyramid is determined by the size of the base (green plants), which in turn is related to the quantity of inorganic salts (nitrates, phosphates, and potassium salts) available as fertilizers for the plants (Odum, 1983). The algal cells are eaten by micro-crustaceans, the micro-crustaceans are eaten by aquatic insects, and the aquatic insects are eaten by fish. Because of the loss of energy between links (due to the effect of the Second Law of Thermodynamics) in the so-called food chain in this aquatic pasture, the amount of algal cells required to produce a unit of fish tissues is relatively large. As a result of the pyramid effect, if a modest production of aquatic animals is expected, the pasture must be relatively large or there must be relatively large quantities of water available. The ratio of fish weight to water volume is relatively low compared to the more advanced stages of aquaculture.

The water also serves as a medium for waste disposal and recycling. The wastes (feces, carbon dioxide, urine, etc.) from the fish are quickly broken down by decomposer microorganisms to simpler organic and inorganic molecules that are recycled. These microorganisms need oxygen to carry out most of the steps in the recycling process. Photosynthesis takes place during daylight, and there is ample oxygen. At night, when there is no photosynthesis, there usually is enough oxygen stored in solution in the container to meet the needs of microorganisms, algae, insects, and fish until the sun rises the following day. Thus, a major function of water in the pasture system is to serve as a storage place for oxygen.

At the intermediate levels of intervention, such as in the culture of channel catfish, the stocking rate of animals is increased, and food needs can no longer be met from the pasture alone. The animals must be fed. The weight of fish in the container may be as high as 6,000 pounds per acre, and as much as 150 pounds of high-protein feed per acre may be fed each day. The amount of organic waste produced in the container is large (Tucker and Boyd, 1985). With so much organic matter (wasted feed and feces) to be decomposed, there is a significant increase in the amount of oxygen required for the recycling process, especially when compared to the lower stages of aquaculture.

The increased quantity of wastes which are processed by the decomposer microorganisms results in increased levels of nutrients to be utilized by the algae or other aquatic plants. Consequently, photosynthesis and oxygen production increases. Thus, feeding results indirectly in the increased need for oxygen for decomposition and the increased production of oxygen from photosynthesis (Tucker and Boyd, 1985). Unfortunately, photosynthesis proceeds only during daylight. During darkness, no oxygen is produced, while respiration continues unabated (Boyd and Hollerman, 1982). Because of the increase in oxygen demand by the biota at these intermediate stages, the dissolved oxygen level begins to decrease at sundown and will continue to decrease until sunrise the following morning. In some cases, the rate of consumption is so high that all of the oxygen stored in the water column is utilized in biological oxidation. In this situation, unless additional oxygen is added to the water, the fish will die. As a result, it is frequently necessary to use mechanical devices for stirring or agitating atmospheric oxygen into the water during the early morning hours to prevent the death of fish (Tucker and Boyd, 1985). At these levels of intervention, the fish weight/water volume ratio is larger than at the lowest stages of aquaculture.

At more advanced stages of aquaculture, such as the culture of trout in raceways, the fish weight/water volume ratio becomes even greater. Large quantities of food are required for optimum growth, more than can be produced in the culture container. The large quantity of feed added to the system results in the production of a large quantity of wastes. Also, because of the high fish to water volume ratio, there is inadequate oxygen production and storage to meet the needs of the fish. To deal with these two water quality problems, a large amount of fresh water is flushed through the raceways, continuously removing wastes and providing a constant supply of oxygen.

In the highest stages of aquaculture (recirculating systems) where a high degree of environmental control is practiced, the fish weight/water volume ratio is at its highest level, and water must be flushed through the container at a high rate to remove wastes and to maintain a high level of dissolved oxygen in the system. The water containing the wastes is passed into a filter system where larger particles are physically removed. The remaining wastes are removed through microbial decomposition in a biological filter. This water subsequently can be reoxygenated and passed back through the system.

In this section, most of the discussion has been limited to the importance and difficulty of managing the oxygen concentration in aquacultural systems. While oxygen may be the most critical of the water quality characteristics, there are several others (carbon dioxide, ammonia, nitrite, salinity, turbidity, and temperature) that on occasion can have a significant effect on the success of the aquacultural effort.

As indicated previously in this section, quality and quantity of water are important considerations in aquaculture. Another consideration is water availability. Availability concerns having water available to add to the container when it is required. Generally, availability increases as the level of intervention increases. However, increased availability usually comes at an increased cost. At the lowest stages of aquaculture, such as where a tidal pond is constructed to hold water and capture small fish and shrimp, water usually can be added to the pond only during the two highest tidal periods of the month. At other times, tidal range is so small that water will not flow into the pond when the gate is opened. Under these conditions, even if water is needed for any reason at a time other than when there is an adequate tidal level, it would not be available. The same problem of water availability is present at some intermediate stages of aquaculture where water is harvested from rainfall and runoff from a surrounding drainage area (Boyd, 1982, 1985). For example, in catfish farming in the hills of east Alabama, ponds are filled during the winter, the period of heaviest rainfall. Generally, unless a pond is filled by early April, it is not likely to fill that year. From April through November, rainfall is generally insufficient to offset seepage and evaporation. Consequently, if a crop of fish is to be harvested after April by draining the pond, it cannot be refilled and put back into production until the following winter (Boyd, 1982; Boyd and Shelton, 1984) (Figure 15).

Water availability is much better for catfish farmers in the Mississippi Delta where levee ponds are filled by pumping from a shallow, high-yielding aquifer. The water is available as needed, but pumping water in the quantities required for filling ponds is costly. Also, continued pumping in that area has led to falling water levels in the aquifer (Fentress, 1987). Pote et al. (1988) provide a discussion on the use of water, its sources and conservation, in catfish farming in Mississippi. This work is a good example of the studies that must be done for virtually all kinds of aquaculture because of the large quantity of water utilized for the culture of most species. As aquaculture continues to grow, the availability of adequate water will become an increasingly important matter (Wax and Pote, 1990).

At the highest stages of aquaculture, water availability generally is not a major problem. Trout raceways are usually filled and maintained with water from springs or permanent streams, so ample water is usually available at all times. Similarly, in recirculating systems, water is available continuously. Usually these systems are connected to the water supplies of a town or city. Also, since the water is recirculated, there is plenty available so long as the filters and pumps function satisfactorily. Obviously, the cost of guaranteeing availability is quite high in this stage of aquaculture.

### *Seed*

For want of a better term, those small, immature animals that are the basis of aquaculture are often called seed. While such terms as fry, fingerlings, spawn, and alevins also are used, the term seed relates aquaculture more closely to agriculture than do the other terms. Seed are essential in aquaculture just as they are in agriculture. In fact, it probably was the collection, storage, and accidental planting of wild seed that led to the development of plant agriculture as contrasted to hunting and gathering food.

In the lower stages of aquaculture, seed are usually obtained directly from the wild. At the lowest stages, seed are obtained and stocked by channeling tidal flow or stream flow containing the small, immature animals into the culture container. A flooding river or a high tide carries the shrimp and/or fish seed into a container which is then closed to capture the water and the seed. This type of seed gathering has been the basis for a significant portion of the brackishwater aquaculture in the tropical

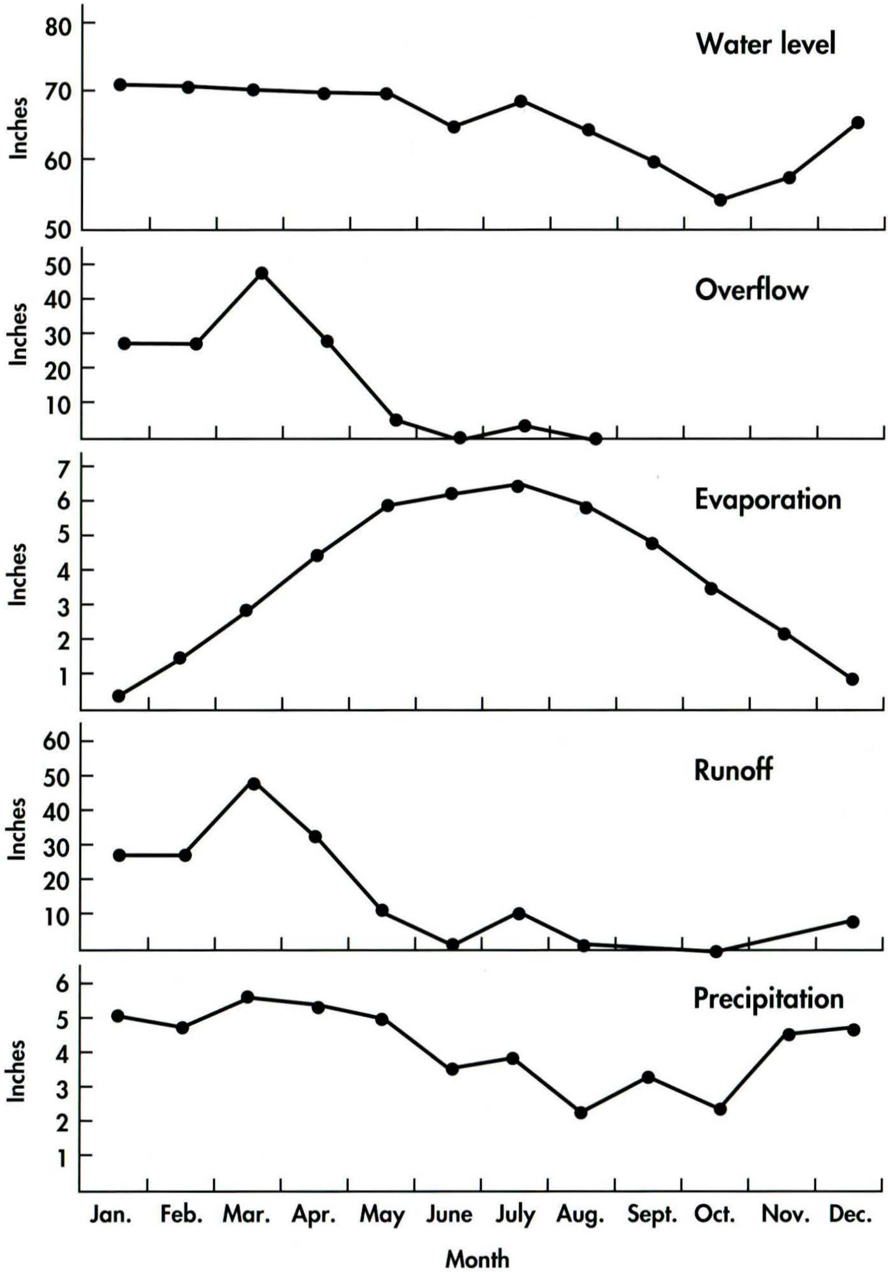



Figure 15. Annual water budget for catfish ponds in hilly terrain in east-central Alabama showing the relationship among rainfall, seepage, and evaporation (Claude Boyd, personal communication).

world. In these situations, there is little or no control over the quantity or quality stocked in the container. The quantity available for stocking is dependent on the quantity occurring naturally. Over time, trial and error have resulted in the accumulation of practical knowledge that provides some minimal control of quantity. Capturing water at certain times of the year, month, and day brings the likelihood of a higher stocking rate.

At higher stages of culture, seed are harvested from natural sources and stored in a holding container until a sufficient quantity is available to provide the required density in a production container. This system of seed harvest and storage is the basis for milkfish culture in Southeast Asia, for the culture of the Indian carps in South Asia, and for shrimp culture enterprises in Central and South America (Bardach et al., 1972). Here, some of the uncertainty of the actual quantity available for stocking at a specific time is eliminated, but there still is limited control over the total number available. There is no control of the number of seed produced in the natural systems. Also, the number may vary considerably from year to year. Finally, there is little opportunity to increase production above a certain level. The total amount (area) of culture that can be developed is dependent on the availability of seed, which cannot easily be increased. In the limiting situation, seed from the natural sources may be harvested to the point that there will be insufficient wild brood animals remaining to maintain the level of seed required. This is the dilemma already facing shrimp aquaculturists in some areas.

At the intermediate stages of aquaculture, seed are usually produced under controlled conditions. For example, in the production of channel catfish seed, brood males and females are kept together in a pond which contains boxes or cans where the female deposits eggs and the male fertilizes them (Busch, 1985A) (Figure 16). The farmer then removes the fertilized eggs to the hatchery (Figure 17). After hatching, the tiny catfish are held in troughs until they begin to accept prepared feed. Then they are moved to rearing ponds where they are grown to a suitable size for stocking in the production units. Although there is a somewhat higher level of control in this situation, compared to the lower stages, there is still a degree of uncertainty over the number of seed that will actually be produced. For example, climate seems to have a strong effect on the number of spawns that will be produced, but predicting spawning success is difficult. Also, not all of the females spawn in a given year. Further, there is some indication that under certain conditions a parent may actually eat the eggs before they hatch. Finally, survival of the recently hatched fish when stocked in the rearing ponds is highly variable.

In the higher stages of culture, the seed quantity is virtually guaranteed by controlled spawning. Mature adults are confined in a container and allowed to spawn. In some cases, they may be induced to spawn or the eggs and sperm may be taken from the adults and fertilization effected. The total quantity can be controlled by increasing the number and/or size of the adults being spawned. For example, the production of seed of the rainbow trout has been developed to the point where the quantity to be produced can be predicted with a high degree of certainty (Piper et al., 1983).

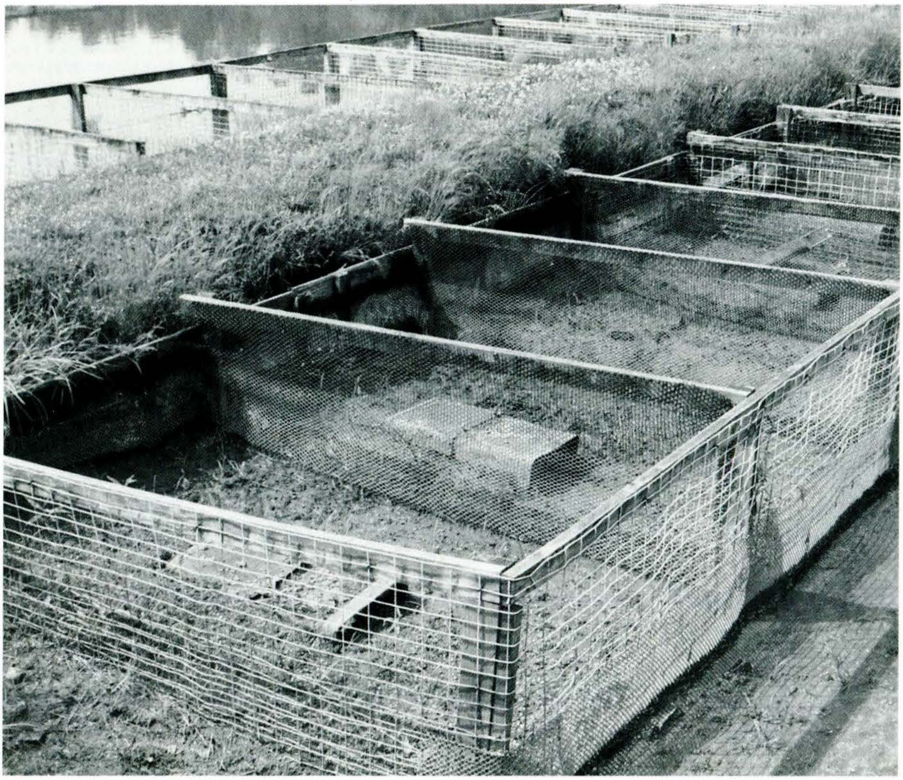


Figure 16. Spawning pens for channel catfish. In some hatcheries a male and and female are stocked in a small pen containing a spawning box or container. After spawning and after the fertilized eggs are removed for hatching, the spent female may be replaced with a new female.

Quality of seed also is an important consideration in aquaculture. Quality refers to the characteristics of the seed that will allow them to survive and grow in response to husbandry. Seed that die soon after being stocked obviously are poor quality, assuming, of course, that water quality in the container was not the cause of mortality. Similarly, if the growth potential of a group of seed is reduced because of inbreeding depression (Piper et al., 1983; Tave, 1986), they are poor quality.

Often, at both the lowest and highest stages of aquaculture, wild seed are utilized. This is because there have been limited efforts to improve genetic quality in aquacultural species. There have been some so-called improved strains of common carp for many years (McLarney, 1984), and there have been some efforts to breed improved rainbow trout (Piper et al., 1983). Recently, a few strains of improved channel catfish have been released to farmers (Dunham and Smitherman, 1985). Also, there has been some effort given to improving the market appeal of tilapia by breeding for a red color (Galman et al., 1988). Except for these few examples, most

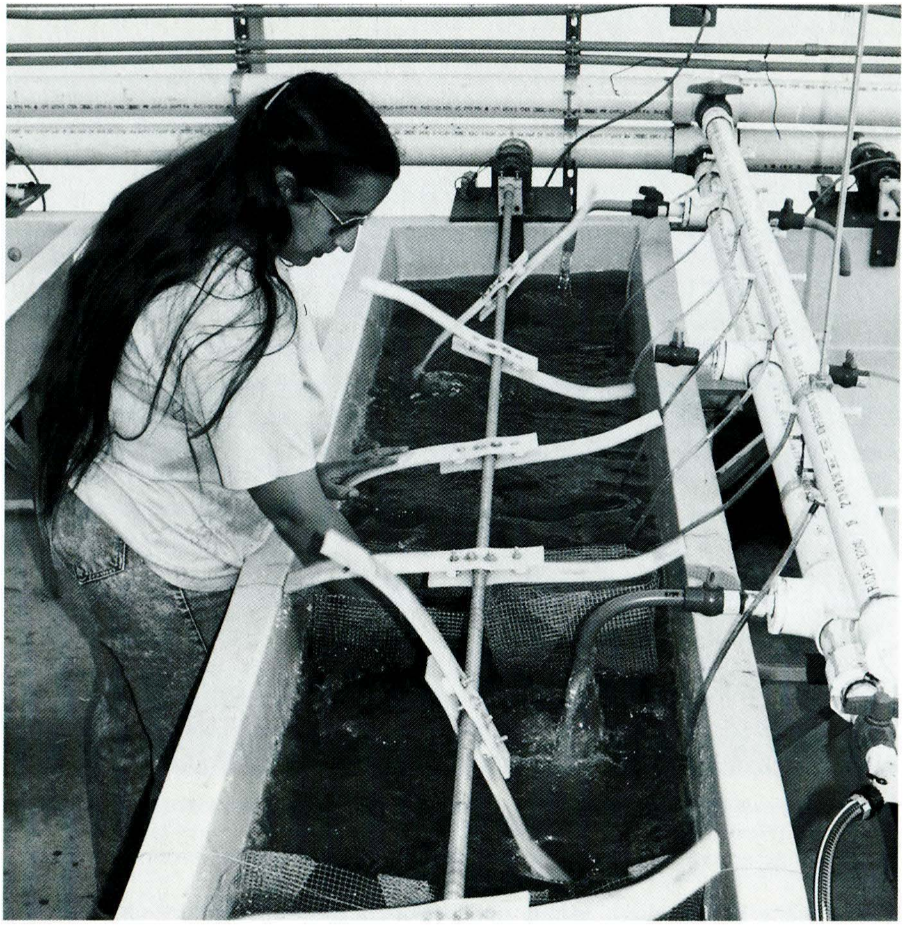


**Figure 17. Paddlewheel trough used in the hatching of channel catfish eggs. The paddles passing through the water create a zone of turbulence around the egg mass, resulting in the oxygenation of the interior of the mass.**

fish seed used for culture are essentially of the same genetic quality as those found in the wild.

In a broader sense, quality of seed also includes having the appropriate species available for stocking. At the lowest stages of culture, there is limited control of the species available. When the water is channeled into the container from a flooding river or tidal flow, all of the seed present at that time are stocked. The desired species are stocked along with the undesirable. Even at higher levels of culture, where seed are harvested from the wild before stocking, farmers are limited to using those species occurring naturally in their areas. At the intermediate and highest stages, the availability of a particular species usually is of limited concern. Farmers obtain the broodfish of the species they wish to culture, or they purchase the kind of seed they need from another farmer who can supply the species desired.

In some cases, the best species for culture may not be available in the country or even in the region (Shell, 1983). The distribution of families of fishes is such that some countries have much better candidates for domestication and aquaculture than others. This was true of the animals (cows, pigs, chickens, etc.) that we culture for food today. At one time, they had a limited distribution. Over time, they have been moved from country to country and from one continent to another. In aquaculture, the opportunity to benefit from the movement of better species is generally limited to the intermediate and higher stages of culture. Where the seed are obtained directly from natural waters, there is limited opportunity to benefit from introduced species.

Seasonal availability is another aspect of seed quality that is important. At the lowest level of intervention, where seed are trapped along with water only at certain times of the year, culture is dependent on seasonal availability. The husbandry must begin when the seed are available. At intermediate stages, where seed are harvested and stored for a time before stocking, seasonal availability is still of some concern, especially if the window of availability is extremely narrow. However, in this situation, the seed can be stored in holding containers for considerable time before they are stocked. This strategy allows the farmer to extend the seasonal availability throughout most of the year. Even at the intermediate stages of culture, where a species is spawned under more-or-less controlled conditions, the period when fertilized eggs can be obtained may be relatively short, requiring storage of the seed for long periods to deal with the problems of seasonal availability.

Channel catfish culture in the southern United States provides an interesting example of a problem with seasonal availability. The spawning season for the species in this area generally begins in mid-May and continues through mid-July (Busch, 1985A). It is extremely difficult to produce seed in May, stock them in ponds, and produce harvestable fish before decreasing water temperatures in November slow growth. For optimum utilization of the growth window (March-October generally), the seed should be available by mid-March, approximately two months before spawning actually occurs. As a result of this problem, seed are produced during the spawning season, then reared under relatively crowded conditions until they are harvested from the containers and stocked in the culture ponds, usually when they are eight to 10 months old but still relatively small.

This problem of seasonal availability is much less common in tropical areas where there is a year-round growing season. There, the recently hatched seed can be stocked into the production ponds without the concern for a temperature-related growth period. However, even in those tropical countries, storage of recently hatched seed for a period is beneficial. The mortality of seed decreases rather dramatically after one or two months. If seed are stocked soon after hatching, survival in the production units will be highly unpredictable. By storing the fish for a few months until they grow larger and then stocking them in the production containers, higher and more predictable survival can be achieved.

With a few species, the problem of seasonable availability is of little or no concern. Tilapias, for example, spawn through the year in the tropics and throughout the summer in the temperate zone. For most species, however, there is a rather limited spawning period. And there has been relatively little progress in extending the period for most species, although it has been demonstrated that the reproductive cycle of fish can be altered drastically by artificially changing the length of day or the amount of light the adults receive (Ingram, 1987A, B). Thus, by holding the fish in a light-proof container and using artificial light, the normal annual daylight cycle can be quickened to cause the fish to spawn earlier. While this procedure is possible, it is not commonly used in commercial aquaculture.

The window of availability of seed of the rainbow trout has been expanded dramatically. Originally this species spawned in the spring of the year. Now there are strains available that spawn virtually every month. This is a particularly valuable characteristic in the raceway culture system for trout where seed may be needed for stocking throughout the year. It is possible to extend the spawning season of the channel catfish to some degree. Large, mature brood fish spawn in the spring, but younger fish that are growing rapidly may reach sexual maturity and spawn for the first time late in the summer. In fact, by using this technique, it is possible to extend the spawning season from mid-May to mid-September. However, extending the season that late is of limited value because, as the water begins to cool, growth is reduced by early October. Extending the spawning season does allow the fish farmer to produce more seed with limited facilities.

### *Nutrients*

Fish, shrimp, and other animals used in aquaculture are not able to make their own food. Unlike green plants (producers) -- which are able to manufacture virtually all of the chemicals (nutrients) they require if provided with inorganic salts, carbon dioxide, and sunlight -- animals are unable to synthesize many of the chemical compounds required for their growth and reproduction. Aquatic animals are consumers. They use food materials produced by plants (Odum, 1983). Their diets must contain protein (as a source of essential amino acids), fats (as a source of fatty acids and energy), and carbohydrates (as a source of energy), along with vitamins and minerals. These essential dietary nutrients must be available in quantity in excess of the requirement for maintenance if growth is to take place (Robinson and Wilson, 1985; Lovell, 1988). There is a nutritional requirement if the animals do no more than maintain their weight. Just maintaining life requires food.

The nutrient requirements of a fish or a shrimp are independent of the stage of aquaculture. Cellular metabolism of a tilapia requires the same nutrients regardless of whether it is in a flooded swamp pond in the tropics or in a complex recirculating system in a developed country. However, there are considerable differences in the manner in which the aquaculturist provides for the nutritional needs of the fish in these two situations.

In the lowest stages of aquaculture, the food to meet the requirements of the animals being cultured is produced in the container itself. For example, in a swamp pond container where annual flooding brings in fresh water, a food chain or food web provides nutrients for the fish being cultured. The fish being cultured are a part of the web. They are consumers, but in death and decomposition they are themselves consumed (Anderson, 1987; Pruder, 1987). Inorganic salts brought in with the flood water are used along with carbon dioxide and sunlight by algae and other plants (producers) to synthesize organic matter and to trap energy. Photosynthesis directly or indirectly provides the organic matter (food) that the various groups of consumers must have. Also, bacteria decomposes dead plants and animals in the system, thus releasing inorganic salts and carbon dioxide to be recycled. The organic matter synthesized by the green plants is consumed by protozoans and microcrustaceans which are, in turn, consumed by insects which are then consumed by fish (Hickling, 1968; Boyd, 1979; Odum, 1983). Also, the microcrustaceans and/or the decaying organic matter (plant detritus) laden with bacteria and small invertebrates might be consumed by the fish.

The food supply for cultured animals in a flooded swamp container is highly variable, and is dependent on the amount of nitrogen, phosphorus, potassium, and other inorganic salts that are in solution in the flood water. Once the flood waters recede, the addition of inorganic salts is limited until the next flood season. In this situation, the salts are quickly taken up by plants and some, especially phosphorus, are adsorbed to soil particles on the bottom (Boyd, 1979), Because of the influence of nutrients in the flood water, there is a "pulse" of organic matter production. This pulse moves throughout the food web and results in a spurt of fish growth. Some of the inorganic salts, organic matter, and energy are trapped in the tissues of the fish as a result of fish growth. Also, salts become part of higher aquatic plants and are no longer available for cycling in the food web on a short-term basis.

The algal cells and many of the small animals in the web have short life spans. If they are not consumed, they die quickly and are decomposed by bacteria. On decomposition, the inorganic salts are released only to be reabsorbed by other algal cells. Obviously, the photosynthetic production of organic matter by algal cells is the driving force in this system, but most animals do not effectively utilize green plants as food. Probably, the dead and partly decomposed algal cells (manure) play a greater role in the nutrition of the animal consumers in the web than do the live cells (Anderson, 1987). This cycling in the container following the annual flood continues, but as it does, more and more of the salts are trapped and lost in parts (fish tissues, higher plants, bottom muds, etc.) of the web that do not turn over rapidly. As a result, inorganic salt concentrations in the water in the culture container decrease, which results in a shrinking of the web. As part of this phenomenon, fish growth slows down, and may cease altogether.

At this lower stage of aquaculture, the farmer has limited control over the crop of animals that will be produced. It is largely determined by the amount of inorganic salts in the flood water. In turn, the level of salts is dependent on the nature of the soils over which the water passed on its way to the swamp (Arce and Boyd, 1980). Fertile agricultural soils provide more plant nutrients than poor agricultural soils. Flood waters from limestone-derived soils contain more salts than waters from soils derived from granite or igneous rocks.

At a higher stage of culture, the farmer adds inorganic salts on a regular basis in order to counter the trapping of salts as they cycle through the food web (Boyd, 1979). These salts are added (fertilization) in quantity and in time to maintain a more or less constant level of algal cells, thus stabilizing the food web and allowing the continued growth of fish in the system. The farmer simply augments the level of salts that are brought to the container in flood water. Even though inorganic salts are added in this situation, the food consumed by the fish is produced in the container.

Even with fertilization, only a relatively low level of fish production can be obtained. The food web essentially becomes self limiting. As the mass of the web grows, the amount of organic matter than can be synthesized through photosynthesis begins to level off. In the extreme case, the bloom of algal cells becomes so abundant that absorption of radiant energy is limited by shading (Smith, 1977; Tucker and Boyd, 1985). The farmer has limited control of the quantity of food produced in the system. Usually inorganic salts are added to obtain the highest possible mass of food in the web. Once the fish crop reaches the point where the food available just meets its maintenance requirements, growth ceases. It is difficult to increase the quantity of food produced as the crop grows.

A slightly higher stage of culture involves adding organic matter, usually animal or plant refuse (manure), rather than inorganic salts to the container (Wohlfarth

**Figure 18. Composting grass and animal manure as a means of providing organic fertilizer to a tilapia production pond in Rwanda, Central Africa.**

and Hulata, 1987; Hishamunda and Moehl, 1989) (Figure 18). In this situation, depending on the species being cultured, some of the organic matter may be consumed directly. However, it may have a limited effect because it does not meet the nutritional requirements of the fish. Usually, the protein level and protein quality (amino acid balance) in plant and animal manures are relatively low (Boyd, 1979). Most of it, however, becomes part of the food web at the same point and in the same way as the dying and decomposing algal cells, protozoans and microcrustaceans, and fecal material from all of the animals produced in the web.

Aquacultural production utilizing manures is generally higher than when depending on fertilization with inorganic salts, because the mass of the food web is not so severely limited by the amount of photosynthetic production of organic matter that can take place in the container. Obviously there is a limit to the level of production that can be obtained in this manner. As was noted previously, photosynthesis plays two vital roles in aquacultural systems, the synthesis of organic matter and the production of oxygen. Fish production can be increased by adding organic matter (manure) from an external source, but at some point the amount of oxygen that can be produced becomes the limiting factor. Decomposition of the manure requires so much oxygen that there is little available for the respiration of the fish.

At intermediate stages of aquaculture, the fish are fed directly (Figure 19). There is limited concern for the natural food produced in the container. Usually, the stocking rate of seed in the container is so high that natural food production plays only a limited role in meeting the nutritional needs of the fish as they grow. There is, however, a considerable amount of natural food produced in the pond. Certainly, more is produced than with fertilization with inorganic salts, but the amount available is small relative to total needs. In some cases, natural food may serve to provide some ingredients, such as vitamins and amino acids, that may be absent or available in limited quantity in an incomplete fish feed (Swingle, 1958).

Fish are fed a mixture of meals made from grains (corn, soybeans, and wheat), plus vitamins and minerals combined with fish meal or some other meal derived from animal by-products. These materials usually are pressed into pellets (Robinson and Wilson, 1985). The pellets are more easily ingested by the feeding fish. Feeding a meal mixture without pelleting is essentially the same as adding manure to a culture pond (Prather, 1957; 1958). Also, there is less loss of water soluble ingredients from a pellet than from a meal mixture. The composition of the pellet is designed to meet the nutritional requirements of the fish as closely as possible.

At the intermediate level of intervention, the amount of feed given to the fish can be adjusted as the fish increase in size and as the total crop mass increases. Although some upward adjustment is practical, there is a limit beyond which the level of feeding cannot be increased without supplementing the natural production of oxygen with mechanical aeration (Tucker and Boyd, 1985). The addition of feed significantly increases the amount of organic matter in the container, which in turn increases the demand for oxygen. Feeding results in some wasted pellets and a large

**Figure 19. Feeding channel catfish in a production pond at Auburn. A blower sprays a measured amount of feed onto the surface of the pond.**

amount of fecal material. As a result, although the fish are being fed directly, there is a high level of indirect manuring taking place (Hopkins and Manci, 1989). In the limiting case, not enough oxygen is produced through photosynthesis and stored in solution in the pond during daylight hours to meet the requirements for respiration and oxidation occurring during the night. To prevent the death of the fish, additional oxygen must be dissolved in the water from the atmosphere using various mechanical devices.

The amount of feed that can be given to the fish also is limited by the water temperature (Robinson and Wilson, 1985). The metabolism of these cold-blooded animals is directly related to the temperature of the water in which they live. For the channel catfish, feeding should be reduced somewhat when the temperature goes below 68°F. When the temperature is less than 55°F, feed is poorly utilized. It accumulates on the pond bottom and requires oxygen for its decomposition.

At these intermediate stages of aquaculture where a single species of fish is fed directly, there is a large and complex food web established, and there may be an accumulation of under-utilized natural foods, such as microcrustaceans and aquatic insects. In this situation, it is possible to add other aquatic animals to the container that feed primarily on those accumulated natural foods. This practice of stocking species with complementary feeding habits in the same container is called polyculture (Hickling, 1968, Dunseth, 1977). Through polyculture, more of the mass of the food pyramid can be utilized for increasing total aquatic animal production in the container without adding more nutrients. Polyculture also provides a means of storing waste organic matter in the tissues of fish where the demand for oxygen is less than if it were being decomposed in the container. Also through polyculture, the waste organic matter can be removed by harvesting the fish thus reducing the amount of oxygen required for decomposing if it were left in the pond.

At the highest stages of aquaculture, there is virtually no production of natural food in the culture container. There is no food web. The nutritional needs of the fish are met entirely through the use of prepared feeds. Also, there is no accumulation of organic matter except in the tissues of the fish as they grow. Generally, the feed utilized at the highest stages is the same used in the intermediate stages. In both cases, a nutritionally complete ration is required. The primary difference in providing nutrition to fish in the different stages is that, at the highest stages, the water temperature does not vary with the season. It is always kept at an optimum level for maximum feed utilization, allowing more feed to be fed over the course of the year. There is virtually no opportunity for polyculture in the recirculating systems, at least in the primary culture container, although the organic matter removed from the system by filtration might be used as a manure in a separate culture system.

## *Harvesting*

Harvest is required if cultured aquatic animals are to become food or be entered into commerce (Busch, 1985B). It is that part of the culture process between production and processing. Harvesting, in its simplest form, involves removing the animals from the container and transporting them to market. However, under some circumstances it can be a complex and costly process and may affect the final quality of the product which the consumer purchases. There are three general steps in harvesting:

1. *Concentrating the animals.*
2. *Removing from containment.*
3. *Transporting to processing and/or marketing.*

### *Concentrating the Animals*

Except for cultured molluscs (oysters and clams), aquatic animals are dispersed throughout the container when it is time for harvest, and it is necessary to restrict their potential for movement by concentrating (confining) them. As described earlier, the tidal swamp pond container is usually constructed by building a low dam through the brush (Figure 4). The pond is usually irregular in shape with an uneven bottom and containing many stumps, snags, and standing brush. It is difficult to concentrate fish when these containers are full of water. Seines, cast nets, and dip nets are difficult to use under these conditions. Generally, the animals can be concentrated only by draining the ponds and trapping them in nets as the water flows out or picking them up by hand or with dip nets from shallow puddles (Figure 5).

Harvesting from tidal swamp ponds also is more complicated because the water from the pond usually can be completely drained out only on low tide. Because of the nature of these production systems, the pond is filled during a high (spring) tide, and it can be completely drained only during low (neap) tide. Neap tides do not occur on a daily basis, but rather at 14 3/4-day intervals and are independent of the diurnal cycle. As a result, the optimum time for draining a tidal pond (at neap tide) can be at an inopportune time considering the need for daylight to be able to see the shrimp and fish. Further, because the window of opportunity to harvest is so narrow, the availability of labor may be a problem.

Concentrating aquatic animals is less complex at the higher stages of culture. For example, at the intermediate stage when channel catfish are produced in the hill country of east Alabama, it is not as difficult as in the tidal swamp ponds, but there still are difficulties. The containers used in this system are constructed by building a dam across a natural valley which contains a small permanent or semi-permanent stream (Figure 10) (Boyd, 1985). Most of the trees are removed from the pond, but it is extremely difficult to remove all of the stumps and small roots. Also, the bottom is uneven. The shape of the natural valley also results in a deep pond with shallow edges. Because of the combination of depth and obstruction (stumps and snags), it is difficult to concentrate the fish by seining. It is possible to trap fish (Smitherman et al., 1979) from these ponds by surrounding them with a net while they are being fed, but no more than 50-60 percent of the crop can be captured in this manner. Also, trapping is labor intensive when considering the quantity of fish that can be removed. If all of the fish are to be harvested, the pond must be drained at least to the point where it can be seined. Often in a culture of this type, the pond will contain 3,000-4,000 pounds per acre of fish. In a two- to three-acre pond, there will be 6,000-12,000 pounds of fish that must be confined before removal. As the pond is drained, the fish are concentrated into smaller and smaller volumes of water (Figure 20). This is a time-consuming process. In larger ponds, it may require several days to remove enough water to be able to seine. Also, because of water movement and the activities of the fish, mud from the bottom is stirred into the water. Under these conditions, the fish must be removed quickly or many of them will die and carcass quality will

**Figure 20. Removing fish with a seine in a hill pond. All of the fish must be concentrated into a relatively small volume before they can be seined.**

deteriorate rapidly. To keep the fish alive and in good condition, harvesting from these systems is usually done during the winter when the water is cooler, it contains more oxygen, and the fish require less oxygen.

It is less complex to concentrate animals in containers usually associated with more advanced stages. For example, confining catfish in levee ponds in Mississippi is much easier (Busch, 1985B) (Figure 21). Those ponds usually are rectangular with relatively smooth bottoms. Virtually all of the fish can be captured by seining without lowering the water level. Confinement in raceways or recirculating water containers is even simpler. Nets are constructed to fit the shape of the container. All of the fish can be "herded" into one end of the container.

### *Removal from Containment*

This is a part of the harvesting process that can become complex and dangerous under some circumstances. In the tidal swamp pond, the concentrated animals can be dipped up with a net and placed in the container to be used for transportation. In hill ponds used in some areas for the culture of channel catfish, the fish are usually concentrated at the lowest point in the basin. The confinement area may be 18-20 feet below the top of the dam and as much as 30 feet below the transportation container on a truck or wagon. In larger ponds, thousands of pounds of fish must be lifted more-

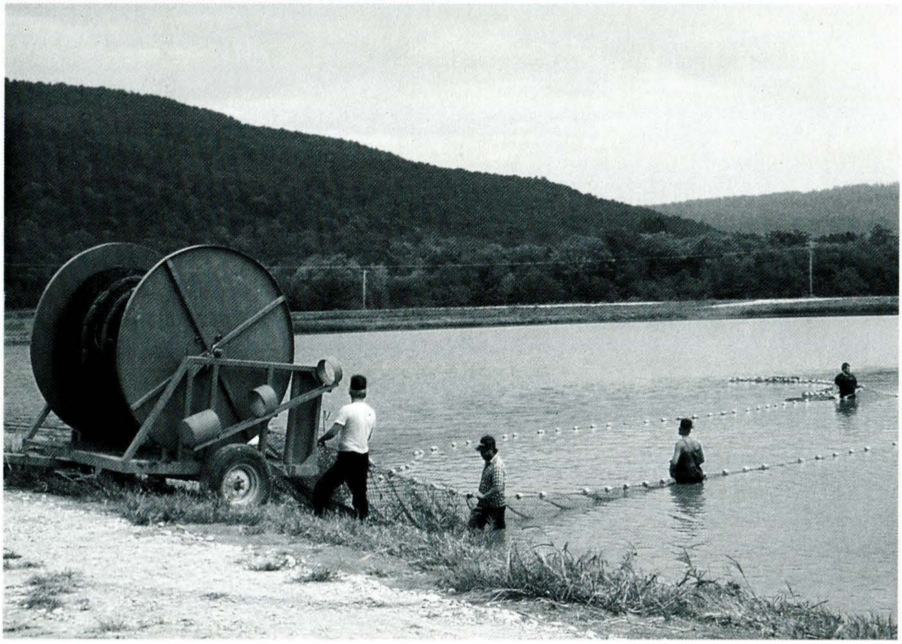


**Figure 21. Harvesting catfish from a levee pond in Mississippi. Fish can be harvested as needed without lowering the water.**

or-less vertically over a distance of 20-30 feet as quickly as practical. The problem of lifting so many live fish this distance is further compounded by the need to restrict the quantity moved at one time. If too many fish are lifted, the weight is so great that those at the bottom of the basket or bucket will be bruised.

Removing fish from levee ponds or more specialized containers (raceways, cages, or tanks) is somewhat simpler, but lifting large quantities of live animals is never really simple. Lifting thousands of pounds of fish or shrimp requires a great deal of energy and powerful mechanical devices. The process is also dangerous. Usually there are people working around and below the animals as they are being lifted. Mud and water contribute to slippery footing. Because of the time and energy required, the potential reduction in quality from bruising, and the danger associated with the process, the use of fish pumps is increasing. These pumps lift the water which contains the fish. With this equipment, large quantities of fish can be moved quickly with little injury.

### *Transportation to Processing*

Moving aquatic animals (Figure 9) from the production site to the processing plant usually is the simplest part of the harvesting process, but it can have a significant effect on the quality of the final product. The quality of the hauling water and/or ice, the time required, and the weight of fish in the container all affect the condition of the animals when they reach the processor. These factors are important wherever aquatic animals are transported, but they become even more significant in semi-tropical and tropical areas where so much aquaculture takes place.

## *Processing*

Processing can be defined as "any action or series of actions that change the physical and chemical characteristics of aquatic animals to enhance their acceptance as food, to preserve them, or to increase their value."

Cultured fish, like those captured from the wild, seldom are consumed without undergoing some processing. This is not a unique characteristic associated with the consumption of aquatic animals. Almost without exception, flesh or meat food is processed before being eaten. This practice is contrasted with the utilization of many plant foods that are minimally processed, if at all.

There are two general phases of processing, both of which will be discussed in the following sections:

1. *Primary processing (butchering).*
2. *Secondary processing (chemical or physical change).*

### *Primary Processing*

Primary processing involves simple butchering or reduction of the carcass. In this phase, those portions of the carcass which have limited value for food (scales, skin, head, intestines, fins, gills, rib cage, and backbone) are removed and discarded. Also, the carcass may be reduced to a number of smaller pieces which can be handled more effectively.

Primary processing generally requires more labor than secondary processing. But because so much of the original weight of the animal is discarded at this stage and because the product requires further processing (cooking, smoking) before it can be consumed, return to labor is more limited. For this reason, the butchering phase is being mechanized whenever practical to reduce the labor input.

### *Secondary Processing*

This stage of processing involves changing the chemical or physical structure of the flesh in some way, and it is carried out for two primary reasons:

1. *Preserving it against spoilage.*
2. *Making the portion more acceptable as human food.*

Aquatic animals are considered to be the most perishable of all of the so-called meat or "flesh" foods consumed by man (Ammerman, 1985). As soon as a fish dies, spoilage begins. Spoilage is a result of a whole series of complicated changes brought about by its own enzymes, by bacteria, and by chemical action (Burgess et al., 1967). Of these three deteriorative changes, those resulting from the action of bacteria are the most extensive. Much of the secondary processing is carried out to counter these deteriorative changes and to preserve fish as food for a period of time. Procedures used in secondary processing include:

*1. Drying and dehydration.*
*2. Freezing.*
*3. Smoking.*
*4. Salting.*
*5. Canning.*
*6. Radiation.*
*7. Fermenting.*
*8. Marinating.*

Secondary processing also is practiced to enhance the value of aquatic animals as food. These procedures visually increase the market appeal of the animals or increase the price which consumers are willing to pay. These also are called "value added" practices, and include:

*1. Cooking.*
*2. Pre-cooking for oven or microwave readiness.*
*3. Special coatings (breading).*
*4. Stuffing.*
*5. Prepacking prepared fish meal.*

Considerable research and development have been conducted in the last 100 years on the processing of ocean fish. The same principles and practices are appropriate for cultured fish. However, while the same procedures and principles apply, some characteristics of pond aquaculture may require that more attention be given to preventing spoilage than with wild-caught fish, especially those taken from the colder ocean waters. Because of the complex food webs that are established in culture ponds, there likely will be a much higher level of bacteria per unit of pond water than in cold ocean water. Also, a high proportion of these organisms in culture containers is likely to be decomposers which can readily affect fish quality. Further, because of the longer growing season, much of the development of aquaculture will take place in areas of the world where the water is warm for much or even most of the year. The increased bacterial load and the higher temperatures result in optimum conditions for deteriorative changes in fish quality. As a result of these characteristics, associated especially with aquaculture where ponds are used as containers, considerable attention must be given to maintaining fish quality during harvest and immediately thereafter.

The level of processing is generally, but not always, correlated with the stage of aquaculture. For example, shrimp are produced in cultural systems in South America, which in some instances represent relatively low stages of aquaculture, but because of the demand for and value of these animals, high levels of processing technology often are utilized. Virtually all of these shrimp are frozen for preservation and large quantities are breaded before final sale. At the same time, trout culture in raceways represents a much more advanced stage of aquaculture, but for most of these animals, processing is limited to removing the gills and intestines and freezing.

Heading and gutting might be practiced at the lower stages, while filleting and steaking are more common at the intermediate and higher stages. Generally, more machinery is used in processing fish from the higher stages. Under these conditions, it is more economical to substitute machinery (capital) for labor.

In general, the type of preservation used is related to a degree to the stages of aquaculture. The more primitive methods, such as drying, smoking, or fermenting, are more common at the lower stages (Figure 22). Freezing and canning would be more common at the higher stages. Value-added processing, such as special coatings (breading), stuffing, or pre-cooking, would generally be utilized only at the higher stages (Ammerman, 1985; Water Farming Journal, 1989).

There is one other aspect of processing that should be mentioned. One of the primary objectives of processing is the separation of the parts of the carcass that are suitable and acceptable for human consumption from those parts that are not. Of course this differentiation is highly culture specific. Parts of the carcass that are routinely discarded in some countries are utilized in others. In most cases, however, processing results in a large quantity of offal. For example, in the basic catfish processing operation, the head, skin, and intestines are removed and discarded. These

**Figure 22. Drying fish removed from lower-stage aquaculture ponds in Thailand.**

parts comprise approximately 40 percent of the total weight of the fish. Fortunately, in the case of catfish processed by the larger plants, this offal can be sold to rendering plants for the production of fish meal. Smaller plants with less offal often have difficulty disposing of it without creating environmental problems. Even larger plants may have problems with disposing offal. The wash water from processing lines contains large quantities of water-soluble organic compounds that cannot be released into adjacent streams without causing water quality problems.

## *Marketing*

A relatively small percentage of all aquatic animals produced through aquaculture is consumed by the farmer or his immediate family where no transfer of title is required. The percentage consumed in this fashion is highest at the lowest stages of aquaculture. Kent (1987) reported on a study of rice farmers in Thailand in which approximately 26 percent grew fish for food for the family. At the intermediate or higher stages of aquaculture, few, if any, of the animals are produced for food for the farmer's family. If the fish are not to be consumed by the family and if the farmer is to obtain a return on his investment, he must exchange title of the product for goods of equal value or currency. This exchange requires marketing. Smith and Klontz (1991) noted that aquaculture can provide a variety of products to satisfy the needs and wants of consumers, but that these products must be positioned through effective marketing to give the industry a competitive edge on the products of captive fisheries as well as red meat and poultry.

Bransom and Norvell (1983) provide several definitions of marketing:

> *1. The processes associated with exchanging one product for another.*
>
> *2. The performance of all of those transactions and services associated with the flow of goods (product design, advertising, shipping, storing and selling) from the point of initial production to the final consumer.*
>
> *3. The process of satisfying human needs by bringing products to people in the proper form and at the proper time and place.*

Marketing is an extremely important component of aquaculture. Without it, aquacultural production would not proceed through many cycles. Although it is a part of aquaculture, it is often separated from the other parts. All of the components or steps except marketing and utilization can be considered as production functions. Marketing, therefore, is the culmination of all of the other steps in the aquaculture process. It is at this point that change of ownership usually occurs. It is the point where demand and supply converge and pricing occurs.

In general, relatively little attention has been given to marketing compared to the effort given to production (Chaston, 1983). Consequently, many of the problems encountered in the development of aquaculture can be traced to a lack of concern for marketing. In too many cases, farmers produce the animals and then search for a place to sell them. This is production-oriented aquaculture. In market-oriented aquaculture, marketing is utilized to assess the needs before production begins; then production is organized to meet those needs.

According to Smith and Klontz (1991), the successful marketing of aquacultural products depends on developing a consumer orientation. This orientation recognizes that the principal task is to be skillful in marketing what the customer wants and expects and not what the market expects.

Chaston (1983) suggests that those charged with marketing aquacultural products answer 12 questions designed to define the nature and characteristics of the market environment before production begins. These are:

1. *What are the markets?*
2. *What major segments exist within each market?*
3. *What is the current size of those markets and their segments?*
4. *Which of those markets and their segments represent areas of growth or decline?*
5. *Who are the primary target customers?*
6. *What is known about customer purchasing behavior?*
7. *What are possible changes that may occur in their behavior in the future?*
8. *Who is the competition?*
9. *What are the strengths and weaknesses of the competition?*
10. *What changes are expected in competition activity in the future?*
11. *What are relevant macro-environment variables of influence (technological, cultural, legal)?*
12. *Which of the relevant macro-environment variables might be expected to change in the future?*

Marketing was defined as a part of the process whereby title of a product changes from a seller to a buyer. This change of ownership is dependent on a number of conditions in which it takes place. In some instances, the farmer will sell his crop directly to the consumer. This process takes place in two steps:

1. *The farmer and customer exchange information and agree on a price.*
2. *Title of the animals changes as they are delivered to the customer and currency or goods of equal value are delivered to the farmer.*

This is a simple marketing system where producer and consumer deal directly with each other (Chaston, 1983) (Figure 23). Simple markets are relatively rare in developed countries and are characteristic of the lower stages of aquaculture

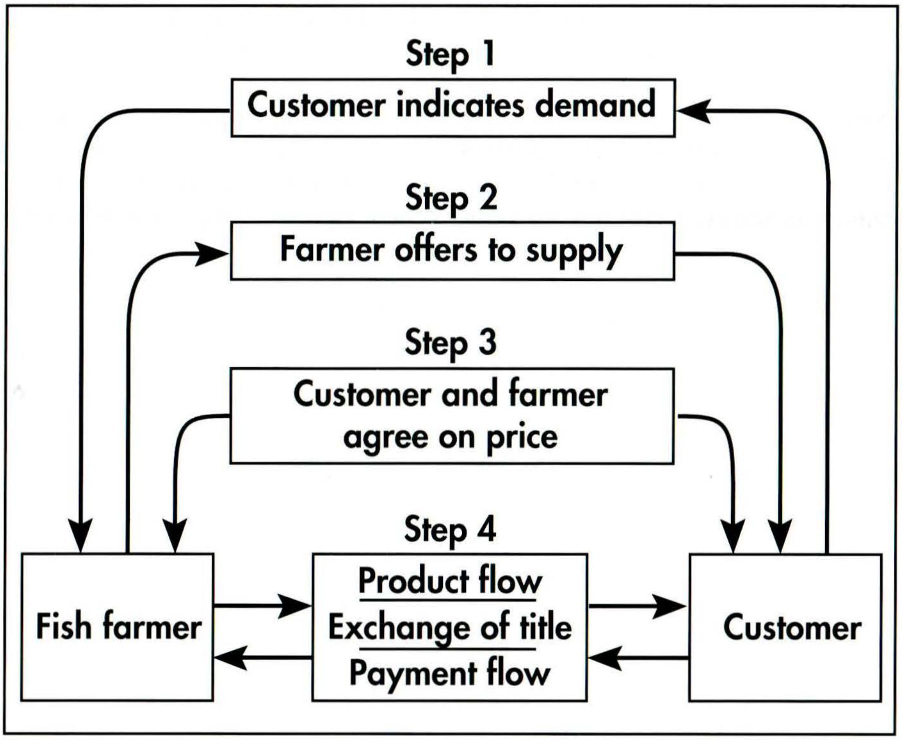



**Figure 23. Representation of a simple marketing system (Chaston, 1983).**

(Hishamunda and Moehl, 1989). Channel catfish produced in eastern Alabama beyond the areas served by processing plants are more likely to be marketed using this simple system. While it is simple, it provides maximum gross return to producers, because they not only sell directly to the consumer but also often process and market the product before selling it. In several cases, individual farmers produce their own catfish seed, grow out the fish to marketable size, process them, and market them through family-owned restaurants. This is vertical integration in its purest form. Production, processing, and marketing are owned and operated (integrated) by the same individual. Under these conditions, demand, supply, and pricing are much simpler.

Direct marketing between producer and consumer offers opportunities for maximum degree of customer satisfaction. Often producer and consumer live in the same community and know each other. Product quality and price often reflect this relationship and there is ample opportunity to deal with disagreements which might affect demand.

In complex marketing situations, the producer does not sell directly to the consumer but rather to an intermediary who may sell to the consumer or to a second intermediary (Bransom and Norvell, 1983). In some cases where there is secondary processing involved before final sale to the consumer, several intermediary buyers may be involved. Under these conditions, the two-step process which leads to exchange of title in simple systems may be repeated several times before the fish reach the consumer. With some seafoods, ownership may change 10-12 times before the products are finally prepared for consumption (John Jensen, personal communication). In reality, a complex marketing system consists of two or more simple systems linked together (Figure 24).

Complex marketing systems are essential for the delivery of large quantities of food in modern, industrial societies where consumers generally are separated by hundreds of miles from the producer. Such systems are also vital in societies where farmer productivity is high enough that only a small number of people are involved in production.

Most cultured aquatic animals are purchased for food, of course, but significant numbers of channel catfish (Huner and Dupree, 1984B) and rainbow trout (McLarney, 1984), and some other species are sold for sport fishing. Fish are purchased by "live-haulers" who transport the fish to a pond or stream where they are released. Then recreational fishermen pay a price for the privilege of catching them with some form of "hook and line" equipment (Figure 25). Most of these fish finally become food, but the recreation involved is the primary force driving the marketing effort. This situation makes a complex marketing situation even more complex because sport

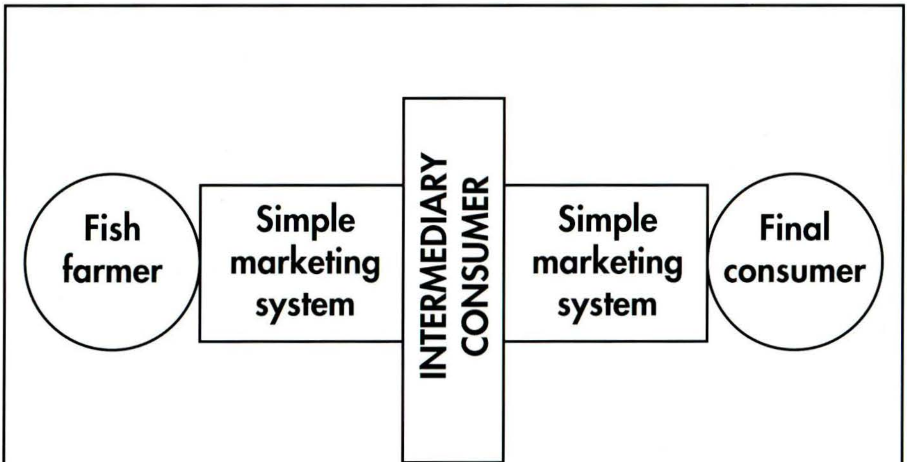



**Figure 24. Representation of a complex marketing system (Chaston, 1983).**

**Figure 25. Recreational fishing at a fish-out channel catfish market.**

fishermen are willing to pay more than the value of the animal for food to catch the fish. Fish cultured for the pet industry (aquarium trade) is another example of an additional level of complexity in marketing. In this case, the purchase of fish is not related to food production or food value in any way.

While complex marketing systems are essential, they create problems in relating supply to demand, in establishing equitable pricing, and in dealing with customer dissatisfaction. This situation is best characterized by the old adage that "a chain is no stronger than its weakest link." In a complex market, a serious malfunction of any one of the links can affect the entire system. For example, when ownership changes several times between the producer and the final consumer, it may be difficult to maintain the quality of the product. All of the temporary owners may not have satisfactory storage facilities. Maintaining product quality could be difficult under those conditions. Also, it would be difficult to determine at what point in the chain deterioration occurred.

Five specific steps that facilitate marketing (Branson and Norvell, 1983) include needs assessment, product design, price determination, promotion, and distribution.

### *Needs Assessment*

The first step in marketing, needs assessment, means that the need for a product should be determined before production begins. Its important role in aquaculture already has been discussed in the section on production.

### *Product Design*

Product design is the second step in marketing. Once the need for a product is determined, specific plans should be developed to produce that item with the specific characteristics that the consumer wants (Senauer, 1989). This step also was discussed in some detail in a preceding section.

### *Price Determination*

The third component of marketing is price determination, termed "price discovery" by Bransom and Norvell (1983). The term price discovery is an appropriate one because the producer (farmer) cannot know in advance how consumers will value his product and how much they will be willing to pay for it. At the same time, consumers cannot know the farmer's production costs. Each side discovers the position of the other in the marketplace. Ekelund and Tollison (1988) suggest that "prices are the essential signals that tell producers and resource suppliers what and how much to produce and the signals that help consumers decide what and how much to buy." Setting the price of a product is important. If it is set too high, consumers will purchase less of the product or will buy alternative products. If it is too low, the producer can make little or no profit or possibly even incur a loss. Therefore, an optimum price between these two limits must be found. The relationship between demand and supply and price elasticity will be discussed in a following section. In theory, price is determined to be that point where the price-demand curve intersects the price-supply curve (Figure 26). Ekelund and Tollison (1988) call this the "equilibrium price." At this point, a given price will result in demand being exactly equal to supply (Chaston, 1983). Because purely competitive market conditions do not prevail, however, price may be set by one or combinations of the following situations:

1. *Cost-based pricing.*
2. *Demand-based pricing.*
3. *Competition-based pricing.*

With cost-based pricing, producers add a profit to their known production costs (Chaston, 1983). This procedure is simple, but when applied alone it can lead to marketing problems because it does not take into consideration demand or competition. In simple marketing situations where the producer sells directly to the consumer and where there is limited competition and strong demand, it is possible to use cost-based pricing. Obviously, these conditions are relatively rare.

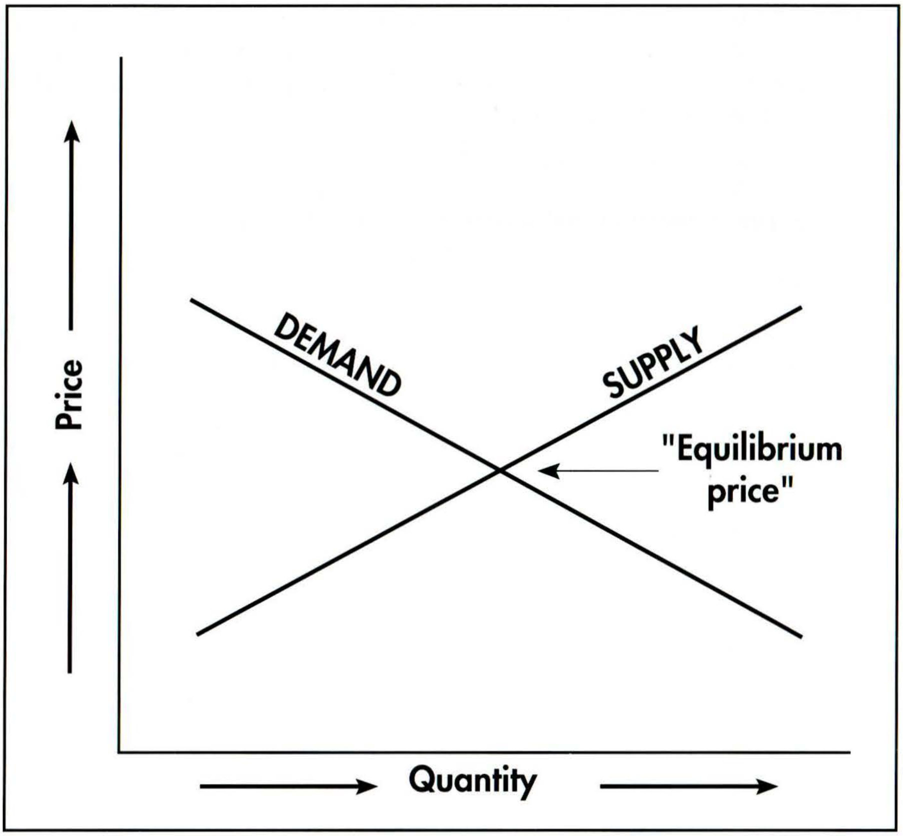



**Figure 26. Generalized demand and supply curve.**

In demand-based pricing, the seller sets prices to manage demand. This situation usually requires that the seller have a mix of products available that will appeal to a broad range of customers. Prices are set on the various items of the mix as customer demand responds. Usually there must be a range of products that will allow a relatively broad range of pricing.

Marketing of fish products commonly involves a number of companies marketing essentially the same species. Under these conditions, the product of one company is indistinguishable from that of another. In this situation, prices are often set by a lead company with due consideration for the smaller ones. When the large company changes prices, the smaller ones usually quickly do the same. This method simply depends on determining what everyone else is charging. It is the most common method for determining price.

The three types of price determination described are more common to the marketing of fish captured from the wild through commercial fishing. Price determination of the products of aquaculture is a much more complex process that results from a combination of cost-plus, demand, and competition factors. The complexity is increased because, in the case of some species, they come to market from farms and from the rivers, lakes, and oceans. For example, in Alabama's channel catfish market, there are four potential sources of fish:

*1. Farmed channel catfish.*
*2. Wild channel catfish from Alabama rivers.*
*3. Other species of catfish from rivers and lakes in other states.*
*4. Brazilian catfish, indistinguishable from channel catfish after processing.*

Once these fish are skinned, headed, eviscerated, and cooked, even the most discriminating customers would have a difficult time knowing which catfish they are eating. Yet the costs of production and demand for these four forms are quite different. Obviously, price determination for those four different, yet similar products is complex. Because the supply of farmed fish is much greater, the price of all four is more or less dependent on prices set for those produced in ponds. If the supply of river fish was larger, it is likely that this product would be a price leader. This phenomenon of dual sources (wild versus cultured) for the same food product is not unique to aquatic food animals, but it certainly is an important example from a volume standpoint.

Price determination of cultured fish is further complicated by the extremely large number of species that is available to the consumer. In a good meat market, it is likely that a consumer would be able to select products from four or five different species; beef, pork, lamb, and poultry would most likely be available. In a good fish market, the consumer could select from at least 10-15 different species.

The increase in fish consumption also complicates the problem of price determination. The consumption of meat, fish, and poultry per capita for 1990 compared to 1970 in the United States is as follows (Putnam, 1991):

| *PRODUCT* | *POUNDS PER CAPITA* | |
|---|---|---|
| | *1970* | *1990* |
| *Meat* | *130.4* | *112.3* |
| *Poultry* | *34.7* | *63.6* |
| *Fish* | *12.1* | *15.4* |

Per capita consumption of total fish and shellfish in 1990 (15.4 pounds) was up 27 percent compared to the 1970-74 average (12.1 pounds). Consumption actually reached 16.1 pounds per person in 1987. This rise in consumption occurred even though price increases for seafood were up 369 percent over that period. Consumer price indices for red meat and poultry were up 193 percent and 140 percent, respectively, during the same period.

Because of the changing nature of competition between farmed and captured products, the large variety of more-or-less comparable species in the market, and the rapidly increasing demand for all kinds of fish, price determination for cultured species will continue to be a rapidly changing and complex situation. The combination of steadily increasing prices and improvements in technology that should lower production costs should result in excellent profitability. Chaston (1983) suggests that these higher profit margins should be invested in the creation of strong customer loyalty for cultured fish.

### *Promotion*

Promotion is the fourth component of marketing. It is defined by Bransom and Norvell (1983) as "any additional sales effort over and above the normal process of taking orders for sales." Even a correctly designed product with a competitive price and an effective distribution system would not result in demand unless potential customers are made aware of the comparative advantages of the product. Customer purchasing decisions are based on their perception of a product. Promotion is a means of creating a positive perception. Promotion is accomplished in four primary ways:

1. *Advertising.*
2. *Personal selling.*
3. *Pricing.*
4. *Public relations.*

Of the four, advertising (Kinnucan et al., 1990) and personal selling are the most important in building long-term customer loyalty, which is a primary objective of promotion. The other two methods, pricing (free samples, coupons, special price reduction sales, etc.) and public relations, usually will have only a short-term effect. While sales may increase during the price manipulation period, they are likely to return to approximately the original level when it is completed. Public relations, where the media is encouraged to publicize some aspect of the product free of charge, usually affects sales for only a relatively short time.

It is important to remember that promotion alone will not result in increased sales unless the other components of marketing also are operating effectively. If there is no need for a specific aquacultural product, if it is poorly designed for the market, or if it is priced poorly relative to alternative products, promotion will have little, if any, permanent effect on sales.

Promotion is most effective when the producer or seller can establish a dialogue with the customer. In this way, questions concerning price, quality, value, and product characteristics can be dealt with quickly. For this reason, personal selling, where the seller or his representatives contact the consumer personally, is more effective than advertising. However, personal selling is difficult unless consumers are concentrated. As customer dispersal increases, the effectiveness of personal selling decreases. Where the sales force must spend a large amount of their time traveling between contacts, total effectiveness declines. At the same time, as customer dispersal increases, the effectiveness of advertising also increases.

The relative effectiveness of personal selling versus advertising is constantly changing because of food fads and other consumer behavior, the introduction of new products, and the degree of maturity of an existing product (Chaston, 1983). For example, in the early days of the development of the catfish farming industry, virtually all of the promotion was done by personal selling. Most customers were confined to the larger river valleys of the central United States. Relatively little effort was given to advertising to promote the product. Now the geographic distribution of customers has broadened significantly, especially toward the eastern seaboard states. As a result of this spread of consumer interest, more emphasis is now being placed on advertising.

While personal selling remains effective in the original sales territory, advertising is the only effective method of promotion to reach a large number of the potential new customers in the population centers of the Northeast. Recently, a new organization has been formed specifically to advertise farm-raised catfish in the major United States magazines and newspapers. This organization, the Catfish Institute, is funded by contributions from the major companies producing feed for the catfish industry (The Catfish Journal, 1989).

There is probably a positive correlation between the stages of aquaculture and the degree of promotion of the products involved. At the lower stages, little or none is required. Pillay (1977) notes that, in the lowest stages, the information that fish are available spreads rapidly by word of mouth among consumers who flock to the fish ponds. John Moehl (personal communication) suggests that most of the fish cultured in Rwanda are sold as a result of word-of-mouth promotion. In this situation, the seller and buyer probably know each other personally. Additional promotion is not necessary. At the intermediate and higher stages, considerably more promotion is required as potential customers become more dispersed. However, the increased level of promotion is not just a function of greater customer dispersal. Higher levels of intervention also tend to be associated with increased production. More production usually requires providing information regarding fish availability to a larger area and to more people.

### *Distribution*

Distribution is the last component of marketing to be considered. It is rare today for the producer and the final customer to be located close enough so they can trade directly without intermediaries. Usually there is a need to establish some type of system to distribute the product to the final customer. A distribution system is a chain of intermediaries along which the product moves from farmer to final consumer and usually involves a sequence of ownership changes as the fish move from link to link. In the simplest distribution system, the farmer and consumer are linked by transaction, but a system with two or more intermediaries is much more common.

The highly perishable nature of aquatic animals makes their distribution more complicated than other meat products. Aquatic animals are among the most highly perishable of humankind's foods, and that quality inevitably falls during processing and distribution (Connell, 1980). Chaston (1983) suggested that the shortest possible distribution channel should be used for cultured aquatic animals, that the number of intermediaries should be kept to a minimum, and that direct marketing should be used when possible. When it is impractical to market directly and the quality of fresh fish cannot be assumed, it is necessary to distribute the product in a form which offers a longer shelf-life, such as frozen or canned.

There are relatively few distribution systems for cultured aquatic products specifically, while there is a worldwide distribution system for fish captured from the oceans (Bligh, 1980). Pillay (1977) suggested that, whenever practical, distribution systems for cultured products be linked to established ocean fish distribution systems. Obviously, there are several advantages to this linkage. Certainly, when the cultured form of a species is to be marketed with the wild form, it would be beneficial to utilize established distribution channels. However, when introducing a new, cultured product, distributing it with well-established species can be a disadvantage. Special efforts in promotion will be necessary to overcome this disadvantage. Although product identification of a cultured product in a wild fish market is a problem, the advantages of using established distribution channels far outweigh the disadvantages. Establishing a parallel system is generally out of the question.

There is a positive correlation between the stages of aquaculture and the complexity of the distribution system. At the lowest stages, the simplest systems generally are utilized. However, this relationship is really between the quantity produced and the complexity of the distribution system. Production is generally lower at the lower stages of aquaculture, so there is no need for a complex distribution system. In fact, most of the product might be marketed at the farm, and very little distribution would be required. Since production at the higher stages of aquaculture usually is greater than local consumers can use, some system for distributing aquatic animals to consumers away from the point of production is necessary.

While there is the general relationship between the stage of aquaculture (level of production) and the complexity of the distribution system, there are factors that can essentially reverse it. For example, some species are so valuable in the marketplace that local people cannot afford to purchase them. Therefore, virtually all of the production must be moved away from the point of production even if the level of production is relatively low. Cultured shrimp is an example of a product that commands such a high price that it usually is not consumed by local people even if it is produced in limited quantity.

## *Utilization*

Utilization is the final input or environmental requirement of aquaculture. Unless the product is consumed after purchase, the entire process of production and marketing would soon come to an end. The term utilization usually implies that something is "used up" or "consumed." At the point where the consumer takes title to the product, the utilization process begins. Utilization in the aquacultural process is defined more broadly. It is much more complex than simply eating a fish to satisfy hunger. For example, fish may be consumed because of the belief that they promote improved health (Lovell and Mohammed, 1988; Rhodes, 1988).

In the past, large quantities of cultured fish were consumed, especially in Central Europe, because of religious beliefs (Dyk and Berka, 1988). In some countries, certain species of cultured fish are believed to increase the probability that pregnancies will be carried to term (Wimol Jantrarotai, personal communication). In the United States, the channel catfish industry developed from a well-established taste for the fish among people who lived adjacent to large rivers in the South. These consumers still provide an important market for the industry. Even when these people move away from the river valleys, they tend to carry food preferences (cultural characteristics) with them. The growth of the catfish industry in California probably can be traced to people who migrated there from the river valleys of the southern United States. Utilization is defined more broadly than actually eating the fish. Watching and enjoying cultured aquarium fish could be considered a form of utilization (Winfree, 1989). As a result of this form of utilization, an important industry for the culture of these fish has developed in Florida. In 1987, the sales of tropical aquarium fishes in that state was estimated at $21.7 million (Harvey, 1988). Similarly, a largemouth bass cultured in a farmer's pond for recreational fishing may be considered to be utilized or "consumed" even though it is returned to the water after capture to be caught again during future fishing trips (Figure 27). Minnows produced through aquaculture also are consumed when

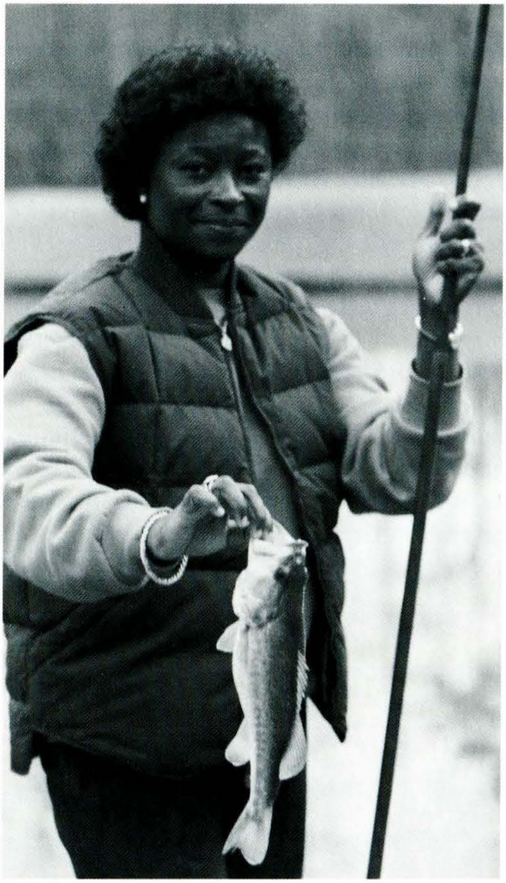


**Figure 27. Utilization of a largemouth bass taken from a recreational aquaculture pond with hook and line. The fish will be returned to water. Hopefully, it will be caught again after it has grown larger.**

they are used as bait to capture piscivorous species such as the largemouth bass or crappie (Davis, 1986).

Utilization, as noted previously, is an essential part of aquaculture, but in its broadest context it takes on added importance. When fish are used as food, the prices that consumers are willing to pay and, in turn, the prices that farmers receive for their product are related generally to their value as food. These prices also have some general relationship to the prices of other meats (pork, beef, poultry, etc.) used for food. This general relationship is relatively broad as is evident in the case of cultured shrimp or Atlantic salmon. With these species, customers are willing to pay more than the prices of good quality beef or pork. Although the relationship is somewhat complex, all of these products are used for food and basically are purchased for that purpose.

In the broader context of utilization, prices are not related except in a general way to the value as food. Some rare, cultured aquarium fishes sell for hundreds or even thousands of dollars per pound, although they are seldom sold by the pound. And bait minnows usually are sold at prices several times greater than the most expensive shrimp or salmon. There seems to be little rhyme or reason for the range of prices other than supply and demand. In the case of cultured fish that are used principally for food, when the set price is too high, the consumer simply changes to beef, pork, or poultry. These shifts are not easily made when other types of consumption are involved. There simply is no good substitute for the large golden shiners that are used as fishing bait for largemouth bass in central Florida. Similarly, there is no good substitute for the Christmas carp used in some family celebrations.

The range of prices associated with the broad range of utilization has an interesting effect on production and marketing of aquacultural products. The prices received often are much greater than the cost of production. In fact, the price received for the product may be so great that there is little or no need to improve the efficiency of production or marketing practices in the short term.

# PART 2 CAPTURE FISHERIES AND AQUACULTURE

THE CENTRAL THEME OF THIS SECTION is the constantly changing balance between human reproductive potential and innovation and environmental "resistance" (floods, droughts, disease, famine, earthquakes, etc.). Slowly but surely, man has tipped this balance in his favor, releasing the full force of the geometric progression that characterizes sexual reproduction. Hundreds of thousands of years passed before the world's population reached 1 billion in 1815 (Figure 28). It took only 115 more years for the population to reach 2 billion, 30 more years to reach 3 billion, and then 15 more years to reach 4 billion in 1975. Estimates are that our population may increase to 6.1 billion by the year 2000 and 10 billion by 2070 (Chantfort, 1988; Ehrlich and Ehrlich, 1988).

With the birth of each child, new resources must be found to provide food, clothing, and shelter. With the birth of enough children to increase the world population by one-third in 16 years, an almost unimaginable amount of new resources must be found and developed in a short time. In the search for new resources, old ones inevitably will be over-exploited. Such is the case with one of the world's most important and continuously exploited resources — fish.

Aquatic animals always have been an important food (Pillay, 1983; Lewin, 1988B). Because 70 percent of the world is covered by water (most of it marine), people were never far removed from fish, shrimp, oysters, or clams (Steinberg, 1980). Early man encountered oysters and clams when the low tides exposed them. Fish were found stranded in tidal pools. River floods left pools containing fish that could be harvested as the water evaporated or seeped away. Many species, such as the salmon, were vulnerable to capture during spawning migrations (Putman, 1988). It was only natural that human diets from the earliest times included relatively large quantities of fish and other aquatic animals.

Fish is an excellent food. It contains only about one-third as much fat as average cuts of red meat. Also, the fat is chemically different from that of beef, pork, or poultry. Some research has shown that replacement of red meat with fish in diets can reduce cholesterol levels in the body (Lands, 1989). Because the level of fat in fish

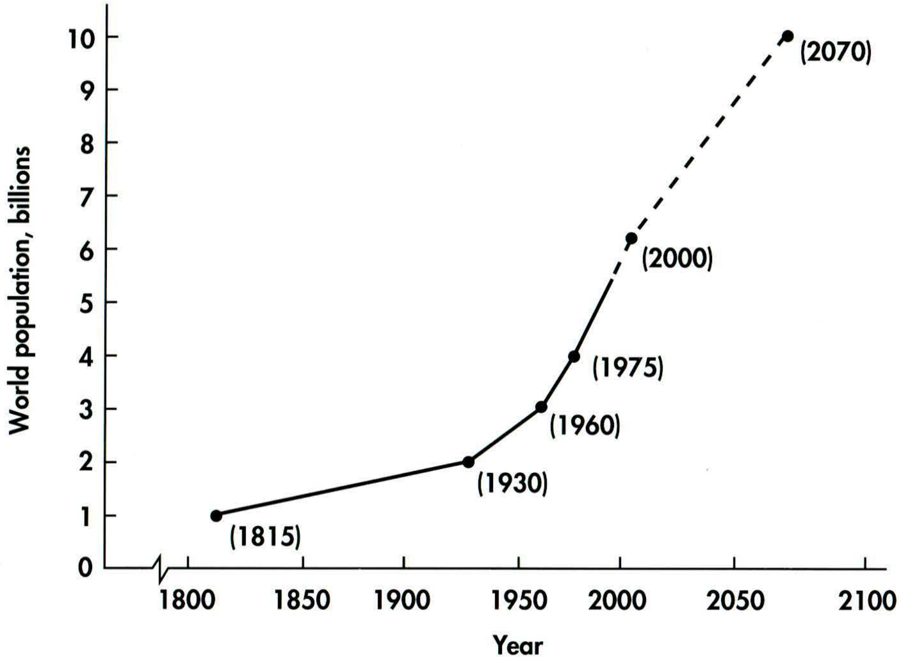



**Figure 28. Change in world population over time.**

is lower, the caloric value of dressed fish is only about one-third that of beef or pork. The quality of fish protein also is excellent (Kent, 1987). Except for whole egg, it meets the human requirement more closely than any other animal protein (Lovell, 1979). Fish also is an important food. Fish comprise approximately 20 percent of the world's total supply of animal protein, and in certain countries may supply as much as 55 percent (Kent, 1987).

# CHAPTER 4
# THE GROWTH OF FISHING

WORLD FISHING HAS PARALLELED the growth of the world population. Fish catch began to expand rapidly (Figure 29) in the early 1950s following World War II at about the same time that the effect of the geometric human population growth began to manifest itself (Figure 28). During the 1950s, the annual catch increased at an annual rate of over 6 percent. The rate of growth was somewhat less during the 1960s, but then dropped dramatically during the 1970s to approximately 1 percent (Comte et al., 1984B). In three years of that decade, there were decreases in catch. In the late 1970s, world catch again began to increase rapidly. This trend continued through the 1980s, but apparently ended in 1989. Catches in 1990 and 1991 have been lower (National Marine Fisheries Service, 1992). Fisheries scientists interpret these data to indicate that we are approaching the level of fish removal that will severely damage many of the world's important food fish stocks. For example, the Marine Fisheries Service noted that most traditional fisheries in the nation's coastal waters are being

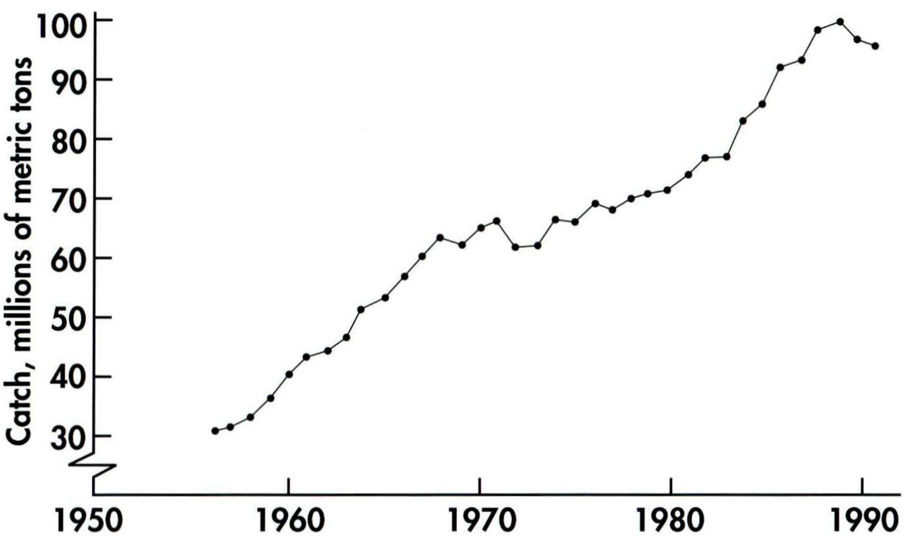



**Figure 29. World fish harvest over a 50-year period.**

harvested at or near maximum sustainable yield and that the commercial harvest of wild species has not increased over the last 10 years (University Corporation for Atmospheric Research, 1989).

The known and projected world catch of fish available per capita from 1950 to 2000 present a disturbing trend of population outdistancing fish catch. Demand for fish is expected to exceed supply by 20 million metric tons by the end of the century (Harvey, 1988). Total demand could reach 114 million metric tons by 2000. Ocean harvest is expected to provide 94 million metric tons of the demand. This situation is especially critical in the developing countries where much of the population increase is occurring and where fish are more important in diets. It has been estimated that two-thirds of the shortfall will be in those emerging nations of the world (Neal, 1987). Availability of fish per person reached a maximum level in the 1970s and began to decline as a result of the combined effects of population growth and the levelling off of world fish catch (Brown, 1985).

Historically, as the human population and the demand for food increased, farmers were able to increase production by increasing the area in cultivation and by increasing the yield from each field (Hayami and Ruttan, 1985). The first of these solutions has been utilized extensively by fishermen. Unfortunately, there are essentially no remaining areas of the world where there is no fishing. The second

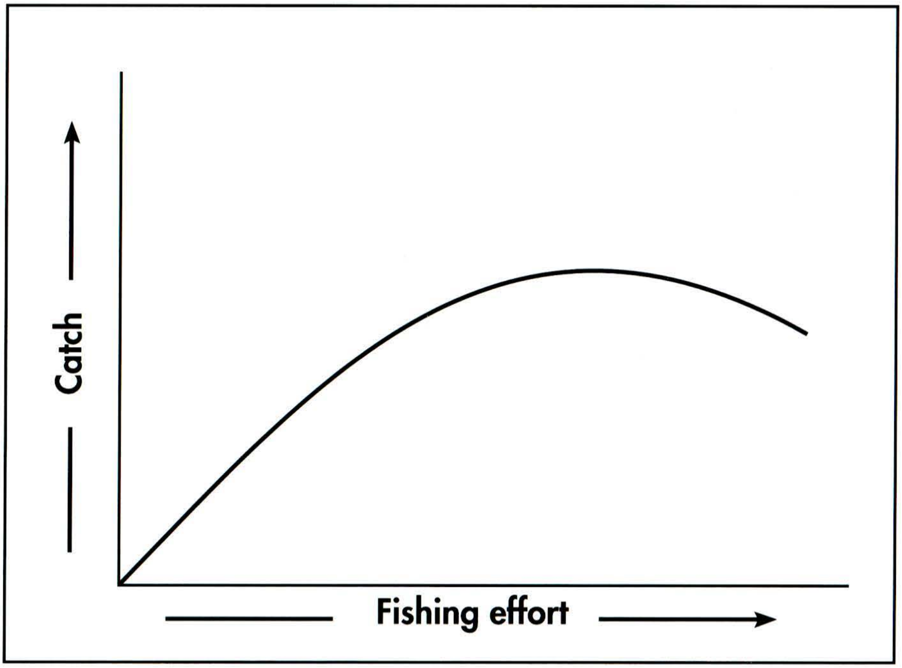



**Figure 30. Generalized relationship between fishing effort and fish harvest (Meany, 1987).**

solution is not available to fishermen. As noted in a previous section, they cannot practically increase production. Their only alternatives are to send to sea more boats with larger nets. Unfortunately, this solution can be used only for a limited time before numbers of adult fish are so few that they will be unable to maintain their populations. The relationship between fish catch and effort then shifts to less and less return for increasing fishing effort (Figure 30). At some point, the harvests equal the number and weight of fish being replaced through reproduction and growth. Increasing the fishing effort beyond that point actually reduces catch (Meaney, 1987). It is difficult to imagine that a body of water as large as an ocean can be fished so heavily that a population of fish can be reduced to a dangerous level. However, there is considerable evidence that many of the more important fish stocks in the world are being over-fished, some severely (Comte, et al., 1984A; University Corporation for Atmospheric Research, 1989).

The increase in the world population, the levelling off of world fish catch, and the increased per capita demand have interacted to create a major effect on fish prices (Pierce, 1987). For example, in 1986 and 1987, the change in the Consumer Price Index for fish was greater than for any other major food or beverage (Parlett, 1987).

The value of fish as food has had a significant effect on consumption, especially in the developed countries. Fish consumption in the United States, for example, has increased steadily since 1960 but began to increase more rapidly after 1980 (National Marine Fisheries Service, 1992):

| *YEAR* | PER CAPITA CONSUMPTION *OF FISH IN THE U. S. (pounds)* |
|---|---|
| *1960* | *10.3* |
| *1970* | *11.8* |
| *1980* | *12.8* |
| *1985* | *14.5* |
| *1986* | *14.7* |
| *1987* | *15.4* |
| *1988* | *15.0* |
| *1989* | *15.9* |

Americans do not consume large quantities of fish compared to the Japanese (150 pounds per capita), the Portuguese (80 pounds), or the Senegalese (89 pounds). However, the United States market is so large that even small changes in consumption have a major effect on world fish supplies. For example, a one-pound per capita increase in fish consumption in one year would require an increase in fish supplies of more than 255 million pounds.

For many years, the United States has been unable to catch enough fish to supply its needs, making fish the only major food that must be imported. Each year, approximately 3 billion pounds of edible fish are purchased abroad. As our population grows and as per capita consumption increases, it is likely that the amount imported also will increase.

## *Demand and Supply and the Developing Countries*

The interplay of demand and supply has resulted in a significantly increased flow of fish from the lesser developed countries to the developed countries. Many of the developing countries desperately need foreign currency to provide funds for their essential imports. The sale of fish from their coastal zones often represents the best source of that currency (Comte, et al., 1984B). In 1989, the trade in fish was the major source of hard currency for the developing world. The net trade surplus in fish was $10 billion, followed by rubber and coffee with $3.1 billion and $800 million, respectively (Food and Agriculture Organization of the United Nations, 1991). Unfortunately, few of these countries have the necessary fishing boats and nets and on-shore processing facilities to exploit their stocks and prepare them for market. As a result, fishermen from the developed countries are allowed to catch and ship fish back to their home ports for processing. Thus, the developing countries not only lose the fish needed as food by their people, but also, by selling only unprocessed fish, they lose the value-added advantage of doing the processing themselves.

Because world population growth will double by the year 2000, the demand-supply relationship for fish will put increasing upward pressure on prices. As a result, the fishing pressure probably will increase further on stocks of fish adjacent to those developing countries, leading to further over-fishing, which could ultimately lead to the virtual destruction of many of these stocks.

In many tropical countries, fish stocks in near-shore waters provide meager diets for extremely high densities of people in coastal communities. Already some of these stocks are over-exploited, even with the primitive gear available to those artisinal fishermen (Pauly and Thia-Eng, 1988). As fish prices escalate, many of these stocks likely will be exploited for export, leading to widespread hunger in those coastal communities. Thus, fish supplies for people in developing countries are threatened by the combination of increased population, slowing fish catch, and export to countries able to pay higher prices.

# CHAPTER 5
# DEVELOPMENT OF AQUACULTURE

THE WORSENING PROBLEM WITH FISH SUPPLIES might have been avoided if early humans had domesticated fish along with cattle, swine, goats, and poultry. In the tapestry of the past, one of the most significant things that occurred in the continuing human struggle with the environment was the domestication of their food supply. Forcing wild wheat, rice, corn, potatoes, goats, swine, cattle, and horses into domestication was a key factor in civilization, releasing the human reproductive potential and providing the basis for the development of statehood. Domestication led to food production instead of food procurement. Before domestication, humans obtained their food by hunting and gathering. This significant change, begun some 20,000-30,000 years ago, has reached a point where more than 90 percent of the world's food supply is obtained from domesticated plants and animals.

The story is different, however, for aquatic animals. Fish, oysters, and crabs were important in the diet of early humans, but these animals were not forced into the predictable, dependable food culturing system. Fish were difficult to tie to a post or keep in a pen. In fact, it was difficult to even see them. Also, because some 70 percent of the world was covered by water, the assumption probably was made that the supply of fish was inexhaustible. Today, more than 90 percent of the fish consumed comes from wild stocks. We use sonar to locate fish and diesel engines to power boats, but still we must chase if we are to eat (Hickling, 1968).

Driving forces behind domestication of food supplies are the high costs in time, energy, and unpredictability of hunting and gathering. These costs associated with utilizing wild fish for food are becoming more important as the costs of fossil energy and time (wages) increase. Also, because some stocks are overexploited, more effort is required per unit to catch, further increasing the cost.

Although domestication and cultivation have resulted in predictable supplies of many types of plant and animal foods, our ability to intervene in the production process of fish in large lakes, rivers, and the oceans is severely limited. We can regulate the harvest of those animals to some degree by setting open and closed seasons, establishing catch quotas (limits), and restricting the type of gear (nets or boats), but we only have limited control of the kind, size, or number of fish being produced. Production essentially must be left to the mercy of the natural order of things.

Aquaculture has the potential to meet the worldwide shortfall of fish. It could provide the required aquatic animals and at the same time, help reduce the overfishing pressure on stocks of wild fish (Grivetti, 1982). Aquaculture also has the potential for providing fish for many poor people in the world who have been priced out of the market (Comte, et al., 1984A).

The cultivation of aquatic animals can be traced back to approximately 1100 B.C., according to Hickling (1968), McLarney (1984), Costa-Pierce (1987), and Parker (1989), where it was practiced first in China. However, because the common carp -- the mainstay of Chinese aquaculture -- is not native to China, but to Central Asia, Costa-Pierce (1987) suggests that aquaculture may have actually originated somewhere in ancient Europe. While the exact origin of aquaculture cannot be established with certainty, it has been established that aquaculture persisted in China for some 1,300 years before its use began to spread into adjoining countries. McLarney (1984) suggested that fish farming spread to Japan via Korea, perhaps as early as 200 A.D. There is little information on the origins of aquaculture in Southeast Asia, but it probably was carried there by Chinese immigrants.

Costa-Pierce (1987) suggests that aquaculture first appeared in Hawaii some 1,500 years ago, and that mariculture may have originated there rather than being brought there from Southeast Asia.

Fish farming appeared in Europe in the Middle Ages. The culture of carp began in Central Europe at the close of the llth century (Berka, 1986). There is little information to suggest how aquaculture came there, but one has to conclude that there must have been an Asian connection. Fish farming grew slowly but continuously in Central and Eastern Europe. By the l6th century, there were about 100,000 hectares of fish ponds in Bohemia, a region in the Czech Republic.

Carp culture has been the basis for aquaculture in Central and Eastern Europe for 1,000 years, but it has never been of more than incidental importance in Western Europe. Consequently, the culture of that species did not come to North America with the first immigrants. In fact, carp were not introduced into the United States until around 1830 (Parker, 1989). Carp were being cultured and marketed in California by 1832. However, the culture of the species never gained acceptance, although they were reproduced and stocked throughout the country by the U.S. Fish Commission in the 1880s. Today, this species is considered to be a trash fish and an aquatic pest in most areas of the country. Relatively few carp are marketed for food.

While food fish culture may have originated in China, apparently the culture of fish for use in recreational or sportfishing originated in Germany in the middle of the 18th century (McLarney, 1984). The first trout hatchery was established in that country in 1741. Over a century passed before trout farming came to the United States. The first trout eggs were fertilized artificially here in 1853, utilizing European techniques. From the beginning in the United States, trout farming has served both recreational and food production purposes. Although sportfishing was the driving force behind the development of cold-water aquaculture, trout farming for food fish benefitted equally from the development of the technology.

The successes achieved in the hatchery production of cold-water fish for use in stocking public waters for recreational fishing led to the establishment of hatcheries for warm water fish in the early part of this century. A number of warm water species were produced and stocked widely across the country. However, warm-water aquaculture in this country was not really significant until the farm pond boom that swept across the country after World War II. Although virtually all of the fish removed from these ponds by recreational fishermen became food for the family, the driving force behind the development of this culture system was sportfishing. The production of warm-water fish for food did not really begin in the United States until the first channel catfish were grown in ponds sometime in the early 1950s.

According to Hickling (1968), efforts to develop aquaculture in Africa did not begin until the early years of World War II when efforts were made to culture tilapia. Although the former European colonial powers made repeated efforts to establish aquaculture, that continent still lags behind the other major land masses in the production of cultured aquatic animals. However, even though progress has been slow, the potential for aquacultural development in Africa is equal to any other continent.

Aquaculture also came relatively late to South America, but it has grown rapidly. Even so, the continent accounted for less than 1 percent of the world's yield of cultured aquatic animals in 1985 (Saint-Paul, 1989). While total production is low, the value of South American aquaculture is relatively high because of the preponderance of Penaeid shrimp produced there and the value of those species on the world market (Aiken, 1990). The potential for the development of aquaculture is also extremely good for that continent. Many of the indigenous species of fishes found there are candidates for aquaculture (Saint-Paul, 1989). It is likely that some of the more important aquacultural species of the future will be found in the Amazon basin or other river basins of the continent.

Aquaculture is approximately 3,000 years old, but it has never provided more than a small fraction of the aquatic animals consumed by humans (Sasson, 1983). Although aquaculture has grown rapidly in the last 25 years, it provides little more than 10 percent of world fish production (13.2 million metric tons in 1987) (Food and Agriculture Organization of the United Nations, 1989). Table 2 contains information on the production of aquatic animals in different regions of the world. It is interesting that the rank of productions on the different continents generally is related to the span of aquacultural history on the continents. Asia, with the longest history of aquaculture, ranks first in total production. Europe, including the former Soviet republics, with the second longest history of aquaculture, ranks second in production. North America ranks third in both length of aquacultural history and total production. Africa and South America, which have much shorter histories, produce approximately the same quantity of aquatic animals through aquaculture. Table 3 includes information about the leading countries in aquacultural production, and Table 4 includes a list of the major cultured aquatic animals in the world.

## Table 2. Production of Finfish, Crustacea, and Mollusca in Different Regions of the World in 1987[1,2]

| Region | Finfish | Crustacea | Mollusca | Total |
|---|---|---|---|---|
| Asia | 5,701,474 | 439,747 | 1,805,745 | 7,946,966 |
| Europe, USSR | 688,006 | 3,285 | 645,430 | 1,336,722 |
| North America | 266,672 | 44,480 | 138,841 | 449,993 |
| Latin America, Carribean | 48,884 | 87,123 | 54,678 | 190,685 |
| Africa | 61,858 | 79 | 515 | 62,452 |

## Table 3. Aquaculture Production in 13 Leading Countries in 1987[1,2]

| Country | Production |
|---|---|
| China | 5,600,604 |
| Japan | 1,226,190 |
| Republic of Korea | 876,788 |
| India | 746,300 |
| People's Republic of Korea | 719,000 |
| Phillippines | 560,970 |
| United States | 437,888 |
| Indonesia | 394,090 |
| Taiwan | 305,429 |
| USSR | 292,588 |
| Spain | 264,949 |
| Viet Nam | 264,949 |
| France | 236,000 |

## Table 4. Production of the More Important Cultured Species in 1987[1,2]

| Species | Annual Production |
|---|---|
| Silver carp (*Hypopthalmichthys molitrix*) | 1,340,718 |
| Common carp (*Cyprinus carpio*) | 927,735 |
| Pacific cupped oyster (*Crassostrea gigas*) | 779,707 |
| Bighead Carp (*Aristichthys nobilis*) | 631,435 |
| Grass carp (*Ctenopharyngodon idellus*) | 535,691 |
| Blue Mussel (*Mytilus edulis*) | 453,841 |
| Milkfish (*Chanos chanos*) | 330,148 |
| Tilapias (*Oreochromis, Tilapia sp.*) | 246,399 |
| Rainbow trout (*Oncorhynchus mykiss*) | 213,642 |
| Japanese scallop (*Pecten yessoensis*) | 196,109 |
| Channel catfish (*Ictalurus punctatus*) | 169,982 |
| Japanese amberjack (*Seriola quinqueradiata*) | 160,285 |
| American cupped oysters (*Crassostrea virginica*) | 134,113 |

[1]Food and Agriculture Organization of the United Nations, 1989.
[2]Measured in metric tons. One metric ton equals 2,204.6 pounds.

# PART 3
# GENERAL ASPECTS OF DEVELOPMENT

A CENTRAL THEME IN THE HISTORY OF HUMANKIND from the earliest times has been the relentless effort to improve quality of life (Machan, 1989). The World Bank (1991) suggests that development is the most important challenge facing the human race. Development has been defined as "bringing out capabilities and possibilities" and "bringing to a more advanced or effective state." Economists would probably define development as increasing the efficiency of the allocation and utilization of resources. The term "development" seems to imply that some positive change is occurring. Combining these various elements, aquacultural development can be defined as bringing out the capabilities and possibilities of culturing aquatic organisms or bringing their culture into a more advanced or effective state as a means of improving directly or indirectly the quality of people's lives. Durning (1989A) defines development from a different perspective:

> *Real development is the process whereby individuals and societies build the capacity to meet their own needs and improve the quality of their own lives. Physically, it means finding solutions to the basic necessities of nutritious food, clean water, adequate clothing and shelter, and access to basic health care. Socially, it means the institutions that can promote the public good and restrain the individual excess. Individually, it means self-respect.*

Sincere (1990) does not define development, but he explains the results:

> *Development makes people live longer and more comfortably, gives people more options in the ways they choose to live and allows cultures to intermingle in ways that are mutually beneficial and educational.*

A considerable body of information has been produced on the development process. The book by Hayami and Ruttan (1985) is an especially good reference on agricultural development. The accumulation of information on aquacultural development is comparatively meager. However, the book by Pillay (1977) and the book edited by Smith and Peterson (1982B) are good sources of information. The latter one is an especially good source of information and philosophy on the importance of the social sciences in the development of aquaculture in emerging nations. The publication, *Thematic Evaluation of Aquaculture*, produced by the United Nations Development Program, the Norwegian Ministry of Development Cooperation, and the Food and Agriculture Organization of the United Nations (United Nations Development Programme, 1987), is probably the best practical source of information on the development of aquaculture. It describes the factors that led to the success or failure of 39 aquacultural development projects in 15 countries. Schmittou et al. (1985) prepared an excellent publication on the development of aquaculture in the Philippines. This publication includes information on the contribution of aquacultural technology, environment, social and economic factors, government, public service institutions, and external assistance on the development of aquaculture in that country.

# CHAPTER 6
# MODELS OF DEVELOPMENT

AQUACULTURE IS A COMPLEX ECOSYSTEM, an intricate system of living and non-living components, as are all ecosystems in which man and his institutions play a central role. However, we must learn to understand this ecosystem, its components, and how to manipulate them if aquaculture is to reach its potential as a tool in improving the quality of life for people.

In general, efforts to promote the development of aquaculture or agriculture, or even economic development, have not dealt with the entire ecosystem of a specific problem. Rather, efforts have emphasized attempts to manipulate some component. Historically, development efforts have resulted in a mixed bag of successes and failures, with failures outnumbering successes by a significant margin (Paddock and Paddock, 1973; United Nations Development Programme, 1987; Durning, 1989B; Hancock, 1989). I suggest that failure to plan and implement development efforts from a unitary whole, or ecosystem perspective may be a reason why the percentage of successful projects is relatively low.

Although it is important to consider aquaculture as a unitary whole (an ecosystem), the complexity of the whole is extremely difficult to deal with conceptually and practically in a development sense. One can appreciate the need for all of the inputs (described in Chapter 3) that are required to produce, harvest, process, market, and utilize aquatic animals, However, it is a complex task to assemble, organize, and apply these inputs so that the possibilities and capabilities of aquaculture are brought out and development takes place.One approach to understanding the formidable, complex ecosystem of aquaculture is to reduce the complexity to a simplified version that encompasses only the most important or basic properties and functions. These simplified versions of the real world, or models as Odum (1983) describes them, do not imply that complexity does not exist. Rather, they provide a mechanism where some related components can be grouped together to reduce the total number of terms in the equation. For example, simplifying the enormously complex process of aquaculture by dividing it into the five parts (production, harvest, processing, marketing, and utilization) is a form of modeling. Even though this model is severely oversimplified, it does provide a useful version of the real world. The objective in modeling is to learn something of the operation of relatively less complicated ecosystems that will help explain the operation of a more complicated system such as aquaculture.

All models need not be simplified or smaller versions of the real world. A model also can be an example taken from the real world, an example that can be studied to understand how it functions. These real-world models provide a basis for establishing "copies" in other real world situations. Two real world models of aquacultural development, tilapia farming in Rwanda in Central Africa and the catfish industry in the southern tier of states in the United States, are described later in this chapter. A report by Popma et al. (1984) on the development of commercial farming of tilapia in Jamaica and a report by Lovshin et al. (1986) on cooperatively managed Panamanian rural fish ponds provide descriptions of other aquacultural development projects which can serve as models.

While models are useful tools in providing a framework for understanding complex phenomena, they often are unreliable in predicting how an ecosystem or a portion of an ecosystem will function at some time in the future under a given set of circumstances. This difficulty results primarily from our inability to predict what individuals will do when making decisions on the use of scarce resources and our inability to predict microclimatological or macroclimatological events. These deficiencies diminish the usefulness of models somewhat, but they are still extremely valuable in providing the framework or matrix for understanding relationships between elements in the ecosystem.

As noted above, the extension of the concept of modeling is to assume that the ecological principles and processes in the more complex aquacultural ecosystem are similar to those in less complicated and more narrowly defined ecosystems. While these principles are seldom directly applicable without some qualification, they nevertheless provide a useful framework for dealing with the complexity of aquaculture. For example, the dynamics of the production and utilization of oxygen in a small, natural pond ecosystem provides a valuable model for understanding the problem of dangerously low dissolved oxygen concentrations that develop in catfish culture ponds receiving large quantities of formulated feeds (Boyd, 1979). Similarly, establishment of a non-native game bird into a new habitat, as was done with the introduction of the Chinese ringneck pheasant (Leopold, 1933) in the upper Midwest in the United States as a wildlife management technique, might be used as a simplified model for the establishment of aquaculture in a country or in a region where there has been little or no aquaculture practiced before. Increasing the production of aquatic animals in an existing aquacultural ecosystem through the use of formulated feeds is somewhat analogous to increasing the production through the use of inorganic fertilizer of fish in a small, man-made pond containing largemouth black bass and the bluegill sunfish (Swingle and Smith, 1947).

If there is general applicability of ecological principles to the development of both simple and complex ecosystems, it may be because all living cells, tissues, organisms, and ecosystems are spatially organized along the "flowing streams" of solar energy from the time it reaches earth as sunlight until it becomes so diffuse as waste heat that it no longer can be utilized. Evolution of cells, tissues, organisms, and ecosystems to conserve energy and to counter the inevitable effect of the Second Law of Thermodynamics (Smith, 1977) insures threads of similarity throughout these processes in simple and complex ecosystems. Cells, tissues, organisms, and ecosystems all are affected by the same general problem of conserving energy efficiently enough and long enough so that useful work (movement, feeding, reproduction, growth, etc.) can take place.

Much of the energy from the sun is quickly dissipated as low quality heat as soon as it reaches earth unless it is trapped in the chemical bonds of complex carbohydrates through photosynthesis. From this point, this chemical bond energy is moved through a series of transformations in which some of the energy is lost at each step (the Second Law of Thermodynamics) until there finally is so little of the original quantity remaining that it has little value. In this process, algae trap the energy of sunlight through photosynthesis. Microcrustaceans consume the algae and are consumed by fish, which, in turn, becomes food for man. At each step in the transformation, there is less energy available than in the preceding step. This sequential loss of energy in the transformations is the reason for the so-called pyramid phenomenon in ecosystems. The centrality of the effect of the Second Law of Thermodynamics in the life processes of all living things probably means that there are many general ecological principles that apply to all of those living things individually and collectively, whether organized into simple or complex ecosystems.

The flow of energy associated with ecosystems involving people (automobiles, microwave ovens, lasers, computers, etc.) is considerably more complex than the flow of energy through the food chain in a natural pond ecosystem, but even here the immutability of the Second Law of Thermodynamics requires the adherence to certain ecological principles, at least in the longer term. Odum (1983) expressed these ideas succinctly:

> *The essence of life is the progression of such changes as growth, self-duplication, and synthesis of complex relationships of matter. Without energy transfers which accompany all such changes, there could be no life and no ecological systems. Civilization is just one of the natural proliferations that depend on the continuous inflow of the concentrated energy ... energy is a common denominator and the ultimate forcing function in all ecosystems...*

The Second Law of Thermodynamics may virtually guarantee that people will make an effort to find ways to increase food production, to increase the efficiency, and reduce the uncertainty of production. All three of these actions are ways in which energy loss from a system may be minimized. There must be a strong positive bias toward reducing the loss of energy from food gathering and producing systems if human populations are to grow and prosper. In this sense, improving the quality of life may be another way of expressing the idea of conserving energy in the system. Given this context, as the system becomes more stable and predictable, and the loss of energy is minimized, the quality of life improves.

## *Development in Lower Animals as a Model*

It has been difficult to do definitive studies on the development process. Human ecosystems are difficult to study effectively because of their size, complexity, and dynamics. For example, the ecosystem that encompasses the production of shrimp in Ecuador and their preparation and utilization for a family meal in New York is extremely large and complex, and it is constantly changing. Also, from the earliest times, conducting experiments on humans has been ethically and morally unacceptable. The Apostle Paul essentially set limits on the direct study of humankind in The Epistle to the Hebrews, Chapter 2, verses 7-8, almost 2,000 years ago:

*You have made him a little lower than the angels;*
*You crowned him with glory and honor,*
*And set him over the works of Your hands.*
*You have put all things in subjection under his feet.*

It has been difficult to conduct research on a creature "a little lower than angels." Finally, the practical effects of Heisenberg's "Uncertainty Principle" also make it difficult to study the development process in humans. The effort and arrangements that must be made to study this phenomenon tend to change the process being studied. The observed process then tends to become the product of the study rather than the object. Because of these inherent difficulties in studying the development process in humans, I have chosen to look at the process in lower animals, to search for biological principles and models that might help us understand more clearly development in our own institutions. Hannan and Carroll (1992) utilize a somewhat similar approach in their book on the dynamics of change in populations of organization. In doing so, I am well aware of the problems of the overzealous application of biological "reductionism," but I am confident that the potential benefits outweigh the dangers.

If we accept the definition given in a preceding section, "bringing to a more advanced or effective state," development has been taking place since the appearance of life on earth. With this definition, the process of evolution is a developmental process. Any animals such as a quail, with a constant internal environment, is more advanced or more effective in functioning in its environment than a catfish or a toad whose internal environment changes with the external temperature. Animals such as the house cat that incubate their young inside the body are more effective in coping with their environment than birds whose young must be incubated outside the body.

Development in lower animals generally depends on the following steps:

*1. The development of new "technology," in this case biological characteristics, through selection, recurrent mutations, and genetic drift that will allow the animal to function more effectively in its environment. Here,* *"technology" is defined as any physical, chemical, or behavioral changes that improve the effectiveness of the animal in its environment.*

*2. Storing the technology in the strands of DNA in the genes.*

*3. Diffusion of the technology through reproduction and dispersal.*

*4. The evolution of mechanisms to capture and expand the effectiveness of the new technology through social interaction (the herd, covey, or flock).*

Development in the lower animals has taken place rather slowly, although some recent research indicates that this process on occasion can result in rapid advances (Robertson, 1987). Apparently, approximately 200,000 years ago the pace of development began to quicken (Gould and Eldredge, 1977; Garrett, 1988). Some of the animals began to utilize trial and error and cause and effect more effectively. The information gained from these efforts was stored in an enlarged brain and shared through improved communications (language). These new capabilities increased the rate of change in the primitive development process and provided the platform for the process of development in which our species of animals are involved in today.

A useful perspective of the development process can be obtained by considering the life cycle of wild bobwhite quail (*Colinus virginianus*). In this case, development involves bringing out the capabilities and possibilities as defined by the physical and chemical characteristics of the strands of DNA in the genes of the fertilized egg (Keeton, 1967). After fertilization, the capabilities and possibilities begin to be manifested. The single cell becomes two, and the two become four. Under gene control, cells differentiate and become tissues. Tissues become organs. Organs are combined into systems. Communication, both chemical (hormones) and neural, arises and results in the integration of the systems. These communication control loops result in a relatively stable internal environment. Before hatching, sensory mechanisms (vision, touch, etc.) arise, allowing the young animal to establish contact with the external environment and monitor it once the animal hatches. This communication system, neural and hormonal, plays a key role in the success of the organism in its environment.

After hatching, the young animal continues to develop. Growth takes place. It is developing toward a more advanced and effective state. External resources (fats, carbohydrates, proteins, vitamins, minerals, and water) are ingested and distributed to the individual cells which divide to increase body mass. While much of this development is still under genetic control, interaction between the internal and external environments begins to play a role through learning from observation (imitation) and trial and error.

The further development of the individual becomes intertwined with the development of a population of individuals (Leopold, 1933; Odum, 1983; Stribling, 1988). And individual characteristics such as competition, sexuality, and territoriality manifest themselves. In the autumn, quail form loose groupings called coveys. This grouping together lessens the likelihood of predation on individual birds and allows for the transfer of information about food and cover resources among its members. Populations of individuals respond to density-independent factors, such as climate and habitat destruction; and density-dependent factors, such as food resources and predation, by increasing and decreasing in size over time (Smith, 1977).

Following Chapman, Leopold (1933) and Odum (1983) suggested that the success of a population of animals in increasing its number in a given environment is determined by the relationship between "biotic potential" and "environmental resistance." In this case, biotic (reproductive) potential refers to the inherent property of organisms to reproduce and to increase their number exponentially. Environmental resistance is the sum total of all of the environmental factors (drought, floods, disease, predation, etc.) which prevent the realization of biotic potential.

The example of the individual quail and the quail population is useful, but the analogy is of somewhat limited value as a model for the development of aquaculture. The "emergent property" principle (Odum, 1983) prevents the exact application of knowledge of ecological relationships inherent in simpler ecosystems for explaining more complex ones. As ecosystems become more complex, new properties and new relationships emerge that were not present in the simpler ones. Still, it is likely that basic ecological principles which determine the nature of simple ecosystems like that of the quail also play the same general role in more complex systems like aquaculture.

The primary value of the quail example is to show that animals and animal populations develop in stages and to suggest that this process, in many respects, is a model for the development of aquaculture. The bird develops first as an individual and finally as a part of a population of individuals, and both the individual and the population are better able to cope with and respond to environmental opportunity and change as development takes place. With each stage in the development process from the individual cell to the covey, the capability to cope with environmental resistance increases, and biotic potential is less constrained. However, although uncertainty in coping with the environment is reduced as the process proceeds, complexity has increased substantially. Also, the interdependence of cells, tissues, organs, and individuals and the division of labor has increased. As the process proceeds, the level of coordination and communication required also grows. Finally, it is important to note that the components develop as their function in the process is required. For example, genetic control of the process provides for the development of a circulatory system in the embryo when the mass of cells becomes large enough so that simple diffusion will no longer suffice.

The development of both quail populations and aquaculture is dependent on a large number of inputs: water, cover, laws protecting private property, learned behavior, new technology, a genetic plan for growth, and business plans. Both developments require a continuous supply of exogenous energy, and effective strategies for the conservation of energy must either evolve in the case of quail or be developed in the case of aquaculture. The Second Law of Thermodynamics and the requirement for energy conservation assure the basic similarity of the process of development in both the quail and the aquaculture ecosystems. One additional comment is in order regarding development in ecosystems involving lower animals. When new technology appears in an ecosystem involving lower animals, the ecosystem changes. For example, if through mutation a predatory fish in a small natural pond inherits a more effective hunting capability, the environment becomes more hostile for the prey species, and selection pressure builds for some mechanism (new technology in the prey species) to counter this new technology that has become part of the biological characteristics of the predator. Over time, a new technology also must be developed in the prey or it may be eliminated. The appearance of new technology in the predator causes disequilibrium in the ecosystem which requires the development of compensating technology if the system is to return to equilibrium (Robinson, 1992).

## *Agricultural Development as a Model*

Studies of agricultural development provide valuable information and insight that can be used in understanding and promoting the development of aquaculture. Hayami and Ruttan (1985) have summarized a vast amount of literature on this subject. Their book, *Agricultural Development -- An International Perspective,* is a valuable source.

As noted previously, agricultural development is an ancient process. Lewin (1988A, B) suggested that it has been in progress for at least 10,000 years and possibly longer, and that this development seemed to take place simultaneously throughout the world. Hayami and Ruttan (1985) commented that there was slow but continuous development even in premodern times, with tools, machines, plants, animals, and husbandry practices showing continuous change. They suggested that these changes were driven by general population increases and price fluctuations. Lewin (1988B) summarizes the work of the anthropologist Barbara Bender and others in proposing that the development of agriculture was the result of the evolution of social complexity or that hunting and gathering could not support the "increasing social complexity and the stratified social and economic order" that was evolving some 10,000-12,000 years ago.

Even though change in premodern agriculture was relatively slow, food production, in general, expanded rapidly enough to meet the needs of a human population constrained in size and growth rate by wars, pestilence, disease, and natural calamities (environmental resistance). Slow increases in productivity (production per unit area) were combined with rapid expansion of the area cultivated, so that food and fiber production kept pace with a slowly growing human population beset with powerful environmental resistance (Evans, 1980).

After World War II, it became obvious that food supply and population probably would become seriously unbalanced. New technology and the rapid diffusion of that technology as a result of the war was finally releasing the full reproductive potential of the human species by reducing the effect of environmental resistance (disease and pestilence). Even though food production was increasing at a respectable rate, in some countries the rate of increase in the human population overshadowed it. With little opportunity to expand food supply by farming new lands, attention was focused on increasing yields from existing farms. Also, in the decade following World War II, the interdependency of agricultural development and economic development became better defined and appreciated. It soon became obvious that nations could not expect stable economic growth without a growing agricultural sector.

It was conceded that farmers themselves could increase productivity on their lands. However, most agricultural development experts felt that this farmer-initiated change would not be fast enough or massive enough to meet the food needs of a rapidly increasing human population and that some direction, organization, and energy would have to be applied to the process. At that point, the discussion and debate on how to speed up the pace of this naturally occurring process intensified. How could it be telescoped in time and space?

Agriculture is our only essential industry because food (energy) is essential for life. The primary goal for agriculture is to provide sufficient food for every person on earth on a sustainable basis. Some 10,000 years of agricultural development have resulted in a mixed bag of accomplishments. We have the necessary technology and the land, water, and climate resources to provide adequate food and fiber for everyone (Hayami and Ruttan, 1985), yet there is some hunger in virtually every country of the world. Governments have defended their domestic agricultures by erecting protectionist trade barriers, adopting exploitive pricing policies, and supporting inefficient land tenure systems. The result has been a widening disequilibrium between productive capacity and actual production.

The great expectations of the "Green Revolution" have not been realized (Roy, 1984). Regardless of obvious successes in some restricted ecosystems, millions of subsistence farmers were left behind, barely able to make a living after the revolution washed over them and moved on. In fact, many were in poorer condition afterward.

In some countries, the shortage of food directly results in thousands of deaths each year. Young (1988) estimated that at least 20 million people in the United States suffer from hunger several days each month. Even some of the developed countries, such as Russia and Japan, though for different reasons, must import food to meet the needs of their people (Martinez, 1986B; Sheeves, 1986). For other countries, there are such large surpluses that enormous quantities must be exported to maintain the health of their agricultural industries (Edwards, 1986).

In virtually every country, there are many people who are unable to purchase food at prevailing prices. In fact, poverty is a primary cause of hunger throughout the world (Stults, 1988; Mellor, 1989). In these situations, governments must provide free food (Matsumoto, 1988) and develop policies to guarantee low food prices. At the same time, many countries must provide direct subsidies to farmers to encourage adequate food production at prices that consumers can afford to pay (Martinez, 1987). In Japan, government agricultural policies are designed to guarantee the survival of the small family farms, while in the United States, government agricultural policies probably have led to a reduction in the number of these small family farms (Martinez, 1986A; National Research Council, 1989).

Structural problems in American agriculture have required massive intervention by the government in an attempt to manage the supply of food (Martinez, 1987; Matsumoto, 1988). Government commodity income, price support programs, tax policy, and agricultural research and extension heavily influence on-farm decisions. Despite the fact that net farm income has reached record levels, federal programs support an unprecedented percentage of total farm income (National Research Council, 1989). In 1986, federal farm program outlays reached $25.8 billion (Daft, 1988), and in 1987 government payments were equivalent to 30 percent of net farm income. Worldwide, government subsidies to agriculture are in the range of $100 to $150 billion annually (Taylor and Frohberg, 1989). These efforts to intervene resulted in severe problems for the agricultural credit system (Manning et al., 1988).

Unfortunately, massive federal outlays for agriculture in the United States have not significantly improved the independent, innovative activity needed in rural America to allow it to adapt to cultural and economic change (Whitener, 1989). Farm policies which result in subsidizing inputs, such as water, credit and grazing land, or guaranteeing prices may actually have inhibited cultural and economic flexibility rather than encouraging it. In general, worldwide efforts to manage the supply of food rather than to manage demand have resulted in similar structural problems. Structural problems in agriculture in the centrally planned economies are the most glaring examples of the results of efforts to manage supply. Unfortunately, there are plenty of horror stories in countries with limited economic planning as well.

Exploitive farming systems that have evolved to increase yields have led to severe degradation of the agro-environment. Massive soil erosion threatens the economic future of India, China, and the former Soviet republics. It is estimated that in India, 6 billion tons of soil either wash or blow away each year (Brown, 1988). In a survey of 38 countries in Sub-Saharan Africa, it was concluded that more plant nutrients were being lost each year from soil erosion than farmers could afford to replace by applying fertilizers (Cherfas, 1990). The excessive use of fertilizers and pesticides may result in serious contamination of ground water in many areas of the world. Groundwater in some 1,400 counties in the United States is potentially vulnerable to contamination from fertilizers and pesticides. Approximately 300 counties are vulnerable to nitrate contamination (King, 1987A). The excessive use of pesticides has resulted in the development of populations of insects that are resistant to the chemicals (Manning, 1988). Increases in rates of production per area of land in many cases required increases in the quantity of inorganic fertilizers and expensive, complex equipment. Increases in the area of land cultivated have resulted in the deforestation of millions of acres of marginal land for crops. Fragile prairie grasslands have been plowed and planted, and valuable wetlands have been drained.

Even with the massive efforts by governments worldwide, some experts feel that the world is facing a major food crisis. Nightingale (1990) listed the following indicators of an impending crisis:

*1. A slowdown in technological change.*
*2. High population growth.*
*3. Limited availability of agricultural resources.*
*4. Environmental degradation.*
*5. Inability of policies and institutions to influence the first four indicators.*

Agricultural development does not serve as a particularly good model for aquacultural development because of the poor balance between its positive and negative results. It is obvious that the whole agricultural ecosystem has not functioned uniformly. One possible reason is that development has not been carried out with enough consideration for the entire ecosystem. Possibly, we have not really understood what the agricultural ecosystem is, how it functions, and how the different sub-systems are related one to another.

One of the reasons agricultural development is so difficult is the perceived need for food security among nations of the world. Most nations perceive that they cannot be politically safe unless they are able to guarantee the food supply for their people. For this reason, most nations are unwilling to let their food supply be determined entirely by the laws of demand and supply. Food security is an important political consideration. Unfortunately, in too many cases it is used as a crutch to justify poor agricultural policies.

## *Development of Aquaculture in Rwanda as a Model*

The growth of aquaculture in Rwanda is a good model to study to increase our understanding of the development process. Fish farming there is a relatively simple and rather limited ecosystem. Yet all of the inputs required in all aquacultural ecosystems are in place.

This discussion of the development of aquaculture in Rwanda is based on a publication prepared by Moehl et al. (1988) and a final report of the Auburn University technical assistance project in Rwanda prepared by Hishamunda and Moehl (1989).

Rwanda, the "land of 1,000 hills," is a small country in Central Africa, virtually all which is hilly. Among the hills are narrow, flat, fertile valleys (marais) that feature fish ponds interspersed among vegetable gardens, cropland, and pasture. The elevation where fish culture is practiced ranges from 1,300 to 2,500 meters.

Consequently, the cool climate has been considered marginal for the culture of warm-water fish.

Rwanda has the highest population density in Africa. In some districts (communes), it reaches 750 persons per square kilometer. Some 95 percent of the population lives in rural areas, and most of the rural inhabitants are subsistence farmers. Farming is practiced on private plots on the hills and in gardens around the houses which are scattered across the landscape. The marais are often farmed collectively to make maximum use of this valuable and scarce resource. A variety of plant and animal crops is cultured on the farms. Coffee, tea, and potatoes are the primary cash crops. Most families have some experience with animal agriculture (cows, goats, pigs, and poultry).

**Figure 31. Typical fish ponds in Rwanda.**

### *A Historical Perspective*

Efforts to establish aquaculture in Rwanda date back to the time of Belgian colonial rule in the mid-1920s. The Belgians introduced the cultural technology they had employed previously for almost a half-century in the Congo. The construction of fish ponds was encouraged by the colonial administration. It was estimated that by the end of the 1950s, there were some 2,000 ponds in the country (Figure 31).

Aquaculture in Rwanda had not been effectively institutionalized in the four decades of Belgian efforts to establish it. During the 1960s there was limited aquacultural activity. Hishamunda and Moehl (1989) suggested four reasons for the lack of development:

*1. A lack of cooperation from native Rwandans because fish farming had been pressed on them.*

*2. Little history of fish consumption.*

*3. A lack of trained personnel for service as extension or change agents.*

*4. Less than adequate farmer understanding of the technology being promoted.*

In 1967, the Food and Agriculture Organization of the United Nations began the first of a series of aquacultural development projects which continued into the early 1980s in Rwanda. During this period, aquacultural development projects also were undertaken by the Canadian International Development Research Center, and a team from North Korea provided technical assistance on the production of grass carp seed. At one point, a Peace Corps volunteer from Zaire helped assess the potential for aquaculture in the country. Also, numerous private volunteer organizations were involved in small aquacultural development projects in many areas. Regardless of this spate of effort, aquaculture in Rwanda remained largely unproductive into the early 1980s. Even though success was limited, two important aspects of successful development emerged during this period:

*1. Farmers had developed considerable interest in aquaculture.*

*2. The National Government of Rwanda (GOR) seemed to be convinced that the development of aquaculture could play an important role in the country's food economy.*

As a result of the converging interests on the part of farmers and the public sector, the GOR requested assistance from the U.S. Agency for International Development (USAID) in establishing the Rwandan Fish Culture Project (Project Pisciculture Nationale, or PPN) in 1983. USAID provided a grant to Auburn University for technical assistance for the PPN for a five-year period.

The primary emphasis of PPN was to encourage the development of existing aquaculture. Fish farming had been practiced in the country for a half-century, so it seemed wise to build on that base. There also was a need to expand aquaculture onto new farms and into new areas of the country where there had been limited development. However, the primary emphasis was on identifying and extending more appropriate technology, given the inputs available in the existing Rwandan aquaculture ecosystem.Several development outputs were projected for the PPN. These included the following:

*1. Develop a package of fish culture technology appropriate for the cooler climate and the limited input capability of Rwandan farmers.*

*2. Increase the annual yield of fish from the pre-project level of three to five kilograms per are (an are is 100 square meters, or 0.01 hectare) to 12-*

*15 kilograms per are.*

*3. A total of 80 percent of the functional fish ponds in the zones of intervention were to be put in production using improved fish cultural practices.*

*4. The rate of construction of new ponds would average 3-5 percent annually by the end of the project.*

*5. Improvements and renovation would be accomplished on six regional fish stations.*

*6. The PPN would help local administrators choose sites for fish culture development that would integrate fish production with other uses of the wetlands (marais) and that would promote good land and water management.*

*7. Promote farmer training in fish culture by improving the capability of extension agents.*

From the beginning it was realized that the level of intervention would be constrained by the availability of inputs and that aquaculture would have to be developed at a lower stage. Prepared feed would not be available. The availability of nutrients would be the limiting factor that would essentially constrain the effective level of intervention with other inputs. In fact, the only source of nutrients would be animal and plant manures.

Farmers were encouraged to seek ways to integrate aquaculture and agriculture. They had been growing crops on pond levees before PPN was initiated. During the project period, they were encouraged to grow only high-value crops to take better advantage of the availability of water nearby and to mix enriched bottom muds into the planting beds when the ponds were drained. They also were encouraged to use pond water for irrigation during periods of limited rainfall and to add animal and plant manures from the family plots to the ponds to increase natural fish food production.

At the end of the five-year project period, the PPN had demonstrated that fish culture in higher, cooler altitudes with limited inputs is technically sound, economically feasible, and socially acceptable. Aquacultural production in the targeted areas increased more than four-fold. Acceptable fish production was obtained at altitudes as high as 2,200 meters. Average internal rate of return on the average fish farming enterprise was 41 percent. During the project, 1,061 fish ponds were renovated, and 661 new ponds were constructed. Fifty-five extension agents, eight regional extension supervisors, and six fish station (hatchery) managers were trained. Finally, PPN clearly demonstrated the value of integrating agriculture and aquaculture in limited input ecosystems with surplus agricultural labor.

Fish culture cannot be considered to be fully institutionalized in Rwanda. Significant progress in the development of aquaculture had been achieved on previous occasions only to go into a period of limited activity. Only time will tell whether this return to the past will be the final result of PPN.

***Production Inputs Utilized***

Although the final fate of Rwandan aquaculture is not certain, it is helpful in our study of aquacultural development to look at the individual inputs that were available and that were utilized in these development efforts.

**Needs Assessment --** The importance of needs assessment as an input in aquacultural development was discussed in Chapter 3. The first input in the process, needs assessment took place at two levels in the PPN:

*1. The change agencies (the governments of Rwanda and the United States).*
*2. The individual Rwandan farmers who made the decisions to commit scarce resources to the development process.*

The governments of both Rwanda and the United States committed significant funding to PPN. These commitments were based on the assumption that aquaculture was needed to improve the nutritional and financial budgets of Rwandan farm families. Over time, many farm families had become convinced that they needed aquaculture to complement their limited agricultural resources and to more effectively use some under-utilized resources.

**Product Design --** Little attention was given to product design in the initial stages of the development of PPN. The use of fish in the diets of farm families and urban dwellers also was relatively limited. Fish had been important primarily only to those people who lived near lakes Kivu and Ihema. Consequently, there were few guidelines for the design of a commodity that could be produced through aquaculture. Biological characteristics of the product, such as the growth potential in the cool climate, was more important initially. The only concern for product design became apparent during the latter stages of PPN when it was realized that cultured fish smaller than 100 grams were difficult to sell even at reduced prices, while fish averaging 120 grams could be sold readily.

**Incentive --** The primary incentives for undertaking their development of aquaculture by both the GOR and individual farmers were to increase food production in the rural areas and to supplement limited farm income. Also, some initial participation was undoubtedly due to political status derived from cooperating with local officials.

**Information --** An important aspect of the development strategy was to provide a new information base (new technology) that would fit the Rwandan environment better. There were several important components in this new package of information:

*1. Improving water management.*

*2. Composting of animal and plant manures in the ponds to improve fish food production.*

*3. Introducing a better species of fish for culture.*

None of this technology was really new. All of it has been used in other countries, but it had been employed little, if at all, in Rwanda. However, all of these management techniques were adjusted to local conditions and field tested at the National Fish Culture Center at Kigembe (Figure 32) before the technology was given to the farmers.

In addition to providing a more effective information base, PPN also improved its information delivery system by reorganizing its extension effort and by providing practical training and experience for its personnel. The PPN (change agency) strategy was based on the premise that the transfer of technology under Rwandan conditions would probably be more effective if there was frequent and continuous contact between extension workers (change agents) and farmers. This approach required that an extension worker be assigned to a relatively few farmers in a small geographic area (zone).

Extension workers were assigned at two levels. Agronomes were selected to serve as regional supervisors. The agronomes were responsible for eight to 10

**Figure 32. The National Fish Culture Center at Kigembe, Rwanda.**

monitors who were responsible for day-to-day contacts with the farmers. In the beginning, it was expected that the monitors would visit each pond in a zone once each week. As farmer experience increased, the frequency of these visits was reduced to no less than two times per month.

Agronomes received second-country training in aquaculture. All of them attended a nine-month course at Bouake, Ivory Coast. The monitors were trained in-country at a training center constructed at the National Fish Culture Center at Kigembe. Training for the monitors emphasized practical fish culture skills in the three-month course. Each trainee was assigned a pond and expected to grow a crop of fish during the training period. Refresher courses (three to five days) were provided for each monitor twice a year.

The two American aquaculturists assigned to PPN as advisors also played an important role in the development effort. One was responsible for the organization of the training effort and served as primary trainer. The second served as advisor for all of the technology transfer (change agent) work. Both of these individuals had considerable experience with warm-water aquaculture before going to Rwanda. Both were fluent in French and had worked in Francophone Africa as Peace Corps volunteer aquaculturists. Five, short-term consultants from the United States also provided technical assistance in fish production, hatchery management, water-borne diseases, and rural sociology.

Rwandan counterparts to the American change agents received training at Auburn University. They attended the Aquacultural Training Program from March to July, 1985. Following this formal training program, they also visited Jamaica to study aquacultural development.

**Credit --** Rwandan fish farmers do not require credit in the usual sense. They do not receive credit from commercial credit institutions. Ponds are constructed primarily on the marais, which are publicly owned lands. There is an opportunity cost (Ekelund and Tollison, 1988) involved in using these lands for aquaculture rather than for some other purpose, and this cost can be considered a form of credit extended by the public sector.

Pond construction was accomplished primarily with hand tools, usually with labor provided by several cooperating families. Again, there were opportunity costs associated with this labor (muscle power), and these would be considered credit provided for the culture of the fish.

Animal and plant manures composted in the ponds to provide nutrients to increase fish production were obtained as by-products from other agricultural activities on the cooperating farms. Usually these same materials also could be used as organic fertilizers in the production of other crops. The opportunity costs associated with using these materials for aquaculture instead of agriculture could be considered to be credit utilized in the system.

Farmers paid approximately two-thirds of the cost of producing the fingerlings. The remainder was provided by GOR. All of these costs were provided in anticipation of a pay-back in economic and social terms at the time of harvest, marketing, and utilization.

The change agencies, both GOR and USAID, provided a substantial amount of credit indirectly to the farmers. The cost of facilities, training, technical advisors, commodities, travel, and administration were provided as credit for the PPN.

**Labor --** Labor requirements for this stage of aquaculture are relatively high. Fortunately, there is plenty of it available at a low cost. As noted previously, pond construction required a large amount of labor. Gathering a sufficient quantity of grass and animal manure also required a considerable amount of labor on a continuing basis and the compost piles had to be mixed daily.

There was little need for labor with special training. Most of the tasks required were similar to those utilized in ordinary farming. Building ponds and composting enclosures and harvesting fish were new to many of the farmers, but these new skills were readily learned. Vegetables commonly are grown on raised earthen beds in the marais. These beds provide better drainage for the plant roots. Movement and placement of clay to construct these plant growing beds are similar to the activities required in pond building.

Virtually all of the labor was provided by the families operating each pond. Because the individual ponds were relatively small and because several families usually cooperated in this effort, there was a sufficient amount of labor available. Also, there is considerable surplus labor in Rwanda.

**Equipment --** Given the stage of aquaculture practiced in Rwanda, the type of equipment required is simple. John Moehl (personal communication) suggested that the only equipment required by fish farmers in the country is a hoe, a machete, and containers (baskets and plastic buckets). Shovels are sometimes used but not required.

**Services --** Fish farmers in Rwanda require almost no services (electricity, telephones, railroads, or highways).

**Containers --** There were approximately 1,400 ponds still in nominal use in Rwanda when PPN was initiated. An additional 661 were constructed during the period that the project was in progress. Virtually all of the ponds were constructed in the marais (Figure 31). The typical pond was dug with hand tools near a stream. Because the topography in the marais was relatively flat, it was necessary to raise a levee around the entire pond area to impound water. Ponds averaged approximately four ares (400 square meters). Because of the high population density and the limited amount of land available for ponds, the size of each pond was limited. Typically, more than one family would be involved in constructing the pond. In a few extreme cases, as many as 50 families would share the management of a four-are pond. In constructing the ponds, usually individuals from several families participated. Clay was dug out of the pond area and carried by hand to the levee where it was set in place.

Walking back and forth on the individual clay "balls" that had been previously set in place tended to fuse them together. Usually a small dam was constructed on the stream to raise the level of the water so it could be diverted through a channel into the ponds for filling and replenishing.

Because cool water temperatures in production ponds was a problem, as the project progressed, farmers were encouraged to reduce the depth of their ponds so that they would warm faster in the morning (Moehl et al., 1988). The maximum depth recommended was less than 120-150 centimeters and the minimum depth 40-50 centimeters.

**Water --** Because of the hill and valley topography and a moderate amount of rainfall, there usually was ample water available for filling the small ponds and maintaining water levels. In fact, the generally good availability of water had led to the practice of flowing water through the ponds continuously. This practice had been encouraged by some individuals associated with previous projects. Unfortunately, the constant inflow of cool stream water lowered the temperature of the pond water and resulted in reduced growth rate of the fish. Because of the high altitude of the country, water temperature in the ponds already was marginal for fish production. This problem was compounded by water flowing continuously through the pond. Continuously flowing water through the ponds also prevented the establishment of efficient natural food webs or pyramids in the ponds. In this respect, the ponds were just enlarged stream sections. Reducing flows to only maintain water levels resulted in increasing water temperatures 2°-4° C.

Most of the water sources were soft and acid. The concentrations of inorganic salts available in the water supply were too low in most sources for the establishment of good populations of algae to serve as the base for food pyramids. Consequently, it was necessary to add fertilizers (nutrients) to the water to increase fish production to an acceptable level.

**Seed --** Historically, the Government of Rwanda had provided seed to the farmers. Unfortunately, when PPN was initiated there were few seed available. The GOR hatcheries were essentially non-functional. Production practices were poor at all of the facilities. At the majority of the stations few or no seed were being produced and distributed. Consequently, it was necessary to renovate several of the 26 hatcheries and to initiate improved seed production, handling, grading, and distribution practices.

*Oreochromis niloticus*, or the Nile tilapia, is indigenous to Rwanda and would have been a good species for culture. Unfortunately, the brood stock at the GOR fish stations were mostly hybrids of *O. niloticus* and *O. macrochir*. Because of the poor conditions of the brood fish, the decision was made to replace them with the Egyptian strain of *O. niloticus*. This strain of the species had been demonstrated to be somewhat more cold tolerant than some strains.

Initially, under the PPN, GOR hatcheries supplied virtually all of the seed required by farmers. Currently, only about 20 percent of the farmers do not produce enough seed to restock their ponds. In the normal production sequence, there is some reproduction in the ponds, and in most cases there are enough young fish produced to restock. Some farmers produce a surplus of seed and share them with neighbors or other farmers in the area. In some cases, at the higher altitudes, reproduction is limited, and not enough seed are produced for restocking. Also, the production cycle may be shortened so severely because of the low water temperature that the food fish being produced for market do not reach a size where they become sexually mature and spawn.

**Nutrients --** As noted in a previous section, most of the water available for filling fish ponds in Rwanda is acidic and relatively low in hardness and alkalinity. Under these conditions, it was necessary to add nutrients to the pond if production was to be high enough to offset the fixed costs of production and to realize an acceptable return on investment.

There are few inputs available for animal agriculture or aquaculture in Rwanda (Moehl et al., 1988). The primary nutrients available are plant and animal manures. In areas of the country where there is some grain production, brans (rice or wheat) are available, but these are poorly utilized as a feed by Nile tilapia. If there are substantial transportation costs required in obtaining these brans, they are not economical for use as a feed because the conversion rates from bran to fish are relatively poor.

The only nutrients generally available were organic fertilizers, primarily dried grasses and animal manures. These materials are utilized by composting them in the ponds (Figure 18). Stakes are driven into the pond bottom along the edge to form an enclosure. It was recommended that one enclosure be installed for each 100 square meters of water and that at least 10 percent of the pond area be enclosed for composting. The compost consisted of 80 percent dried grass and 20 percent dried animal manure by volume. Grass and manure should be added weekly and the compost pile in the enclosure mixed daily.

While the recommended use of compost does result in substantial fish production, the availability of nutrients will continue to be a limiting factor in the further development of aquaculture in Rwanda. The collection of grass and manure is a labor intensive activity and must be scheduled along with many other home and food plot duties. These materials are somewhat difficult to transport, so they should be obtained near the pond site. Finally, grass and animal manure are difficult to store. For optimum quality, they must be obtained and utilized within a relatively short period.

Although production is primarily based on composting, pond operators are encouraged to feed available household wastes to fish. Unfortunately, family meals based primarily on beans and potatoes do not result in substantial quantities of household wastes. Some farmers also utilized chopped leaves as feed. This practice originated many years ago when ponds were stocked with *Tilapia rendalli*. That species readily accepts virtually any green plant material as food. In contrast, *O. niloticus* are primarily planktivorous and generally will not feed on plant materials. Feeding of the chopped leaves does, however, add to the organic fertilization provided by the decomposing compost piles.

### *Harvesting*

Farmers could begin partial harvesting of their ponds after four months and were encouraged to remove all the fish after seven to nine months. Fish were harvested by seining the ponds to remove as many fish as practical before lowering the water level to remove the remainder (Figure 33). This procedure was followed by farmers who were being provided technical assistance by the change agents (monitors). In these situations, the agents provided a small seine for partial removal of the fish.

When farmers were not assisted by extension agents, they generally did not have seines for partial harvesting. Under these conditions, they waited until the entire crop was ready for harvest, and they broke the levee to drain the pond. A basket was placed in the breach to prevent the loss of fish. When the water level was low enough, the farmers waded into the pond and dipped up the fish in baskets.

**Figure 33. Harvesting from a farmer's production pond in Rwanda.**

### *Processing*

There is limited processing of any type before the fish reach the consumer. Virtually all of the fish are marketed in the "round" (just as they were taken from the pond).

### *Marketing*

Molnar et al. (1990) reported that most of the production from the ponds is utilized by the farmers as food, but that selling fish for cash is a common practice. Apparently, the quantity sold generally does not exceed more than half of their production. Sales of the fish were more common when the ponds were operated by more than one family. Cash received for the fish was more easily divided.

John Moehl (personal communication) noted that the fish are marketed on the pond bank as they are being harvested. News that the pond will be harvested travels by word of mouth throughout the community, and buyers come to the pond at the appointed time to purchase the fish. When the farmer was being assisted by the extension agent, fish were sold by weight, but when the scales were not available from the agent, they were sold by the "piece" or by the "pile" of fish.

Harvesting and marketing often were scheduled to coincide with the time of the month when local civil servants were paid. Cash flow is so limited in those rural areas that it is necessary to wait until a new supply of cash comes into the community before customers are able to purchase the fish. Also, harvests may be scheduled to coincide with the time of coffee harvest and marketing when cash is more readily available. A high percentage of the markets were simple ones. The fish farmer sold directly to the consumer, with few middlemen involved. In a few cases, bar owners purchased fish from the farmer for resale as a grilled product in their establishments. Some 15-20 percent of the fish were sold through a more formal marketing procedure. Usually a market area is located near the commune administration building. Farmers and craftsmen gather there on a weekly schedule to sell their produce and wares. On occasion, a farmer carried a basket of fish to the market where they were displayed in the round on a rack made of sticks.

### *Utilization*

Fish have been eaten since ancient times in areas adjacent to lakes Kivu and Ihema and some smaller lakes in the northern and eastern regions of Rwanda. Fish were not widely utilized in the interior. In fact, for many years they were considered to be taboo. This situation has changed recently, and fish are readily accepted as food throughout the country. However, the taboos left a legacy of ignorance regarding the preparation of fish as food. When fish began to be more readily available in the rural areas as a result of PPN activities, women threw fish which had only been gilled and gutted into the bean pot. The resulting mixture of cooked beans, fish flesh, scales, fins, and bones was poorly accepted. Now most of the fish consumed in the home are roasted or grilled after the scales, gills, and intestines are removed.

Some bar owners purchase fish from farmers to serve along with beer and soft drinks. The fish are scaled, the gills and intestines removed, and then the dressed fish is grilled over charcoal. This product apparently competes favorably with roasted goat meat or roasted chicken. The utilization of fish in this manner apparently was influenced by visitors from Zaire where there is a longer history of aquaculture and of the preparation of farmed fish for food.

***An Overview***

Aquaculture in Rwanda is practiced at a relatively low stage. Intervention is limited. All of the required inputs are limited both in quality and quantity. Fortunately, the entire aquacultural ecosystem (production, harvesting, processing, marketing, and consumption) is relatively well balanced. Even though fish farming is being practiced at a low stage, it is producing acceptable results because the inputs are balanced. It is fortunate that the change agencies involved were wise enough to choose a system of aquacultural technology for diffusion that could be supported by inputs already available in the country.

Fish farming has grown rapidly in Rwanda since the initiation of PPN. The number of ponds has increased dramatically, along with the rates of production. Yet with this level of progress, aquaculture is a relatively insignificant food-producing system. Although significant progress has been made, aquaculture cannot be considered to be institutionalized. Similar progress had been achieved in previous efforts to establish it, only to have the farmers lose interest after a few years. The likelihood of eventual institutionalization is promising this time because the inputs seem to be better balanced than they were with previous development projects.

The primary threat to institutionalization will come from the probability that the inputs will become unbalanced over time. For example, given the return on investment, more ponds are likely to be constructed, and management practices will be improved so that total fish production can be increased dramatically. When this happens, the inputs will become unbalanced. Marketing a significantly larger quantity of fish on the pond bank will be difficult. To market this larger quantity of fish, simple marketing arrangements will no longer be adequate. The surplus fish will have to be transported to population centers where cash flow is higher and more predictable. This need to change the marketing input could create severe unbalance in the system that could be solved only by increasing the levels of intervention for the other inputs. To support the added costs associated with the complex marketing system, it probably would be necessary to increase the stocking rate of seed and to improve the nutrient system. Certainly, better equipment (especially seines) would be necessary, and it would be wise to construct ponds with drains.

Because there are potential problems that could result in another failure in Rwandan aquaculture is no reason to try to prevent it from being developed to a higher stage. Development to a more advanced stage must be a basic objective of GOR. However, if the inputs are not available at the required levels to balance the ecosystem at a higher stage, the PPN successes to this point could quickly be lost and fish farming once again largely abandoned.

## *Development of the U.S. Channel Catfish Industry as a Model*

The growth of the channel catfish industry also provides a useful example for the development of aquaculture (King, 1987B; Egan, 1990). The industry is only approximately 30 years old, although catfish have been cultured for a longer period primarily as a sportfish. The industry is confined geographically, making it convenient to record its growth (Wellborn and Tucker, 1985). Also, relatively good records are available regarding most aspects of the growth of the industry from the beginning, primarily because scientists and scientific institutions in the region have been deeply involved in the development of the industry from the beginning.

### *A Historical Perspective*

The growth of the culture of this species in the United States has been phenomenal (Figure 34). Thirty years ago, virtually none were being produced, but in 1987 (Table 4) the channel catfish ranked 11th among the fishes cultured worldwide in terms of total weight produced. Now, it ranks fourth behind pollock, salmon, and cod in United States landings of fin-fish species. The annual rate of growth in catfish processed has been more than 25 percent for the period 1970-1989, although there has been considerable variation from year to year.

Early efforts to culture the channel catfish were undertaken because of its value as a sportfish, although its qualities as a food fish probably had been established years earlier in the southern tier of states by the Indians and then later by the settlers. The species was harvested for home use and for local sales by fishermen along the swift flowing creeks and rivers of the South for many years before its culture was considered.

Smitherman and Dunham (1985) noted that the first recorded spawning of channel catfish was accomplished in 1892, and that the Kansas State Fish Hatchery began propagating the species as early as 1910. H.S. Swingle stocked channel catfish obtained from a local creek into some of his first experiments on aquaculture at Auburn in 1934. He concluded that because the fish did not reproduce, they were not a promising species for stocking into recreational fishing ponds (Swingle et al., 1936). Some 13 years later, in 1949, he decided to take another look at the species. In the intervening decade, he had developed an interest in the production of fish for food. In 1956, he began a series of experiments that were to lead to three publications on the culture of the channel catfish (Swingle, 1954, 1956, 1958) and that were to provide much of the information base for the early development of the industry.

While Swingle's early experimentation provided important information for the growth of the industry, there were other developments taking place in Arkansas that were equally important. The culture of baitfish for use in recreational fishing had developed rapidly in that state following World War II. By the late 1940s, there were at least a dozen successful bait fish farming operations (Bureau of Sport Fisheries and Wildlife, 1973). Some of these farmers had begun to spawn the channel catfish and grow the fingerlings for sale for stocking in recreational fishing lakes. Ben Nelson (1956), a minnow farmer in Arkansas, described the procedures he used to spawn the channel catfish and rear the fingerlings (seed). He commented that in 1951 he had produced 104,100 fish totaling 1,542 pounds in a 5.76-acre pond. His comments also suggested a good future for culturing the fish for table use.

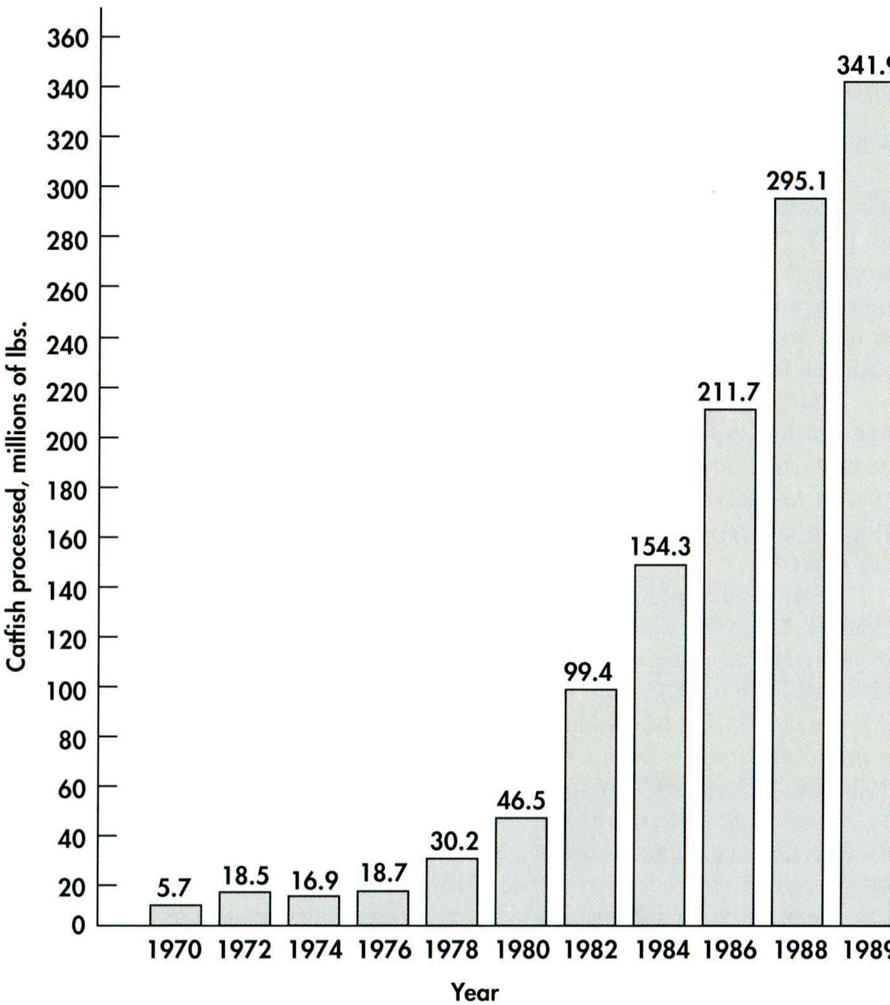



**Figure 34. Quantity of channel catfish processed during the period 1970-1989 (Harvey, 1990).**

By 1953, some of the minnow farmers in Arkansas had started to produce the buffalofish (Bureau of Sport Fisheries and Wildlife, 1970, 1973). Wellborn and Tucker (1985) reported that by 1960 there were 1,458 hectares of ponds with buffalofish and 101 hectares of ponds with catfish in that state. For several reasons, the culture of buffalofish was not successful, and the farmers converted the ponds used for that species to channel catfish culture. By 1963, there were 1,451 hectares of ponds in catfish production and 303 hectares of ponds in buffalofish production.

Commercial production of channel catfish as a food fish did not begin in Mississippi until 1965, although there were some farmers producing fingerlings for sale as early as 1959. Commercial production in Alabama began in 1959, after Chester O. Stephens, Jr., began to spawn the species on a farm near Greensboro, Ala. Stephens and two partners, Joe Glover and Richard True, constructed the first catfish processing plant in the United States at Greensboro in 1964. The development of the plant provided a powerful stimulus to the growth of the industry in that area.

From the beginning, it was obvious that the culture of channel catfish would be done at an intermediate stage. In his first publication on the subject, Swingle (1954) concluded that the production of this species would not be profitable as a farm crop using only natural foods produced in the pond as a result of adding inorganic fertilizers. The cost per pound of fish produced was relatively low, and total production was much too low to cover fixed costs and provide a return on investment. He also concluded from his work that, even with feeding, the stocking rates would probably have to be relatively high.

### *Production Inputs Utilized*

With some of the early history of the catfish farming industry established, it should be worthwhile to briefly look at the inputs that were required in the development of the culture of that species and to consider how their availability has determined the nature of the development of this industry. It is not intended that this review provide a detailed description of the technical and biological aspects of catfish farming. For this degree of detail, the reader should consult the publications, *Third Report to the Fish Farmers*, edited by Dupree and Huner (1984), and *Channel Catfish Culture*, edited by Tucker (1985). Rather, the objective in this section is to look at each of the inputs required in culturing channel catfish and consider the level of intervention involved.

**Needs Assessment --** There was no formal effort to do a needs assessment before the channel catfish farming industry began to develop. In the late 1950s, no one really appreciated or could imagine the potential of aquaculture. There was little concern for world population growth, and certainly no one in the southern states could foresee how increased exploitation would affect the harvest of fish from the oceans. There likely was some realization that catfish could be marketed for food in the river towns of the South, and the potential of this species for recreational fishing was appreciated. However, there was no indication that any of the farmers could see the need for or predict a market for more than 300 million pounds of farmed catfish.

Keenum and Waldrop (1988) suggest that the real impetus for the development of the industry in Mississippi was not an assessment that there was a growing demand for fish. Rather, the Delta farmers were responding to an assessment of need regarding alternative agricultural enterprises. During that period, commodity prices were depressed, and there were restrictions on cotton and rice, the two major crops on the clay soils of the Mississippi Delta and in Arkansas. Almost from the time the first commercial ponds were harvested, the industry began to grow rapidly. Except for a "shakeout" period in the interval 1973-1975, the industry has expanded continuously.

Needs assessment that has resulted in an appreciation for the potential market for farmed catfish is a recent phenomenon. Catfish farmers and potential farmers are well aware of the growing demand for fish in the United States and the rest of the world, and they are making substantial investments in response to their assessment.

**Product Design --** There was little, if any, concern for product design when the catfish farming industry was beginning to develop. Most of the catfish were marketed live or freshly cleaned and iced. My earliest experience with this fish was the result of accompanying some of my relatives to the home of a river fisherman on the banks of the Escambia River in northwest Florida some 50 years ago to purchase river cats (channel catfish) for a fish fry. The fish had been captured either by hook and line or by trapping, and they were held live in a cage consisting of a wooden frame with wire mesh that was submerged in shallow water in the river. If I remember correctly, the fisherman was paid for the fish and for skinning them. They were prepared for the table by rolling them in corn meal and frying them in oil or possibly melted animal fat. Some variation on this general theme characterized the channel catfish as food when the industry began to develop.

Fish farmers and the early processing plants had little difficulty with product design. The product which they imitated or competed with was an extremely simple one. However, with the passage of time, the increasing demand for the product away from river bank towns, and the increasing production, the product has changed significantly. The farmed channel catfish no longer competes with the river fisherman's catch, but with halibut, salmon, flounder, cod, snapper, shrimp, lobster, and crabs in a wide array of product forms. Paying attention to product design is essential today, and it is growing increasingly important as new specialty items come on the market and as more seafood restaurants and restaurant chains appear on the scene.

**Incentive --** Apparently, as suggested in a preceding section, the primary incentive for the beginning of catfish farming was the result of an effort to find alternatives to cotton and rice as farm crops in Arkansas and Mississippi. In Alabama, it was a need to identify any crop or land use that would provide some improvement in a dismal rural situation.

Once farmers began to produce catfish, however, it soon became obvious that this was potentially a crop that could provide substantial farm income. Net returns to intensive catfish farming were better than for rice, soybeans, or oats. There was no comparison with other crops, but returns for catfish certainly would also have exceeded those for cotton. These returns for fish were based on production obtained with relatively low stocking rates (usually 2,000 per acre or less). Once stocking rates were increased and feeds and feeding practices were improved, net returns increased dramatically. Today, the return on investment is acceptable, even with relatively high feed prices. With return on investment as the principal incentive, production is being expanded at a rate of 5-10 percent per year.

**Information --** While there are some serious gaps in the knowledge base for the catfish farming industry, the lack of information has not yet been a serious bottleneck to the development of the industry. As noted previously, there was a successful baitfish culture industry in Arkansas prior to the beginning of catfish farming in that region (Bureau of Sport Fisheries and Wildlife, 1970, 1973). Some of the information required in the culture of catfish was adapted from the minnow farmers (Prather et al., 1953). Even rice farming in that region provided some useful information on pond construction and water handling. Also, for a number of years there had been a number of progressive, well-managed Federal and state warm-water fish hatcheries in the region (Parker, 1989). Although these hatcheries produced fish primarily for use in recreational fishing, many of the culture techniques they developed were directly transferable to catfish farming.

In 1955, the U.S. Fish and Wildlife Service, utilizing funds from the Saltonstall-Kennedy Act, sponsored research on channel catfish at the University of Oklahoma (Bureau of Sport Fisheries and Wildlife, 1973). In 1956, the Alabama Agricultural Experiment Station at Auburn University began a systematic study into virtually all areas of catfish culture. In 1958, funds provided under Public Law 85-342 (the Fish-Rice Rotation Act) were utilized to develop the Fish Farming Experimental Station in Stuttgart, Ark., to be operated by the U.S. Bureau of Sport Fisheries and Wildlife. In 1959, the Southeastern Fish Cultural Laboratory was established by the same agency at Marion, Ala., on federal land adjacent to a National Fish Hatchery. These state and federal research laboratories provided a wealth of practical information on many aspects of the catfish farming industry. From the beginning, these programs were highly responsive to the informational needs of the developing industry, while working in areas that posed potential problems.

There was good availability of information from the beginning of the industry and most of the farmers involved were experienced in obtaining information and utilizing it (Bureau of Sport Fisheries and Wildlife, 1970). Virtually all of them were progressive in the adoption and exploitation of new technology.

In later years, strong aquacultural research programs were established at Mississippi State University, Louisiana State University, and Texas A&M University. These programs have added substantially to the information-developing system supporting the industry.

At the beginning of this section, I suggested that the lack of information had not limited the growth of the industry substantially, if at all. This comment is not meant to suggest that all the information needed is available. This is not true at all. There are weaknesses in the information base. Sooner or later, when competition increases, the off-flavor problem (Wellborn and Tucker, 1985; Lovell, 1983, 1986) and the lack of information on how to prevent or control it will be a serious threat to the stability of the industry. Similarly the winter kill problem in Mississippi (MacMillian, 1985) would be devastating in a highly competitive environment. Hopefully, solutions to these and other perplexing problems will be forthcoming before the need for the appropriate information becomes more critical.

**Credit --** Catfish farming requires a high level of capital (Keenum and Waldrop, 1988), and consequently utilizes a large amount of credit. Fortunately, the availability of credit has not been a limiting factor in the development of the industry. As noted previously, the early interest in catfish farming developed among farmers with large land holdings who were looking for alternatives to traditional agricultural crops. These farmers were experienced in dealing with credit and with private and public lending institutions. The large farms also served as good collateral for the credit.

Obviously there was some early skepticism among the lending institutions, especially in Arkansas, because of the failure of the buffalofish farming industry. However, this skepticism was dispelled relatively soon. Later, catfish loans were to be considered among the safest loans that lending institutions could make on any farm-related enterprise.

**Labor --** The catfish farming industry developed most rapidly in Arkansas and Mississippi, primarily on large soybean, rice, and cotton farms. There usually was a considerable amount of general farm labor available. While the labor was not trained for work in fish farming, because of the similarities between land and water farming, the transferability of this labor was not a major problem in the beginning. However, as the industry developed and stocking and feeding rates were increased, the risks involved also increased. Labor requirements became more specialized, but even under these conditions the availability of labor (quantity or quality) has not been a limiting factor to the development of the industry.

The labor situation in west Alabama has been somewhat different. Fish farming also developed on the larger farms there, but they generally were not nearly as large as those in Mississippi and Arkansas. On the Alabama farms, a higher percentage of the labor was provided by owners of the farm and the immediate family. When they added catfish production to their farming operations, the owners had to increase their labor input significantly, especially at night. While the labor situation in west Alabama does not seem to have slowed development, at least in the short-term, it has placed a heavy burden on those farm families, and it may affect their competitiveness in the long-term.

**Equipment --** The availability of equipment has been adequate for the needs of the developing catfish farming industry. Tractors, trucks, wagons, and hand tools were already available on the farms. Seines, nets, and hauling tanks were available from businesses supporting the bait minnow industry in Arkansas. Feed bins were available from suppliers of poultry equipment. Pumps, pipe, and water handling equipment were available from suppliers of equipment to the rice farming industry. The availability and easy transferability of equipment was a significant factor in the development of the industry.

**Services --** As noted previously, the catfish farming industry developed in rural Arkansas and Mississippi. The Delta is the least industrialized and urbanized area in either state. However, the presence of successful and influential planter families in those areas meant that services (roads, electricity, communications, spare parts, etc.) were readily available. The availability of services never limited the development of the industry in either of the two states.

**Containers --** The areas where catfish farming has developed most rapidly (west-central Alabama, southeast Arkansas, and west-central Mississippi) are characterized by relatively flat land with a heavy clay soil. Under these conditions, the construction and maintenance of ponds is relatively easy and inexpensive. Most of those areas were already cleared for row crop or pasture agriculture. Because of the nature of the terrain, it was possible to construct large-area containers with low dams. Because the containers are shallow and the bottoms smooth, harvests can be made without removing the water. The only disadvantage to this type of terrain is that, because it is so flat, it is usually necessary to construct a levee or dam around the entire pond. The general utility and effectiveness of containers that could be developed in those areas contributed significantly to the rapid development of the industry.

**Water --** Much of the catfish industry is located on either side of the Mississippi River in Arkansas and Mississippi. This Delta is underlain by several different aquifers. Each of these is at different depths, and ground water in different amounts and quality (Pote et al., 1988) is available from each. The most important is the Mississippi River Alluvial Aquifer. This aquifer is approximately 40 miles wide on either side of the river in the vicinity of Greenville, Miss. It ranges in thickness from approximately 50 to 200 feet in that vicinity. The water is only 20 to

50 feet from the surface, and wells penetrating the aquifer yield from 250 to more than 5,000 gallons per minute. The water is of excellent quality for aquaculture. The quantity, quality, and availability of water has been a significant factor in the development of the industry in the Delta. Another factor involving water utilization was the experience gained in pumping and moving large quantities of water in the rice farming industry in Arkansas. Much of this technology was directly transferable to the fish farming industry.

The water supply for the catfish farming industry in Alabama is quite different from that in Arkansas and Mississippi, having limitations caused by both water source and soil type. Aquifers underlying the principal fish farming region in the west-central section of Alabama yield considerably less water to pumping, and they are much deeper. Generally, they are not suitable supplies for pond aquaculture. Much of the soil in the area is a heavy clay. Because rainfall does not penetrate very deeply into such soils, there are relatively few permanent streams. Virtually all of the farms there are dependent on harvesting the run-off following rain storms. Because of the impervious nature of the soil, a high percentage of the rainfall runs off quickly following storms. Gently rolling topography results in large watersheds that direct storm flows into broad, flat valleys. The culture ponds are located in these valleys. Also, much of the land in the watersheds is in improved pasture so the water yield from a storm is relatively high. Storm flows are captured behind dams in shallow ponds.

In normal years, the rainfall total is approximately 50 inches. This level of precipitation, together with the large watersheds and low seepage rates from the ponds, guarantees enough water to fill and maintain water levels in the ponds each year. Unfortunately, rainfall is not evenly distributed over the year. Although ponds fill quickly in the winter, it is generally unlikely that they can be drained and refilled between May and November. Fortunately, most of the ponds are relatively shallow, and only a few feet of water must be drained before the fish can be removed with seines.

The quality of the water available to the fish farmers in west Alabama is much more variable than that available to farmers in Mississippi and Arkansas. Rainwater flowing across the land carries with it any compounds or materials that will go into solution or that are light enough to be carried along by the current. Harvested storm flow can contain a variety of pollutants and turbidity. Generally, however, the quality of water is adequate for fish farming.

The water available to fish farmers in Alabama is cheap. Obtaining it requires no pumps or pipe and there are no aquifers to be pumped down. Unfortunately, the supply is less predictable and the quality not as constant as would be the case if aquifers were available.

**Seed --** The development of aquaculture for some species is severely limited by the availability of seed. Availability was never a serious problem in the development of the catfish farming industry. Fingerling catfish were being produced in state and federal hatcheries and on private farms for a number of years before demand began to increase (Nelson, 1956; Busch, 1985A). The private sector has provided virtually all of the seed required by the growing industry. From the beginning of the industry, meeting the demand for seed involved little more than increasing the number of brood fish and the number of fingerling grow-out ponds as demand increased. The seed production process was somewhat unpredictable, but not great enough to limit the growth of the industry.

**Nutrients --** It was suggested earlier in this section that there never was any serious consideration given to growing catfish without prepared feeds. Consequently, almost from the beginning of the industry, research was being conducted on the nutritional requirements of the species and how to meet those requirements with practical diets (Shell, 1967; Lovell, 1988). Before the beginning of the fish farming industry, the intensive production of poultry was well developed. Catfish feeds were similar in many respects to poultry feeds. In fact, much of the information available in the broadly based poultry, swine, and pet feed industries was readily transferable. The same ingredients were utilized in all of the feeds for these animals. Also, much of the same feed processing equipment could be used. Plenty of high-quality feed was available, and feed distribution, marketing networks, and sales points were well established before the beginning of the catfish industry.

***Harvesting***

Harvesting has not been a constraint in the development of most of the channel catfish industry. From the beginning, approximately 90 percent of the total production has taken place in levee ponds. Most of these ponds were constructed with wide levees so that heavy equipment could be easily used around the perimeter (Figure 21) (Busch, 1985B). Also, these containers are relatively shallow with smooth bottoms. It is simply a matter of encircling fish in a section of the pond or even the entire pond with a seine. Then the seine is slowly pulled out of the water onto the levee, concentrating the fish in a small circle of net against the levee. The fish are dipped out and placed in a tank on a truck for hauling to the processing plant. Usually it is not necessary to drain any water out of the pond in order to harvest the fish.

Obviously this is an over-simplified description, but it describes the process that is followed. However, considerable research and development efforts have gone into improving the efficiency of the system and in designing practical, effective seines, live cars, lift nets, lifting equipment, and hauling tanks. Huner et al. (1984) and Busch (1985A) include descriptions of the harvesting process in levee ponds.

Harvesting fish in the so-called hill ponds or dammed, watercourse ponds (Figure 20) is more complex (Smitherman et al., 1979), although the principle is essentially the same. Because of the rolling characteristic of the land where most of those ponds are constructed, the water is usually relatively deep near the dam, and it is not possible to seine this deep water effectively. Consequently, it usually is necessary to drain the pond partially. This draining results in a shallower pond and more concentrated fish. In the extreme case where land slope is more severe, it may be necessary to drain away 80-90 percent of the water before the pond is shallow enough to seine. In this case, the fish become so concentrated that all of them must be removed within a short period or they will die from lack of oxygen.

### *Processing*

It was noted previously that approximately 90 percent of the channel catfish industry is located on either side of the Mississippi River in southeast Arkansas and west-central Mississippi. These areas have limited histories of animal agriculture. Most of the agriculture has been agronomic. The nature of the soils provided limited opportunity for pasturage, and except for some recent interest in soybeans, there has been little feed grain produced there. Certainly, the area had limited experience in commercial butchering and processing of animal carcasses and equally little experience with processing equipment, processing lines, sizing, and packaging. Also, the labor force, although farm oriented, had little experience in this area. Virtually all of the technology had to be transferred from other areas or developed on site.

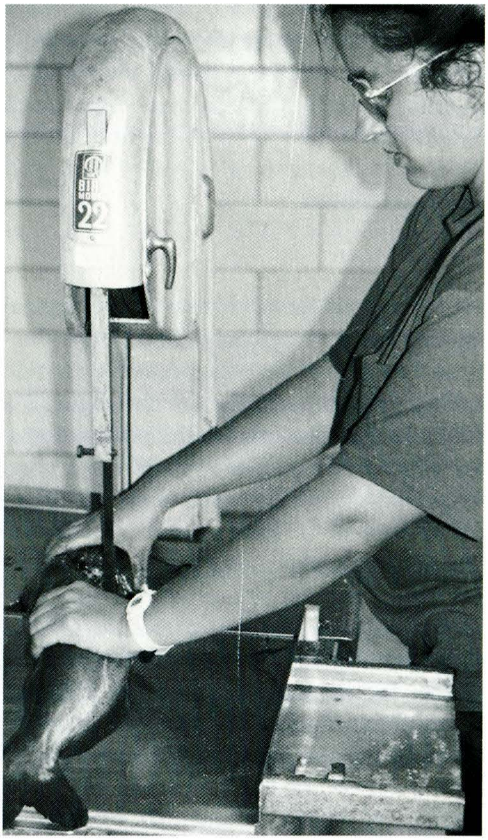


Figure 35. Bandsaw used to remove catfish heads.

The situation was somewhat different in west-central Alabama where there was a considerable amount of animal agriculture. Much of the land that was destined to become catfish ponds was in improved pasture. Farmers had considerable experience with cow-calf grazing operations that provided cattle for the feed lots of the high plains in the West. Although farmers there produced animals, there was little processing. It is interesting, however, that the first commercial processing venture in the state was in the back of a grocery store meat market in

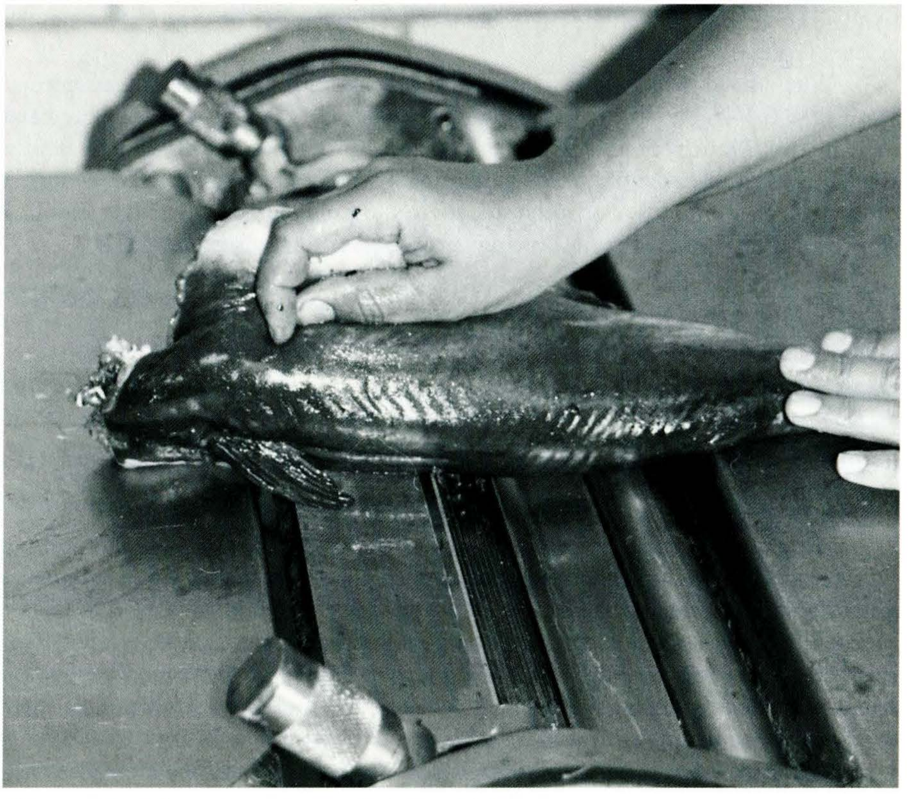


**Figure 36. Machine used to remove skin from catfish.**

Greensboro, Ala. Later, the owner of that business joined two other businessmen to establish the first commercial catfish processing plant in the United States. The catfish industry in Alabama developed around that plant and its successors.

River fishermen were processing their catch for many years before the industry began. They used a knife to cut through the skin on the circumference of the fish just behind the gills. Then pliers or tongs were used to strip the thick, heavy skin away. Finally, a knife was used to eviscerate the fish and cut off the head. This same procedure was utilized for a few years after commercial production began. Soon, however, processors began to use a bandsaw (Figure 35) to remove the head and a Townsend membrane skinner (Figure 36) to remove the skin. Ammerman (1985) provides a description of the entire butchering (transportation, receiving, cleaning and dressing, sizing, and packing) process.

Butchering is a labor-intensive process. While machines have been designed that will remove the head automatically, the skin cannot be effectively removed from the "round" carcass. This must be done in a hand operation by passing the fish across the roller of the skinning machine. There are machines available that will fillet the fish and remove skin from the fillet, but these machines can be used only when the filleted product is wanted.

When the industry was just beginning, processing consisted of butchering and storing the fish on ice. Later an increasing percentage of the fish were butchered and then frozen. More recently the trend has been to butcher and then fillet before freezing, and in the past five years increasing attention has been devoted to further processing of the fillets. For example, an article published in the Water Farming Journal in 1989 reported the following percentages of processed products:

| *PRODUCT* | *PERCENTAGE* |
|---|---|
| *Frozen fillets* | *27* |
| *Fresh whole* | *24* |
| *Fresh fillets* | *19* |
| *Frozen, other* | *14* |
| *Frozen, whole* | *11* |
| *Fresh, other* | *5* |

Although processing channel catfish is relatively labor intensive, this has not constrained the development of the industry. However, ultimately more equipment (capital) will be substituted for labor. As noted previously, most of the catfish are processed in areas where there is an excess of relatively unskilled farm labor. This labor situation has been essentially the same in west-central Alabama, west-central Mississippi, and southeast Arkansas. Because of this similarity, neither of the three areas had a comparative advantage from the labor cost in processing. With time, it is likely that the wage scales for this labor will be increased to the point that there will be an increased incentive for use of machinery in processing.

***Marketing***

As suggested previously, there had been a good market for channel catfish along the rivers of the South for many years before the beginning of the catfish farming industry. As the major cities along these river corridors grew, the demand for the fish increased. At the same time, interest in commercial fishing began to wane. Although there are few good records to support the claim, anecdotal sources suggest that catch per unit of effort was decreasing, possibly because of a combination of pollution and over-fishing. The return on investment to the river fishermen certainly had to be low considering the primitive fishing methods they used.

The 1960s also brought the realization that capture fisheries in the world's oceans, lakes, and rivers could not keep pace with demand. The Food and Agriculture Organization of the United Nations underscored this concern when it held the first worldwide conference in Rome in 1966. It was during this decade when world population spurted and increases in the world fish catch began to level off.

Also during the 1960s, there was increased interest in recreational fishing. Transplanted Southerners in many of the industrialized cities responded favorably to the opportunity to catch catfish out of nearby "put-and-take" fishing ponds (Figure 25). Livehaulers would transport the fish from farms in the lower South upriver to stock in fish-out ponds. Interest in this market was intensified by research conducted by Prather (1964) at Auburn on the operation and management of fish-out ponds.

Until 1970, farmers could sell virtually everything they could produce because of this combination of demand for channel catfish as a food fish and as a recreational fish (Bureau of Sport Fisheries and Wildlife, 1973). Livehaulers and processing plants competed for the limited supply of fish. Unfortunately, in the early 1970s, supply began to overtake the limited marketing efforts in place at that time. The first processing plants had been established by fish farmers. While trying to learn the processing business, producers neglected marketing. As a result, there was a severe shakeout of marginal and unprofitable producers when the cost of feed increased due to a shortage of fish meal (Dupree and Huner, 1984).

After 1977, the industry began to cooperate on a more sophisticated marketing approach. Following the 1973-1976 shakeout resulting from limited and temporary disequilibrium between production and marketing, the demand for fish increased regularly. For more than 13 years production and marketing have increased regularly each year. This long-lived sellers market has been the result of three factors:

*1. Continuing increases in demand for these fish for recreational fishing (fish-out).*
*2. Increased interest in all forms of seafood for the promotion of good health.*
*3. Shortages of fish of all kinds worldwide as the leveling-off trend in capture fisheries continues.*

Much of the success of the channel catfish industry can be traced to the strong, increasing demand for the fish. This growing demand has helped overcome the numerous problems encountered in this pioneer-stage industry. Problems such as winter kill, bird predation, off-flavor, seasonal growth, poor product name (catfish), and strong regional product identification would be sufficient to stymie the orderly development of virtually any other food industry. Yet, because of the growing availability of markets (demand), those problems have not seriously threatened the industry. This situation substantiates the old adage:

*A good idea is a jewel to cherish, but I would*
*rather have an ordinary idea whose time has come.*

***Utilization***

Virtually all of the catfish produced in the United States are ultimately used for food. Even those fish that are harvested by hook and line from fish-out ponds are taken home by the angler and eaten. There is little evidence of catch and release of the channel catfish that is prevalent in recreational fishing for the largemouth bass. Some anglers enjoy catching catfish, but most are caught to be used as food.

Essentially no catfish are used as live bait to catch other fish, and relatively few are used for ornamental purposes in aquaria. Also, the species is never prevalent enough in the wild or easy enough to harvest to have been considered as a source of fish meal.

Although the channel catfish is native to virtually all of the large rivers in the eastern United States, it has never been an important item in the diets of Americans. The species generally does not constitute a large portion of the fish population in streams. Its feeding habits place it relatively high on the food pyramid, just below the piscivorus species. Also, these fish are not easy to harvest in large quantities without a considerable amount of effort. They do not occur in large schools in the riverine habitat. Further, the physical characteristics of most rivers preclude the use of surrounding gear (seines or nets) for harvesting them. A high percentage of the fish have been harvested with baited hooks or baited traps.

Historically, because of the general difficulty of harvesting this fish and its relative scarcity, it has been considered a specialty item in the diets of even those people living in the river corridors. These consumers never seemed to consider catfish as a form of seafood. More than anything else, people have seemed to want to eat catfish more as a "celebration of life" than for any other purpose. A Saturday night fish fry was a tradition.

In the early days of the development of the catfish industry, at least in Alabama, farmed catfish were purchased for the same reason as river catfish. They still were not a staple item in diets. Farming, however, did make them available on a more reliable basis and further away from the rivers. People who wanted to eat catfish no longer had to go to the river to get them. In the past decade, the nature of the utilization of the catfish has changed. Eating them is still a special event. Even with the rapid growth of the industry, Americans still eat only approximately one pound per person per year. There are still many people in the South who go out to specialty restaurants to eat catfish. But more and more, people in the South and especially in other regions of the country now consider catfish to be a seafood to be selected from a menu that includes salmon, lobster, shrimp, and crabs. In fact, the catfish has become quite popular as a seafood item.

As noted previously, catfish harvested with hook and line from fish-out ponds are eaten. The consumer gets the double value of the recreation of fishing and the use of the catch as food. It is an unusual situation for a food to be utilized for such divergent purposes. This double value phenomenon provides some fish farmers with a unique opportunity for marketing their fish. While the producer may not receive more than 80-85 cents per pound for his fish when sold to a processor, it is not uncommon to sell the same fish to an angler through fish-out for $1 to $1.25 per pound. The fish-out also provides a ready market for farmers with a small acreage of ponds located too far away from a processing plant to use it as an outlet for their fish. However, unless the farmer is located near a sizeable population center, it would not be practical to expect to market a large quantity of fish through fish-out.

### *An Overview*

The development of the channel catfish farming industry in Alabama, Arkansas, and Mississippi is a useful example of the introduction of aquaculture into areas where it had been practiced sparingly, if at all. It also provides a good model for the development of existing aquaculture after it became established. In Mississippi especially, there had been virtually no aquaculture and little animal agriculture. Development succeeded almost spectacularly because all of the physical, chemical, biological, technological, social, economic, and political requirements for development were either already available or were made available relatively easily. The stage of aquaculture or levels of intervention chosen for introduction and adoption were especially well adapted for introduction into that environment at that time.

While all of the required inputs were generally available when needed, it would be a mistake to overlook the importance of "demand-pull" in the development of this industry. Lewis (1982) suggested that "the 'push' of new technology yields the greatest rewards when it is guided by the 'pull' of the marketplace." For reasons discussed previously, the quantity of all kinds of fish utilized in the United States began to increase soon after the beginning of the catfish industry and has continued to increase regularly. Because the American market is so large, only a small, regular increase in utilization would absorb all of the production that the new, expanding industry could supply. As noted in a preceding section, a one-pound-per-capita increase in utilization by Americans during one year would translate into an increased demand for more than 250 million pounds of processed catfish or more than 400 million pounds of whole fish before processing. This level of utilization is almost a third greater than the total annual production of the entire industry.

In the development of the catfish industry, the demand-pull for the product has been so strong that problems with the quality or quantity of any of the inputs have been "flattened" under the onrushing expansion. A strong demand by consumers willing to pay good prices relative to production costs will overcome all but the most intractable input limitations. Fortunately, given the demand-supply situation for aquatic animals worldwide, the demand-pull for virtually all cultured products will be strong. In most cases, it will be strong enough to simplify the solutions to problems related to input shortages and imbalances.

The strong demand-pull for catfish relative to supply probably tends to mask a rather serious imbalance in the ecosystem. As the industry matures, almost certainly there will be a need to better coordinate production and marketing functions. The present system -- where production is largely independent of processing and marketing -- is highly disorganized, and there is a substantial loss of energy. I suspect that ultimately most of the catfish will be produced using the vertically integrated model of the poultry industry (Barnett, 1987; King, 1988).

The successful development of the channel catfish industry in the three primary states does not mean that this same technology would prosper as well in other environments. The availability of relatively cheap feed grains to be used as nutrients has been an important factor in the development of the industry. Catfish farming would not be profitable without high-protein feeds. These feeds are available in relatively few other countries of the world. The point here is that the environment in Alabama, Arkansas, and especially Mississippi was ideal for the introduction of aquaculture. This does not mean that catfish farming will continue to grow at the current rate. In fact, over time, the environment might change so that catfish production in those states will not be competitive with production in Florida or Mexico. As the environment changes, however, there is hope that new technology will be developed that will permit those fish farmers to remain competitive.

In one sense, the development of the catfish industry is not a good model. While the economies in Alabama, Arkansas, and Mississippi are at a more advanced state as a result of the development of the industry, it is not a good model because it was not a planned effort. This model does not show us how we might purposefully design a development project and then implement it. While it is a good example of the dynamic tension between disequilibrium and compensation in the ecosystem, it does not provide a good example of how this process might be purposefully set in motion in a developing country, for example.

# CHAPTER 7
# DEVELOPMENT OF HUMANKIND

**The development process in Homo sapiens** seems to be similar to the development of lower animals, except that we are able now to exert considerable control over the process. Development in our species depends on the same basic steps that were described previously for the lower animals, although there are some obvious changes and refinements:

*1. Development of new technology -- such as ideas, understanding, processed products, and machines -- or more effective and equitable use of existing technology results in improved quality of life.*

*2. Simultaneous, if not prerequisite, development of a social framework or structure is necessary for the application and management of technology.*

*3. Technology is diffused through the basic processes of communication and learning by observation.*

*4. Technology is institutionalized so that it is widely used and so that other components of the ecosystems have adjusted and adapted to it.*

*5. Development of procedures such as taxation allow society to capture some of the benefits from the utilization of the technology in order to obtain resources for statecraft and the creation and support of public institutions (Adam Smith's "Invisible Hand").*

From all available evidence, the process of development was extremely slow during those millennia following the appearance of our species on earth some 100,000 years ago (Putman, 1988). Then, some 35,000 years ago a "cultural explosion" took place. During that period, real tool technology appeared. People began designing and making things to solve problems. And they were learning to store primitive technological information through cave art and carvings.

While the slow but steady process of technological development certainly played a major role in the evolution of our species (Stavrianos, 1971), the development of language and social structure played an equal if not greater role (Lewin, 1988B). Inventing a more efficient tool certainly is an important element in development, but it is no more important than having a language so that its manufacture and function can be diffused to potential users. Also, the new technology would be of limited benefit without a social framework that promotes and institutionalizes innovations and that provides for the capture of benefits for society as a whole.

To look at the time involved, it is obvious that the rate of development was painfully slow. But the important thing was that the rate at which the process was taking place was increasing. The rate increased through the "old stone age," the "new stone age," and the "iron age." While it started ever so slowly, the faster development took place, the greater it accelerated. It increased at an exponential rate. But nothing in those by-gone days prepared us for the explosion of technological and social development that has taken place in the 20th century. While this explosion has provided us with almost unlimited opportunities for development, it has left us with some of our most intractable problems.

In the discussion of the development process in the lower animals, it was suggested that new technology introduced into an ecosystem creates disequilibrium and that the genetic selection process intensifies to counter its effect. An important part of human development lies in the institutionalization of new technology so that it can be widely used and so that other components of the ecosystem can adapt to it. Unfortunately, when new technology can be developed so rapidly, it is virtually impossible for all components of the ecosystem to adjust to it within a reasonable period of time.

In many countries, new agricultural technology has made it possible for farmers to become more effective in producing food. Fewer people are required in agriculture. Unfortunately, those countries have not developed the compensating technology for providing alternative opportunities for displaced farm workers. In the United States, new technology has resulted in a significant increase in human life expectancy. Unfortunately, we have not developed the necessary technology to effectively accommodate so many elderly people. Through technology we are rapidly becoming a "throw-away" society, only to discover that we have no place to throw anything.

It seems that for every significant technological advance, there are at least several problems created in the web of the ecosystem. New technology developed in one area of the web often initiates reverberations that are extremely difficult to dampen or control. Roger Bacon's comment, "In nature, things move violently to their place and calmly in their place," succinctly describes this situation. This situation will only become more difficult until some limiting rate of the development of new technology is reached, if there is such a limiting rate. As noted previously, new technology provides wonderful opportunities for development or to "bring to a more advanced or effective state." Our challenge is to develop enough understanding of the process so that we can anticipate the disequilibria that likely will result from the new technology. That will not be a simple task.

The problem of disequilibria in ecosystems resulting from the introduction of new technology also is important in another area of development. As suggested previously, the development process through which people strive to improve the quality of their lives has been in use for tens of thousands of years, according to all the evidence. Unfortunately, for many reasons, the process has not produced uniform results (Shepherd, 1985; Bailey, 1988; Durning, 1989B). The quality of life varies widely among people from country to country and within a country. This disparity has been observed and recorded for at least two thousand years. The plight of poor people has been a central theme in the religious teachings of the Buddhist and Christian religions from their beginnings. However, little was done until the 20th century to deal systematically with the problem of disparity.

Early concerns with disparity were largely ethical ones, but the concerns have become more socially, politically, and economically focused. With the birth of the philosophy of earth as "lifeboat," the concerns have become more practically oriented. Early efforts to deal with disparity of the quality of life were carried out by individuals or small groups of people. Now disparity is the concern of broad public consensus in many countries. Early efforts to help dealt with symptoms -- hunger, disease, exposure, etc. Modern efforts, while still concerned with symptoms, also attempt to deal with causes.

Because so much emphasis has been placed on development that benefits the world's poor, we tend to lose sight of the fact that development relates to all people regardless of economic or social class. Every person in the world is involved in development to some extent. Our ability to assist in the development processes that benefit the Third World depends on the continuing development of the remainder of the world. The wealth that might be shared with the less fortunate in one country or region must be generated from expanding or increasing those economies in the other countries or regions. Unless there is continued development in the so-called developed countries, resources needed to assist the less fortunate can be made available only by reducing the standard of living for everyone.

Another problem relating to our understanding of the meaning of development is a result of dividing the world into two groups -- developed and "less" developed countries, or "North" and "South" countries. This division doesn't really exist. There are no developed countries. While there may be considerable differences in the availability of food, shelter, and clothing and in the quality of life among countries, none have developed to the point that poverty, hunger, traffic congestion, pollution, crime, child abuse, and discrimination have been eliminated. Food, shelter, and clothing alone do not adequately define the limits of the quality of life. All countries are on a development continuum, and there is some considerable separation, but none can be considered to be developed.

The lack of a suitable scale of measurement is also a major problem in promoting development. Traditionally, economic planners and development experts have utilized changes in per capita Gross National Product (GNP) -- "the dollar value measured at market price of all final goods and services produced in an economy in a year" (Ekelund and Tollison, 1988) -- to determine the successes or failures of their efforts. However, it is now being recognized that the general well-being of the people in a country is better correlated with the way GNP is utilized than with the absolute value. Consequently, the United Nations is studying a new scale for measuring development (Hammond, 1990). The Human Development Index (HDI) combines life expectancy, literacy, and purchasing power into a single measure. Although HDI includes three important aspects of development, it does not include equally important aspects such as political freedom, human rights, free elections, or the level of investment in education and health. Even though there are obvious deficiencies in HDI as it is proposed, it is much more meaningful than GNP because it puts a "human face" on the measuring scale.

In the last 40 years, billions of dollars have been spent in attempts to improve the quality of life for less fortunate people around the world. These efforts have resulted in both successes and failures (Paddock and Paddock, 1973; Herman, 1991). Hancock (1989) provided numerous examples in which efforts to help were actually detrimental to development. Singh (1989) commented that the economies of most countries in Africa and Latin America have regressed sharply, although there have been significant efforts to promote development there. Sincere (1990) quotes the Third World political philosopher Ivan Illich regarding the situation: "Under the cover of development, a world war on people's peace has been waged." Illich looks on development as a means "to disrupt traditional societies, to disfigure people's cultures, and to destroy long-lasting ways of life." He has characterized economic development as "violent."

Sincere (1990) suggests that most development programs are simply government-to-government transfers of money, and as such they are recipes for economic decline. Lord Bauer, the British economist, said assuming that "aid helps people help themselves is very nearly the complete opposite of the truth." He further suggests that "foreign aid also tends to encourage the adoption of inappropriate external models in development and planning." Molnar and Jolly (1988) concluded that relatively few appropriate agricultural innovations have reached farmers in the Third World, and even fewer have penetrated or energized subsistence farming systems. Singh (1989) commented that the crisis of development challenges the entire community involved in the process to devise new strategies that will work.

Schuftan (1991) listed some of the reasons why our efforts to promote development have produced mixed results:

> *But I think we can stand accused for the staleness of our approach; for our complacency toward the status quo; for our lack of criticism of the overall lack of progress; for our political naivete - more likely—for our choice not to get involved in the politics of it all; for uncritically pushing forward to do something and get things done and over with; for not solving problems boldly using workable approaches agreed upon with those who must live with our decisions; for our paternalistic and ethnocentric approach.*

Given the record of successes and failures, it is important to ask a basic philosophical question regarding development, especially the promotion of development: Who has the right or responsibility to decide that someone else should be more advanced, or be happier and healthier, or have more options in life? Who has the right or responsibility to put the lives and cultures of other people at risk? Sincere (1990) comments that the attitude of Western development agencies toward the people of the Third World can best be described as patronizing. An equivalent term is "condescending." To help someone through development efforts, we must first make a judgement that someone has fewer choices, is less healthy or wealthy, or is not as happy as we are.

Although efforts to promote development have resulted in a mixed bag of successes or failures, we cannot afford to reduce our efforts to help. The growing interdependence of the world's peoples and their societies makes it essential that we do so. Helping just makes good sense. David Landes notes that "development is not to be taken for granted. It is hard business" (Sincere, 1990). There have been too many failures in our efforts to promote development, but we must look beyond those to find methods that are effective. As suggested previously, the entire development community must now become involved in the process to devise new strategies that will work (Singh, 1989). We must be willing to stop development practices that we are currently using and move decisively with the beneficiaries into new directions that have greater potential for solving the chronic and self-perpetuating problems of maldevelopment (Schuftan, 1991).

# PART 4
# PLANNING A DEVELOPMENT STRATEGY

AQUACULTURAL DEVELOPMENT HAS BEEN DEFINED as bringing out the capabilities and possibilities of culturing aquatic animals or bringing their culture into a more advanced or effective state as a means of improving either directly or indirectly the quality of people's lives. Aquaculture has many possibilities and considerable capabilities that can be brought out in the process of development (Pillay, 1973; Comte et al., 1984A; Brown, 1985; Molnar and Duncan, 1989). It has a considerable potential for growth, and in growing, to contribute significantly to improving the quality of life for many people.

When considering implications of the development of the human species through its long evolutionary history, it is obvious that considerable development already has taken place and is continuing to take place. The process drives itself; it is self-actuating. It will continue at some rate regardless of whether there is an effort to promote it. The physical, chemical, biological, social, economic, and political forces that brought us to this time in history are still operating. One problem with this approach is that it often takes a long time for needed changes to take place. Also, the results of this self-actuating process often are uneven. Not enough of the people who should benefit most from development do so (Werlin, 1987). Because of the rapid changes taking place in human populations as a result of the development and diffusion of new technology, allowing the process of culturing aquatic animals to grow slowly and unevenly (at its own pace) is not acceptable. The process must be telescoped in time and space. It must be quickened.

In the natural process, development proceeds by "starts and stops." As it proceeds, scarcities or bottlenecks develop that slow or stop the whole process for a time. Remember the analogy of the predatory fish in a small natural pond which became a more efficient hunter as a result of a genetic mutation. The process slows or stops until the bottleneck can be removed or opened. Then the process continues until the next bottleneck develops. Hayami and Ruttan (1985) provide an excellent discussion of the operation of this process in agriculture.

The strategy for speeding up and managing this process (bringing out the capabilities and possibilities) involves understanding how it operates, what factors are involved, anticipating where the bottlenecks are likely to occur, and preventing them from developing to the point where they can slow or stop it. The strategy involves emphasizing those activities that maximize the biotic potential of aquaculture and that reduce or minimize the environmental resistance. Obviously, accomplishing these tasks is difficult, but this is how, in general terms, development must be promoted. The principle is relatively simple even if its application is not.

I suggest that a practical strategy for the application of the general principle defined above involves five different steps, which will be discussed in the following chapters:

1. *Determining the goal(s) of the development.*
2. *Planning development from an ecosystems perspective.*
3. *Planning aquacultural development for people.*
4. *Selecting the activities for implementation that will provide the level(s) of intervention required to meet the desired goal(s) and determine whether the necessary inputs are available or can be made available to sustain those levels of intervention.*
5. *Implementing the development process by encouraging the appropriate participation of the public sector (government), diffusing the required technology among the target individuals or groups, developing any new technology necessary to sustain the process, and establishing an effective communication network that includes all elements of the developing aquacultural ecosystem.*

# CHAPTER 8
# DETERMINE GOALS OF DEVELOPMENT

IT IS IMPORTANT IN PLANNING AN EFFECTIVE STRATEGY to determine the specific purpose(s) or goals for developing aquaculture in a given situation. The strategy to be followed in developing aquaculture to provide animal protein in provincial villages would be considerably different than the strategy for developing aquaculture to provide an export product for the "white tablecloth" market in a developed country.

An obvious and necessary step in the introduction of aquaculture in a new environment is to determine as precisely as possible exactly what is expected of it in that environment. Determining the specific need that aquaculture is expected to meet would, in ecological terms, be similar to determining the ecological niche of an animal before it is to be introduced into a new environment (Odum, 1983). Without a relatively precise determination of the purpose, goals, and outputs expected, it will be difficult to develop the necessary strategy to make the introduction successful.

It is essential that farmers, investors, government officials, or others who will be responsible for supplying the scarce resources for the introduction be encouraged to determine as precisely as possible what they expect. Many failures in aquaculture result from poorly defined expectations (Werlin, 1987). These expectations should be defined in precise terms. Producers should determine the amount, size, and species, that can be harvested from production systems and how frequently harvests can be made. The expected return in kilograms should be related to the investment required of land, water, labor, and capital. Even for the lowest stages of aquaculture, the expectations should be defined in terms of return on investment. In fact, defining expectations in terms of return on investment may be more important at the lowest stages of aquaculture, where the availability of resources may be limited, than at the higher stages. When investors are interested in the fish because of their exchange value rather than their food value, then expectations should be defined in those terms and related to return on investment. Similarly, where the expectation is the reduction of imports, it should be defined in those terms and related to investment required.

## *Characteristics of Fish Important in Development*

Fish have a number of characteristics that can be exploited through culture to meet several different development purposes or goals. The more important of these characteristics are:

*1. Fish size appears to be indeterminate. Fish apparently can continue to grow until death if adequate food is available (Moyle and Cech, 1988). In mammals, the limit to size seems to be fixed genetically.*

*2. Fish and most other aquatic food animals are cold-blooded, so there is no expenditure of energy to maintain a constant, relatively high body temperature, as is the case with virtually all other domesticated animals (Hickling, 1968).*

*3. Fish are essentially weightless in water. As a result, energy is not required to counter the effects of gravity. In contrast, land animals utilize large amounts of energy just remaining upright (Hickling, 1968).*

*4. Because of weightlessness and the peculiar method of locomotion (swimming) developed in fish, the skeletal system of fish is not as massive as in most domesticated food animals.*

*5. As a result of the nature of their metabolic system, fish produce more animal protein per unit of food energy consumed than do other domestic food animals (Lovell, 1979).*

## *Capabilities and Possibilities of Aquaculture*

Exploitation of these positive characteristics can provide a number of benefits to society. Some of the capabilities and possibilities which contribute to the biotic potential of aquaculture are listed in the following section:

*1. Farming in water complements farming on land, thus improving the efficiency of resource utilization (Shell, 1986).*

*2. Aquaculture encourages good stewardship of water (Hickling, 1968).*

*3. Aquaculture encourages better utilization of land resources by providing a use for marginal agricultural lands.*

*4. Cultivation of aquatic animals can be utilized to produce large quantities of high-quality animal protein in a wide range of environments.*

*5. Given the large number of kinds of fish, it is possible to develop highly efficient "polycultures" of species with complementary feeding habits (Hickling, 1968; McLarney, 1984).*

*6. Because of the world fish demand and supply situation, aquaculture can be a profitable farm enterprise and can substantially brighten an otherwise dim agricultural profitability situation.*

Pillay (1977) lists capabilities and possibilities of aquaculture from a broader perspective. These include:

*1. Farmed fish can help replace the loss or shortage of important species usually taken from natural waters.*

*2. Aquaculture can help meet the demand for high-valued species.*

*3. Cultivation of aquatic animals can contribute to trade or import substitution efforts.*

*4. Fish farming can be a tool in generating rural employment and prosperity, thus preventing the drift of rural populations to the cities (also see Dicks and Harvey, 1988).*

*5. There is a well-established world trade in seafood that can be utilized to market and distribute the products of aquaculture.*

Once it is decided exactly what need aquaculture is expected to meet in the specific environment in question, the next step is to decide whether aquaculture can be expected to meet that need. This is a critical step. Once it is taken, if the decision is positive, resources must be committed to the process. Beyond this point, the costs of aquacultural development increase rapidly.

It is important to remember that aquaculture is not a panacea for all of the social and economic problems on a farm, in a region, or in a country (Smith and Peterson, 1982B). Also, it is not a "goose" that always lays a "golden egg." Regardless of the excitement about aquaculture and the often extraordinary claims that are made for it, it is clear that farming the water is dependent on and responsive to the same market economy forces that limit agriculture or any of man's other activities (Kent, 1986). The investment of resources in aquaculture and the return to investment must be evaluated in the same terms as any other investment.

## *Resistance to the Development of Aquaculture*

While there obviously is considerable potential (biotic potential) for the development of aquaculture to play a role in improving the lives of people, there is considerable environmental resistance to the realization of this potential. As Ben-Yami (1986) has so aptly pointed out, "results of efforts to develop aquaculture in many 'Third-World' countries have brought meager results regardless of efforts and financial resources committed." While the term "resistance" is useful in conceptualizing the problems that must be dealt with in the development of aquaculture, these environmental factors do not in reality oppose development. More simply stated, there are some factors that must be dealt with or considered in bringing out the capabilities and possibilities of culturing fish. Some of these are described in the following section:

*1. The environment-animal interaction is much more complex in water than on land. Therefore, farmers must develop new understanding and new skills.*

*2. It often is difficult to see or to correctly inventory the stock.*

*3. Virtually all animals used in aquaculture are cold-blooded, so most of their physiological functions (growth, reproduction, etc.) are strongly temperature dependent.*

*4. Generally, aquaculture requires that the animals be contained. Because of the hydraulic and erosive properties of water, containers must be relatively strong and consequently expensive.*

*5. The culture of fish requires more water per unit of food produced than any other food-growing system.*

*6. Because of the dynamics of oxygen absorption, production, and utilization in water used for aquaculture, catastrophic losses of fish to anoxia can occur quickly and with little warning.*

*7. In most types of aquaculture, the same water that serves as the medium for production also serves as the medium for waste disposal.*

Obviously, in addition to these biological and physical characteristics, there are several social, cultural, and economic characteristics that also can resist, slow, or even prevent development of aquaculture in certain situations (Smith and Peterson, 1982A). These include:

*1. The tradition of fish farming is not widely distributed in the world. Changing traditions can be slow and tedious (Pollnac, 1982).*

*2. Aquaculture is not an effective means of alleviating hunger if the problem stems from a deficiency of calories rather than of protein (Grivetti, 1982).*

*3. Aquaculture is not usually an effective development tool if significantly increased employment opportunity is a major goal (Food and Agriculture Organization of the United Nations, 1986).*

*4. Competition for water and space in environmentally sensitive areas can be a major impediment (Wijkstrom and Jul-Larsen, 1986).*

*5. Excessive government regulations and stringent permitting requirements can severely restrict development (Fitzgerald, 1987).*

*6. The general economic climate in a country or region can have a significant effect on realizing the capabilities and possibilities of fish farming (Pillay, 1977).*

*7. The interaction and interdependence of biological, physical, social, cultural, and economic factors that influence development are not well understood by those planning or implementing aquaculture (Pollnac et al., 1982).*

*8. The principles and procedures required for diffusion and acceptance of the innovations and technology of aquaculture are generally poorly understood by those planning for the development of aquaculture (Pollnac, 1982).*

Aquaculture does have the potential for meeting many of the varied needs of farm families, investors, and governments (Food and Agriculture Organization of the United Nations, 1986). At this point in the development process, the question is whether aquaculture can be expected to meet a specific need in a specific environment. This is not a simple answer to determine. Investment in aquaculture is like any other investment. There always is some probability that even a sure bet will fail. There simply is no way to guarantee that aquaculture will meet a specific need in a specific environment. The decision-making process is further complicated by the fact that the more conservative the decision-making process becomes, the less likely the development process will result in unusual successes. In the investment field, the guaranteed return will always be much lower than with high-yield investments, but the risk of loss is the inverse. The higher the expected yield, the higher the chance of loss. Decisions such as this have very practical consequences. Farmers, investors, or countries with limited resources generally must make conservative or guaranteed return decisions. In those cases, a decision that results in the loss of the investment can be catastrophic. Unfortunately, in many cases, it is these groups with limited resources that might benefit most from the adoption of a high-yield strategy.

The only guarantee, if there is such a thing, against making a poor investment in aquacultural development is experience with the development of aquaculture meeting similar needs in similar environments (Werlin, 1987). This is a relatively simple matter if development involves introducing aquaculture on a farm when there has been a successful introduction on an adjacent farm. The prediction of the likelihood of success becomes much more difficult if there are no adjacent farms where it has been successful, or where it is to be introduced into a region of a country where it has not been practiced before.

# CHAPTER 9
# PLANNING FROM AN ECOSYSTEM PERSPECTIVE

THE TERM "ECOLOGY" IS DERIVED from the Greek word "oikos" which means household and the word "logos" which means study. The term implies that ecology is the study of the household. Webster's Seventh New Collegiate Dictionary defines ecology as "the totality or pattern of relations between organisms and their environment," and defines an ecosystem as "a complex of ecological community and environment forming a functional whole in nature."

Aquaculture is an ecological process, because it involves the manipulation of living organisms and their environment. It also is an ecosystem process, because it involves the totality of the interaction of people and their environment and aquatic animals (all living organisms) and their environment. Because of the nature of this relationship, the development of aquaculture must be approached from this perspective if it is to be successful. Aquaculture is a web (Figure 1) of interconnected and interdependent physical, chemical, biological, psychological, sociological, economic, and political processes. The production, harvesting, processing, marketing, and utilization of aquatic animals is an ecosystem. It is a unitary whole. Intervention at any point on the web ultimately reverberates throughout the whole. Problems or bottlenecks that develop at any point on the web affect the function of the entire system. The promotion of aquacultural development requires that we understand the nature of the ecosystem (web) with all of its components and linkages and the flow of resources through it.

It is important to think of aquaculture from an ecosystems perspective in planning and implementing a development strategy. It is equally important to understand that the nature, size, and complexity of the ecosystem changes with the stage practiced. Obviously, the aquacultural ecosystem of the farm family culturing just enough tilapia to meet its immediate needs would be considerably smaller and less complex than the aquacultural ecosystem that produces large quantities of aquatic animals for export to another country. In general, the size and complexity of the ecosystem is positively correlated with the stage of aquaculture practiced (Figure 3).

As noted above, the aquacultural ecosystem (web) has physical, chemical, biological, psychological, sociological, economic, and political dimensions. Before proceeding further with the discussion of the development of aquaculture, it would be useful to discuss some of these dimensions. In the following sections some aspects of the biological, psychological, sociological, and economic dimensions will be considered, and some general comments on how each of them impinge on the development process will be presented.

## *Biological Dimensions of Aquacultural Ecosystems*

While the size and complexity of aquacultural ecosystems vary considerably, the general principles governing their function apply over the entire range. There are a number of principles that seem to govern the progression of processes in simpler ecosystems, such as natural ponds, swamps, temperate grasslands, or deserts. Four of these also seem to be especially relevant to understanding aquaculture as an ecosystem and in promoting its development:

1. *Environmental stability and ecosystem complexity.*
2. *Energy conservation in organized ecosystems.*
3. *Liebig's Law of the Minimum.*
4. *Shelford's Law of Tolerance.*

### *Environmental Stability and Ecosystem Complexity*

The stability of an environment can have a significant effect on the complexity of an associated ecosystem. When a physical environment is relatively stable or benign with a low probability of a major or catastrophic disturbance, then a high level of structure or complexity can be achieved and maintained as a steady state or climax for long periods. In contrast, a lower level of organization or complexity is likely in a stressful environment subject to periodic disturbances (Odum, 1983).

Experts are becoming aware that the stability of the environment in a country can have a profound effect on development. In a report prepared by the World Bank (1991), it was noted that a stable macroeconomic foundation is one of the most important public goods that governments can provide. This same principle also probably applies to the development of aquaculture in a general way. For example, in a country with a high degree of economic or political instability, it would be difficult to develop and sustain a high stage of aquaculture. Under these conditions, the level of infrastructure and services necessary to support a high stage of aquaculture would not be available on a dependable schedule. Investors would be reluctant to provide the funds required where there would be a high probability of catastrophic loss as a result of some economic or political disturbance. John Jensen (personal communication) has noted that in countries with high and unpredictable rates of inflation, investors are reluctant to fund complex aquacultural development projects because of the uncertainty of the value of currency over the period of time required to develop a fish farm and to produce a crop.

Where there is a high level of environmental instability, it still is possible to develop aquaculture, but it must be developed at a lower level of complexity. For example, the stage of aquaculture being developed in Rwanda, described in Chapter 6, would be functional even in environments with relatively high levels of instability, while the catfish production system in Mississippi would not.

***Energy Conservation in Organized Systems***

I have noted on several occasions the central role played by the Second Law of Thermodynamics in the organization and function of an ecosystem. In this section, I want to examine the general implications of one aspect of this phenomenon in the development process. Smith (1977) has noted that the better organized (balanced) the system, the longer the energy is retained. Even though the loss of some energy is inevitable, more of it is retained longer if the system through which it is passing is better organized or balanced.

The principle of "energy conservation in organized systems" probably explains to a degree why vertically integrated farming systems tend to be more efficient in the utilization of resources. The same management is involved in essentially all aspects of the entire ecosystem (production, harvesting, processing, and marketing). Communications and coordination within the web that tie all of these activities together are much more effective. There is much less energy loss at each nexus or at each transformation point. The vertical integration of the poultry industry (Barnett, 1987; King, 1988; Paarlberg, 1989) is a good example of the advantages of organized systems. This principle does not apply just to situations involving large corporations. Individual fish farmers also can benefit from improved organization or from vertical integration if they produce, harvest, process, and market their animals. In this situation, energy losses are minimized, and the individual farmer generally will realize a maximum return on investment (Baldwin, 1989; Burnett, 1989).

Energy conservation in organized systems explains why aquatic animal production in ponds stocked with several species that have complementary feeding habits (polyculture) is greater than in ponds stocked with a single species (monoculture) (Dunseth, 1977; McLarney, 1984; and Burnett, 1989). The polyculture systems are better organized. There are more connections and feedback loops in the production web.

Unfortunately, while better organized systems conserve energy more effectively in its transformation, these systems tend to be more complex. There is a net benefit from increasing size and complexity to a point. This relationship gives rise to the so-called economy of scale phenomenon. However, this process cannot be continued indefinitely. Even with the best possible organization, there is enough loss of energy at the various transformation points that the economy of scale will inevitably become a diseconomy of scale and the system will have reached the point of diminishing returns.

Polyculture is a good example of the problem of diseconomies of scale that can result from too much organization. The culture of more than one species provides a better organized production system. Yet the system is much more complex. Seed availability may be different for the different species. Growth rates often are different. Market requirements with respect to size and timing may be different. In many cases, the species must be harvested at different times. Because of the increased complexity, input requirements -- especially labor -- often are greater. Also, increased coordination in harvesting, processing, and marketing is required. In different environments, these increased requirements can have a telling effect on the effectiveness of the function of the entire system. As an example of this relationship, polyculture in China probably would be more effective than in the United States, all things considered, primarily because of the availability of cheap labor in that country. There are some situations, however, where polyculture does work effectively in the United States. There are a few fish farms in Alabama that are successfully growing several species of fish in the same ponds. There are a few special cases in which the farms are vertically integrated. Seed production, market fish production, harvesting, processing (where required), and some marketing are done at the farm. These farms serve restricted markets. And the owner is manager, laborer, processor, and salesman (Baldwin, 1989; Burnett, 1989). In these cases, increased labor costs associated with polyculture are more than offset by the advantages of the highly organized production and marketing system.

An interesting extension of this relationship between energy loss and organization is the relationship between metabolic rate and size. According to Odum (1983), the rate of metabolism (energy consumption) is inversely related to size in many living things. According to this relationship, while an elephant would require more total energy than a mouse, on a per unit of weight basis the mouse would require more. The energy-use efficiency would be lower in the small mouse. The practical effect of this relationship is that small mammals must search for food almost constantly to obtain enough energy to meet their needs.

Martinez (1986A) commented on the decline in the number of farms in the United States since 1935. According to his data, by 1985 the number of farms had dropped to a third of the 1935 level. With this reduction in number, there has been a commensurate increase in average size (Paarlberg, 1989). Harvey (1989) suggested that catfish farms seem to be following the same pattern. Farms seem to be decreasing in number but increasing in size. Probably as a result of increasing in size, they also become more efficient in the use of energy.

Not only are farms increasing in size, but also the larger ones seem to increase their efficiency of operation. Martinez (1986A) noted that 5 percent of the farms in the United States (the largest farms) accounted for 49 percent of the total crop and livestock production. The smallest farms (48 percent of the total number) produced only 3 percent of crops and livestock. The larger farms are much more efficient in the use of resources (energy) relative to their size than the smaller farms. Extrapolating the biological relationship, I suggest that if small farms are to compete with large farms, the operators are going to have to work extremely hard to do so. Also, operators of those small farms will be forced to organize so that they can work closely with each other. They might approach the efficiency of the larger farms if they are organized to reduce the loss of energy (resources) from the system.

Highly organized systems are more efficient in managing the loss of energy. As a result, society often benefits from less costly products. However, it is important to remember that there are opportunity costs associated with increasing the degree of organization. We cannot increase the level of organization without giving up something. For example, Bailey (1988) describes how the rapidly growing shrimp-farming industry in the tropics has displaced traditional small-scale fishermen and aquaculturists from the coastal mangrove areas. Intervention in the production of aquatic animals in the coastal zone has resulted in a better organized system, but at the same time has resulted in some negative cultural changes for many of the individuals involved.

***Liebig's "Law of the Minimum"***

In 1840, the German chemist Justus Liebig wrote that the growth of a plant is dependent on the amount of feedstuff which is presented to it in minimum quantity (Smith, 1977; Odum, 1983). This statement is the basis for Liebig's Law of the Minimum. It simply implies that where there are several factors involved in the functioning of a natural system, such as the growth of a plant, the level of function will be determined by the factor present in the lowest or limiting quantity. A simplified example of Liebig's law from inorganic chemistry is the formation of one molecule of water from two molecules of hydrogen and one molecule of oxygen. If there are a hundred molecules of hydrogen available and only one molecule of oxygen, only a single molecule of water will be formed. The remaining 98 molecules of hydrogen would be of little value.

The five primary factors or steps in aquaculture (production, harvesting, processing, marketing, and utilization) must all be in place if the ecosystem is to function at all. However, the system functions most efficiently when the factors exist in a narrowly defined relationship with each other. If there is little production, the ecosystem will function inefficiently. At the same time, if production is excessive in relationship to marketing and consumption, the system will function poorly, if at all.

The importance of the Law of the Minimum is explained by the fact that the level of production that can be obtained in a specific culture situation, or the stage of aquaculture that can be attained, is dependent on the available level of any input (incentive, credit, water, equipment, etc.) relative to the required level. For example, it would be extremely difficult to install an advanced aquacultural system in dammed, tidal stream ponds. Even if all of the other inputs were available commensurate with a higher stage of culture, the level of container available could limit the stage of culture that could be attained.

For each stage of aquaculture there is a rather specific combination of the levels of the different inputs required for optimum efficiency. There would be a rather specific combination of levels of information, container, credit, equipment, and labor for each stage. The levels of intervention for the environmental requirements must be essentially equal. A complex container system, for example, should be matched with a high level of credit, labor, and processing. Any major deviation or imbalance in this combination would increase the stress (disequilibrium) in the system and the likelihood of failure.

There have been several failures of introductions of channel catfish farming systems in areas of Alabama and Georgia in the Southeastern United States because of a lack of attention to the balance of inputs or environmental requirements (Liebig's law). In virtually all of these cases, a processing plant which would be needed at a higher stage of aquaculture was installed in a system where the ponds, credit, information, and water were available at a much lower level. The processing plants and aquaculture failed because the remainder of the system could not provide the number and size of fish on the schedule required by the plant. When the plant failed, the remainder of the system also collapsed.

The South American shrimp culture industry also suffers to some extent from an imbalance in environmental requirements. Many of the inputs, water, processing, and marketing are available at levels required at intermediate stages of aquaculture. However, the seed procurement system of capture from the wild is characteristic of lower stages of aquaculture.

Application of Liebig's Law of the Minimum is important in the development of aquaculture. There is a general tendency to want to install the most advanced stage of aquaculture possible in a given situation. Without a clear understanding and application of this ecological principal, systems will be put in place that cannot be sustained because a specific input is not available at the required level. This principle applies equally to those situations where aquaculture is being developed in an area where it has not been practiced before or where an effort is being made to develop a more advanced stage of aquaculture. In either situation, it is important to have a thorough understanding of the levels of the various inputs that will be available to sustain a specific stage.

***Shelford's "Law of Tolerance"***

Liebig's law applies to those situations where a necessary factor is present in limiting quantity, thus limiting the function of an ecosystem, but there also are many situations where a factor can be present in excess. The fact that too little or too much of an environmental factor could be limiting was incorporated into the Law of Tolerance by V. S. Shelford in 1913 (Odum, 1983). For example, the amount of heat energy in the water of a rainbow trout production unit can determine the level of function of the system. The rainbow trout is a temperate zone species, with an optimum temperature for growth of 17.8°C. However, when the water temperature falls below 10°C, growth slows significantly and becomes a limiting factor in production. At the same time, rainbow trout do not grow well when the water temperature reaches a level of 20°-24.4°C, and when the temperature increases to approximately 23.3°-25°C, the fish die (McLarney, 1984). Conversely, species of the tropical genera *Oreochromis* and *Tilapia* do not function well in environments with cooler water temperatures. Virtually all of these species die when the water temperature goes as low as 10°-12°C. They do not feed well at temperatures below 2O°-22°C, and they grow at the fastest rate only when the water temperature is greater than 26°-28°C. These two examples show that different species of animals are likely to be most successful in relatively specific environments or ecosystems. At the margins of this optimum environment or ecosystem, the animal utilizes available resources inefficiently. Reproductive success decreases, growth rate decreases, and the incidence of disease increases. Applied to aquacultural development, Shelford's Law of Tolerance suggests that a given stage of aquaculture in which all of the inputs are balanced is most efficient in a relatively specific environment or ecosystem. If that environment changes or if that specific stage of aquaculture is moved to a different environment, the efficiency of resource utilization may decrease, and efforts to develop it may fail.

A subsidiary to Shelford's Law of Tolerance is that organisms may have a greater degree of tolerance for one factor than for another (Odum, 1983). For example, dissolved oxygen and carbon dioxide are both important in the habitat of a channel catfish, but the well-being of the fish is somewhat more determined by the quantity of dissolved oxygen present than of the quantity of carbon dioxide. The fish are more tolerant to major change in the level of carbon dioxide (Boyd, 1990). However, carbon dioxide does antagonize the use of oxygen. At high levels of carbon dioxide, channel catfish will become stressed even at moderately low levels of oxygen.

As an example of the Law of Tolerance and its subsidiary principle, labor and equipment are essential if aquaculture is to proceed, but there is more flexibility with respect to the levels available for those inputs than with some of the others, such as processing and marketing. Marketing probably plays a greater role in determining success (return on investment) than any of the other inputs. There are some opportunities for accommodating some imbalances in the other requirements. There is less opportunity to do so with marketing. Marketing is the environmental requirement or input that determines the level of return that must be applied against investment. Unless the change of ownership of the product is effected quickly, efficiently, and at a reasonable level of return, the production functions (containers, credit, nutrients, etc.) cannot be maintained. The level of the marketing system available or that can be developed is a major determining factor in the selection of a system of aquaculture. Other inputs vary in relative importance. The availability of seed also is one of the more important inputs. The range of tolerance is much more narrow for seed availability than for some of the other inputs.

Factor interaction also plays a role in the strict application of Liebig's Law of the Minimum and Shelford's Law of Tolerance. An excess of one factor can affect the need for other requirements. For example, some plants require less zinc when growing in the shade than in full sunlight. The relatively unlimited availability of sunlight increases the need for zinc (Odum, 1983). Obviously, there is factor interaction in the environmental requirements for the success of an introduced aquaculture system. The availability of equipment affects the requirement for labor. Labor can be substituted for equipment to a degree. There also is a strong interaction between the requirements for containers and water.

Utilization affects the requirements for all the inputs. When fish are utilized as food by the family producing them, the levels of the other inputs required are relatively well fixed. If one of the inputs is applied at a greater level than is required, it is essentially wasted and the return on investment is affected. However, generally speaking, when fish are utilized by watching them swim in an aquarium, there is much more flexibility with respect to the levels of the other inputs required. In this case, the return on investment can be so high that inefficiencies resulting from the imbalance of levels of inputs is of little consequence. In a similar situation, a farmer growing channel catfish has much more flexibility with respect to the balance of inputs if he allows sport fishermen to harvest the fish from his pond than if they are harvested by seine and sold to a processor. Fishermen are willing to pay a much higher price for the live fish than the processor will pay.

## *Psychological Dimensions*

Because there is so much emphasis on groups of people, nationalities, races, and their activities and problems, it is easy to forget that the affairs of the world are really the aggregated affairs of billions of individual people making choices and taking actions based on those choices. The development of aquaculture can take place only when individuals choose to commit and to sustain the commitment of scarce personal resources to the process over a period of time. Development basically is an individual people business. Development is about the mental processes that individuals use to make decisions regarding commitment of scarce resources and their behavior once those decisions are made. The study of these characteristics of individual people is the essence of psychology (Myers, 1989).

In a preceding section, I discussed some of the biological dimensions of the ecosystem where the development of aquaculture takes place. Those dimensions were concerned primarily with the dynamics of the flow of energy through that ecosystem and the effect of organization on its flow. In this section, I will discuss briefly some of the psychological dimensions of that ecosystem or dimensions that are derived from the mental processes and behavior of individuals as they impinge on the development of aquaculture.

There are many psychological dimensions in the aquacultural ecosystem that are important in the development process. These include, but are not limited to, the following:

*1. Consciousness.*
*2. Learning.*
*3. Decision making.*
*4. Behavior.*
*5. Conformity.*
*6. Persuasion.*

### *Consciousness*

Myers (1989) defines consciousness as selective attention to ongoing perceptions, thoughts, and feelings. Psychologists have a difficult time defining the term. In general terms, consciousness refers to the process by which we continuously, at least during our waking hours, mentally identify, evaluate, organize, and integrate aspects of our internal and external environment. It is the process by which we maintain an awareness of our needs, wants, aspirations, concerns, observations, capabilities, fears, accomplishments, and potential as we relate to our external environment. Consciousness is the principal characteristic that separates us from the lower animals. It is a product of our larger, more complex brain.

Although the phenomenon is difficult to define, it is the wellspring of our efforts to improve the quality of our lives and to make decisions regarding the commitment of scarce resources. The complexity of the ebb and flow of this ongoing process, as all of those factors interact, is probably a primary reason why it is so difficult to predict decisions that individuals will make on any specific issue at a given time (Buchanan, 1987).

Consciousness is the process by which we visualize the need for "bringing to a more advanced state" (development) some aspect of our lives and environment. It is the process by which we can imagine the contribution that adoption of new technology will make to our lives. It is the basis of our fear of failure and conservatism. It is the process where we weigh a broad range of costs and benefits related to the commitment of scarce resources. Individual consciousness is the basic material that change agencies and change agents (extension agents) have to work with in efforts to promote aquacultural development. To encourage development, individual consciousness must be focused on the opportunities to be realized, on the commitment of scarce resources required, and on the necessary steps in the process.

In the list of psychological dimensions presented at the beginning of this section, consciousness was listed first, followed by learning, decision making, behavior, conformity, and persuasion. All of the other dimensions listed are really aspects or manifestations of consciousness. This relationship should be kept in mind as each dimension is considered.

### *Learning*

Psychologists define learning as "a relatively permanent change in an organism's behavior due to experience." Learning is at the heart of the development process. I have suggested in a preceding section that development means to bring to a more advanced state, and that it depends on individual choices, commitments, and actions. Individuals cannot make the necessary choices and commitments or implement the required actions for development without some change in their behavior. The term development implies a change in behavior. Changes in behavior are the results of learning. Myers (1989) summarizes this concept succinctly:

> *Indeed, nature's most important gift to us may be our adaptability—our ability to learn new behaviors that enable us to cope with ever changing circumstances.*

Learning is essential for development, and equally important for those of us who encourage and promote development. Things that can be learned have the potential for being taught, and what has already been learned has the potential for being reinforced or canceled by additional or new learning. This phenomenon is the key to our involvement in development. Individuals must make the choices and the commitment of scarce resources and engage in the required activities, but we can play an important role in the process by participating in their learning of new insights, new perspectives, new skills, and new approaches to old problems.

Psychologists suggest that there are three basic ways in which we learn, each of which will be discussed in the following sections:

1. *Classical conditioning.*
2. *Operant conditioning.*
3. *Learning by observation.*

**Classical Conditioning --** The classic example of classical conditioning was Pavlov's research in which dogs learned to expect food and would begin to salivate at the sound of a bell. They learned to associate the bell with food. This is a more elemental, involuntary type of learning. While it is valuable in a basic way to prepare animals, including humans, to cope with their environment, it probably is less valuable in preparing them to manage their environment.

A form of classical conditioning is used effectively in modern advertising to engineer "want" responses in potential consumers (Kinnucan et al., 1989). The form used in advertising is much less obvious and more complex than the form used by Pavlov. One only has to watch well-designed commercial advertisements for beer or for a chain of seafood restaurants to fully appreciate the realized and potential importance of classical conditioning. Classical conditioning is an effective counter-weight to be used in balancing the demand-supply equation. Typically, suppliers produce goods with the hope that there will be a demand for them. Classical conditioning is a means of engineering or creating demand.

**Operant Conditioning --** Operant conditioning is the process of learning to repeat actions that bring good results and avoid acts that bring poor results. This is the classical process of learning by trial and error or learning by experience. Over the long span of our history, our ancestors made mistakes and learned not to make them again. They not only learned by mistakes, but they also learned from success. They learned to repeat those things that brought good results. Learning by experience certainly has played a role in the development of much of the technology that we utilize. It was the basis for the development of new ideas, new techniques, and more useful objects in pre-historic man. In fact, virtually all animals are able to learn through trial and error.

Operant conditioning also is essentially the basis for the scientific method. Sir Francis Bacon emphasized the importance of this way of learning:

*Truth will sooner come from error than from confusion. The induction which is to be available for the discovery and demonstration of sciences and acts, must analyze nature by proper rejections and exclusions. To man it is granted only to proceed by negatives and at last to end in affirmatives after exclusions have been exhausted (Platt, 1966).*

We use learning through operant conditioning in the development process even more intensively today, especially in the development of new, biologically based technology. However, much of this type of learning is done by change agencies in conducting applied research (institutional learning), and then the results are passed on to the individuals who must make the choices and commitments. When the individuals themselves must learn through operant conditioning, the development process tends to proceed sporadically. When the learning is done by the public sector at public expense (research and extension), the process can proceed more smoothly. This phenomenon will be discussed more fully in a following section.

Bheenick et al. (1989) commented that, in a study of successful development projects in Africa, many of those successes could be traced to the change agency learning by experience. They suggested that those projects were successful because the change agencies (governments in those cases) utilized the following operant conditioning learning process:

*1. A government implements a set of policies to achieve specific objectives.*

*2. After a period of time the policy makers learn that those policies will not achieve the stated objectives.*

*3. The change agencies modify the original policies and/or implement new policies.*

Those authors commented on the importance of learning by experience in the development process:

> *This (the process described above) makes it clear why learning from experience is so important. At any point in the process, if new policies fail to solve satisfactorily the problems that have arisen, the program may be judged a failure. For the program to succeed, it must continue to adapt and solve problems as they arise during implementation ... Whether we are talking about an individual or a society, progress is bound to be slow and erratic unless people can learn from experience. Repeating the same mistakes over and over ... is a terrible waste.*

Operant conditioning is important in aquacultural development. Learning from experience is practical only if there is effective evaluation of development efforts. Pollnac (1989), writing on the monitoring and evaluation of small-scale fishery projects, commented that "adequate monitoring and evaluation of the impacts of development projects is essential as a means of providing the information necessary to both adjust ongoing projects and formulate new ones." The publication (edited by Pollnac) cited several chapters by different authors on the mechanics of evaluation and monitoring. Molnar and Duncan (1989) provide an especially useful chapter on the monitoring and evaluation of aquacultural projects.

**Learning by Observation --** Learning by observation is a characteristic of the higher animals and is extremely important in our species. It is succinctly stated:

*Monkey do as monkey see.*

Lord Chesterfield stated the importance of learning by observation:

*We are, in truth, more than half what we are by imitation (Myers, 1989).*

If learning through operant conditioning is the heart of development, learning by observation is its arms and legs, for this is how new technology that is so essential to development is diffused. Learning by observation, by watching others, is the essence of the range of extension methodologies used so effectively to teach others how to do new things. Bheenick et al. (1989) commented on the importance of "learning by observation" in the development process:

> *... Repeating the same mistakes that other countries have made is a terrible waste that developing countries can ill afford. Similarly, neglecting the implications of other countries' successful development policies is a wasted opportunity.*

Learning by observation is enhanced severalfold by the use of language. Myers (1989) suggests that language -- "our words and how we combine them to communicate with each other" -- is one of the signal achievements of our species. Words combined with observations are a powerful stimulant to learning. In this manner, we are able to communicate details that the observation is unable to grasp easily from observation alone. Uncertainties can be handled quickly. Questions and answers provide a matrix for understanding.

Spoken language along with demonstration are powerful aids to learning. Written language without observation is much less effective. Anyone who has attempted to assemble a Christmas toy following written directions can attest to the difficulty of learning from written language alone. Words are powerful tools when combined with observation, but they become relatively weak, plastic, indefinite symbols when written. While they are relatively ineffective in conveying ideas and emotions, they are relatively effective in conveying facts.

### *Decision Making*

I suggested in a preceding section that development was primarily the result of individuals making decisions (choices) to commit scarce resources. Consequently, it is helpful to understand something of the way in which people make decisions and the typical problems they encounter in doing so.

Our lives are an almost continuous series of decisions. Except for breathing and other bodily functions that are controlled by our autonomic nervous system, virtually every other action is the result of some decision made in our consciousness. Most of the successes and failures in our personal, social, and economic lives are a result of decisions that we make. I have followed the development of the catfish farming industry in Alabama closely throughout its short history, and I have been awed by the cascading effects of seemingly simple decisions made by individuals and groups involved in the development of the industry. Of course, it is much easier to judge decisions after the fact, but it is a useful exercise to trace both failures and successes back to those key decisions and to try to understand how they were made.

Most people use a heuristic approach to make decisions (Myers, 1989). This approach is based on a "rule-of-thumb" strategy. Decisions based on heuristics are empirical rather than reasoned. We tend to make decisions based on bits of knowledge which we have obtained in the past and based on similar decisions that have provided good results. While the use of heuristics provides a basis for making reasonable decisions rather quickly, this approach can lead to difficulty. People tend to relate decisions that must be made to a prototype decision or to quickly put a new decision in a category with other decisions which they have made. When we consider a decision to be made according to some prototype decision, we are using a representative heuristic.

The effectiveness of decisions we make following this strategy will depend on how well these decisions are represented by a prototype. Errors in making decisions also can result from trusting the quality of information in our memories (availability heuristic). We too often feel that we have accurate recall on the nature of the situation that led to a previous decision. In too many cases this is not true at all.

Myers (1989) refers to the work of psychologists Daniel Wheeler and Irving Janis in listing five steps to arriving at decisions based on a logical, reasoned process rather than on heuristics:

*1. Accept the challenge. Important decisions won't just disappear. Go ahead and make them.*
*2. Search for alternatives.*
*3. Evaluate the alternative. List positive and negative considerations.*
*4. Make a commitment. Choose the alternative that gives you maximum benefits at minimum costs.*
*5. Adhere to the decision. Once the decision is made, adhere to it and proceed with its implementation.*

Rogers (1983) and Pollnac (1982) suggest that decisions on whether to commit scarce resources to aquacultural development are based on people's evaluation of five characteristics of the technology in which they are being asked to invest:

*1. Complexity.*
*2. Compatibility.*
*3. Advantage.*
*4. Trialability.*
*5. Observability.*

**Complexity --** This attribute generally relates to the perception by people of the difficulty in understanding and implementing new technology that might result in an improvement of the quality of their lives if adopted. Rogers (1983) suggests that the rate of adoption of new technology is negatively correlated with complexity. The rate of adoption is slower for more complex technology. People perceive new technology by comparing it with what they already are doing. In developing new technology, those promoting change should be aware of the complexity of the new in relation to the old. If the new technology is significantly more complex than that already in use, the process of adoption will be slowed considerably.

The importance of the perception of complexity in the development of aquaculture probably changes with the stages of aquacultural development, although there is little information available regarding this relationship. At the higher stages where aquaculture tends to be practiced as an investment, perceived complexity seldom would be an issue. At these stages, people investing resources in aquaculture would likely assume they could employ someone who would be able to deal with the complexity. The same would not be true at the lowest stages, where the farmers themselves would have to deal with it.

Complexity is a more important consideration in establishing aquaculture where it has not been practiced before. In general, aquacultural technology is more complex than agricultural technology, and it appears even more complicated than it really is to people unfamiliar with it. People generally know very little about the characteristics of fish that are important in husbandry. Farmers, for example, faced with the problem of understanding the dynamics of oxygen production and utilization in the culture container and contemplating the difficulty of managing water quality are likely to be concerned about the investment of scarce resources in such a complex technology. They seldom would face situations of equal complexity in animal agriculture.

As noted earlier, the complexity of aquacultural technology increases with the stage of aquacultural development or with the level of intervention. It also was noted that uncertainty of the production system decreases as intervention and complexity increase. Farmers obviously would want to minimize uncertainty, but probably would not feel comfortable accepting the level of technology required to moderately decrease uncertainty because of the perceived complexity issue.

Complexity is a factor even for farmers trying to make a decision on the adoption of aquaculture as part of their farming operation, even when neighbors around them are practicing it. They still must deal with the complexity of the entire system simultaneously. It is less of a constraint in this case, however, because they are able to conceptualize the system by observing their neighbor's operation (learning by observation). This opportunity to watch the entire system function on a neighbor's farm makes it seem much less complex.

**Compatibility --** This factor relates to farmers' perception of whether the new technology will be compatible with their farming practices, lifestyle, or culture. Will it mesh with the things that farmers are already doing? Rogers (1983) also suggested that the rate of adoption of an innovation is positively correlated with compatibility. The rate of adoption is faster when an innovation is compatible with the culture and lifestyle of potential adopters. As noted in a previous chapter, aquaculture is a series of interrelated steps which includes production, harvesting, processing, marketing, and utilization. Obviously, there are sub-sets of sequential activities within each of these. The efficient utilization of resources requires that these elements be kept in some sort of balance. Changes in any of the elements may result in an imbalance and may require a restructuring of the whole system. It is within this context that a potential adopter will evaluate the compatibility of new technology, and it is within this context that new packages should be developed.

The importance of compatibility would tend to change with the stage of aquaculture. At the lower stages, individual farmers and their families are likely to be directly and continuously involved in the new technology. Fitting any new technology or any additional activity into their already busy lives often is difficult. At the higher stages of aquaculture, especially where it is to be practiced as an investment, compatibility would be of little consequence.

**Advantage --** While compatibility of an innovation relates to how well it will mesh with existing practices, advantage relates to the perception of whether the new will be better than the old. Is there an advantage in change? The rate of adoption also is positively correlated with advantage (Rogers, 1983). When potential adopters perceive that an innovation offers significant advantage, they tend to adopt it more quickly. Probably this is the most important of the attributes of the decision-making process. Improving one's "lot," as suggested earlier, is a powerful incentive to change. However, relative effectiveness of the old and new is not the only consideration. Relative costs are also considered. Even if an innovation is an improvement, it will have little or no attraction if its cost more than offsets its advantages. Personal characteristics of the potential adopter also play a major role here. Relative advantage would almost certainly be evaluated differently by the innovative and the late adopters (Maunder, 1973).

Relative advantage is related to the change in the rate of return on investment expected from the use of the innovation compared to the practice in use. Where aquaculture has not been practiced before, advantage or relative advantage is more difficult to perceive. Farmers might have a good idea of the rate of return from various agricultural enterprises, but would have difficulty in comparing those returns to the returns they might receive from aquaculture, a largely unknown innovation.

**Trialability --** This attribute relates to the degree to which an innovation can be tried before making a complete commitment or before full-scale use. Potential adopters are more likely to be interested in trying new technology if they do not have to make an irreversible commitment to it (Rogers, 1983). For example, farmers might be interested in using a new piece of equipment if it can be returned to the dealer if it does not meet their needs. They would not have to make a final decision until they had tried the innovation. In some cases, innovations cannot be tried without a firm commitment. For example, if farmers want to try a new feed, they can do so only by using it. That portion which is used cannot be returned. Changing pond design is an example of an even less "trialable" innovation. A commitment is necessary in order to try the new container design.

Trialability also is positively correlated with the rate of adoption (Rogers, 1983). This is an extremely important attribute in the promotion of aquaculture on farms, in provinces, or in countries where it has not been practiced before. It is difficult to try aquaculture without committing considerable resources to it. Generally, once production containers are constructed, for example, they cannot be used for anything but aquaculture. Water supplies developed specifically for aquaculture have limited use for other purposes.

Because aquaculture has limited trialability in these situations, potential adopters must be much more conservative in their decision-making process. Those with limited resources would likely be difficult to convince that they should invest in aquaculture.

**Observability --** This factor relates to the observability of the results of using new technology. The rate of adoption also is positively correlated with observability (Rogers, 1983). Obviously, people who commit resources want to see a dramatic change as the result of adopting an innovation. They also are concerned with how long they will have to wait to see a difference.

The results of technology cannot be observed until someone has made the decision to commit resources to a trial. This would be a major consideration with poorer farmers. They would be unlikely to commit scarce resources until they can observe positive results. In this situation, it usually is necessary to encourage farmers with more adequate resources to try the technology or to have a public agency invest the funds and take the risk. This latter approach is not without a potentially important limitation. Trials funded by public agencies may not provide a good picture of what will happen when farmers apply the technology. It is difficult for public agencies to try their technology in the same manner as farmers would. Agencies generally have more resources to use and are less concerned when the technology fails. Also, it is difficult for public agencies to adequately count all of the costs involved.

Observability can be a problem in the acceptance of new technology in areas where aquaculture has not been practiced before because a relatively long period is required to produce a crop of aquatic animals. In the meantime, people who have invested resources are anxious for some indication that the trial will be successful. Further, it is likely that those with limited resources would be more anxious than those who had considerable excess funds to invest. Also, farmers with limited resources would want to be able to clearly observe positive results in which an acceptable return on investment is obvious. Farmers with more resources likely would be satisfied with less observable results.

Encouraging individual farmers to adopt new technology is obviously much easier when their neighbors already use it, as opposed to introducing innovations in areas where no one practices aquaculture. In both cases, observability is likely to be more of a problem than when promoting a change in technology on farms already involved in aquaculture.

Demonstration farms are an effective means of dealing with the problem of observability. Whether they are operated by a change agency (Extension Service) or on a private farm with significant involvement by the change agency, these farms provide potential adopters with an opportunity to observe the entire process. Although demonstration farms tend to be somewhat unnatural because of the involvement of the change agency and its agents, they still offer sufficient observability to meet the needs of most potential adopters. The use of "Farming Systems Research" (FSR) is a valuable tool in dealing with the problem of observability in making decisions. Through the use of FSR, farmers are more closely involved with the development and diffusion of new technology. Consequently, they are more comfortable in making decisions concerning its use. Molnar et al. (1987) provide a useful discussion of the use of FSR in the development of aquaculture.

**Other Factors --** In addition to the more tangible attitudes toward new technology, (complexity, compatibility, advantage, trialability, and observability), there are a number of relatively intangible factors that affect peoples' decisions to commit limited resources to aquaculture. According to Pollnac (1982), these factors include:

1. *Education of the potential adopter.*
2. *Social status.*
3. *Attitude toward credit.*
4. *Level of aspirations.*
5. *Degree of contact with change agents.*
6. *Exposure to mass media.*
7. *Social stratification system.*
8. *Degree of socio-cultural stability.*
9. *Degree of subsistence versus market orientation.*

***Behavior***

Behavior, or the way people conduct themselves, is central to the development process. Myers (1989) provides a good definition:

> *Behavior is best understood in terms of the interplay of internal and external influences. At every moment our behavior is determined by our genes and our experiences, our personalities and our environments.*

Development is dependent on the choices that people make, the actions they take in extending those choices, and the manner in which they conduct themselves in those actions. Myers (1989), reviewing the work of Alfred Bandura, suggests that people's behavior can be derived through a learning process, through conditioning, and by observing the actions of others. This process involves a "reciprocal determinism" in which our personal needs and wants interact with our environment to affect our behavior; our behavior then affects our needs and wants, which leads us to alter our environment to improve the quality of our lives. This interaction between a person's internal and external environments is another perspective of the ecosystem concept. Working effectively with this interaction is central to the success of development.

An important aspect of our behavior is whether we feel (from our consciousness) that we are in control of our environment or whether our environment controls us. People who feel they can exert some control over their environment or that they control their own destinies tend to achieve more in school, to be more independent, to be more capable in dealing with stress. This perspective also seems to influence a person's persistence and assertiveness. In contrast, people who are helpless and depressed tend to perceive that control of their lives is external. Some studies have indicated that this feeling of helplessness can be learned. When people must face repeated traumatic events over which they have little or no control, they tend to feel helpless, hopeless and depressed. Obviously, these aspects of behavior would be extremely important in the development process. Promoting development among people who feel they have little or no control over their lives would require a different strategy than when working with people who feel they do control their destinies.

### *Conformity*

How individuals respond to social influences is important in the development process. Conformity, the need to be similar or identical, is one important behavioral response to social influence. Myers (1989) suggests that we conform because we feel more secure when we follow "understood rules for accepted and expected behavior," and because we are unwilling to gamble that the price for being a non-conformist may be too severe. He further suggests that we conform because we have learned that the social "group" can provide valuable information regarding uncertain situations and that the group wisdom and experience can be valuable. He quotes Asch in describing conditions that strengthen conformity:

*1. When we are made to feel incompetent and insecure.*
*2. The group includes at least three people.*
*3. The opinion of the group is unanimous.*
*4. We admire the group's status and attractiveness.*
*5. We have made no prior commitment to a position.*
*6. Our behavior will be observed by others in the group.*
*7. The group strongly encourages respect for cultural standards.*

Obviously, the effect of conformity on the development of aquaculture can be a two-edged sword. A high degree of conformity in a target group would simplify efforts to diffuse new technology throughout the group. Once one group member adopted it, adoption by other members should follow quickly and easily. In contrast, however, it would seem likely that a high level of conformity would tend to stifle innovation or the creation of new technology which is extremely important in development. Obviously, a low level of conformity would make it much more difficult to diffuse new technology, but might be a better environment for the creation of technology.

### *Persuasion*

Persuasion is an essential aspect in the development process. Development is dependent on individuals making choices to commit scarce resources. Because individuals must be persuaded to make the desired choices, the factors that influence persuasion and how individuals respond to persuasion are extremely important. There are four elements in the process:

*1. The communicator.*
*2. The message.*
*3. The medium.*
*4. The audience.*

**The Communicator --** Myers (1989), summarizing Bernay's work, suggested that there are two important characteristics of a good communicator -- attractiveness and credibility.

He suggests that people respond more favorably to persuasion by physically attractive communicators, especially when they have the same general physical characteristics as the audience, and that the attractiveness of the communicator is more important when the message concerns matters of lifestyle, tastes, and values. In contrast, if the communicator is attempting to persuade the target group on matters of fact, physical attractiveness is less important. In this situation, the credibility of the communicator is more important.

**The Message --** The nature of the message is important in the persuasion process. There is considerable interaction between message content and the nature of the communicator and the audience. For example, a message that asks for an extreme change in position on the part of the audience is more likely to be accepted if the communicator is highly respected and credible. Less credible communicators are more effective when they are delivering a message with a position that is similar to one already held by the audience. Less credible communicators cannot expect to persuade audiences to accept significant changes in their opinions.

Whether the message is appeals to reason or emotion also is important in the persuasion process. If the audience is informed regarding the message and they have a vital interest in it, they are more likely to respond to a logical and structured presentation. In contrast, when people are less informed and less interested, they will respond positively to a more emotional message.

**The Medium --** The medium used to deliver the message also can influence the persuasion process. When the message involves minor or unfamiliar issues, radio, television, and newspapers can be extremely effective. These mass media are less effective for more substantive issues. In this situation, face-to-face appeals are considerably more persuasive.

**The Audience --** The audience is the most important element in the persuasion process. When the message is important or if it can be made important, the audience will become mentally involved. In a sense, they participate as communicators to themselves. Myers quotes the French philosopher and mathematician Blaise Pascal concerning this phenomenon:

> *People are usually more convinced by reasons they discover themselves than those found by others.*

Persuasion is significantly enhanced if the audience can be encouraged to become involved in thinking about the message. Personal characteristics shared by an audience also affect their responsiveness to persuasion. Individuals with strong opinions or positions regarding the message are much more difficult to persuade than those with less well-defined ones.

## *Sociological Dimensions*

Biological and psychological factors doubtlessly play an important role in the development of aquaculture, but there are other factors that have equal or even greater effects. These are sociological and cultural principles, including property rights, inheritance patterns, dietary habits, division of labor, social organization, and other factors. These aspects of the development process have received far too little consideration. Peterson (1982) commented that while technical descriptions of aquacultural systems abound, there are few descriptions that include social and cultural aspects of the ecosystem. Further, the more usual reason for the failure of development efforts is that the technical aspects are considered in isolation rather than as an intricate part of an ecosystem. Pollnac (1982) suggests that projects are likely to fail unless there is careful consideration of economic, socio-cultural, scientific, and technological factors.

### *The Nature of Sociology*

All living things are part of some ecosystem and all share certain biological characteristics. However, people have some characteristics that tend to set them apart from the so-called lower organisms. Darwin implied -- although he did not specifically say so in the case of our species -- that environment determines the nature of all living things. The nature of lower animals is determined by natural selection, recurrent mutation, and genetic drift in response to characteristics of the physical, chemical, and biological environment. Available evidence suggests that the nature of our species also has been formed by this same process, over some 450,000 years. However, approximately 35,000 years ago, we began to take charge of determining ("reciprocal determinism") our response to the environment (Myers, 1989). From that point onward, we have made major contributions to our nature or to our ability to respond effectively to our environment. Diamond (1989) refers to this sudden change from genetic response to cultural response as "the great leap forward." He suggested that this momentous event could have been the result of a mutation that altered our tongue and larynx so that the development of language was possible. He suggests that language is a requirement for the development of culture. According to Robertson (1987), language is the keystone of culture. Culture cannot be shared except through the medium of language. The anthropologist Misia Landau provides an even more intriguing picture of the role of language in the development of culture:

> *...Language is not merely a device for communicating ideas about the world, but rather a tool for bringing the world into existence in the first place. Reality is not simply "experienced" or "reflected" in language, but, instead, is actually produced by language (Lewin, 1988B).*

For whatever reason, approximately 35,000 years ago our ancient ancestors began to develop a response capability to "environmental resistance" through the processes of discovery, invention, and diffusion. The totality of these responses is called culture, and that is what allows us to adapt to our environment. These responses are the shared products of the cumulative effort by our ancestors and ourselves to adapt to our environment. In a given environment, a number of people will share or utilize the same culture. Those who do so are referred to as a society.

Culture can be divided into two basic components, material and non-material:

*1. Material Culture — Artifacts or physical objects that we create to help us adapt to our environments. Examples include the wheel, clothes, shelter, books, telephones, roads, and farms.*

*2. Non-material Culture — Products of abstract effort to provide for the more efficient utilization or application of the objects of our material culture. Examples include languages, beliefs, rules, customs, skills, political systems, and ideas.*

The importance of this culture differentiation will become obvious in a following section.

Each of us individually must adapt to his or her environment. No two people have exactly the same culture. Sociologists aggregate these individual adaptations to define a shared culture. This aggregation, while describing the average adaptation of many individuals to their environment, may not predict with any degree of accuracy the adaptation of any specific individual. It is extremely important to keep this phenomenon in mind in promoting the development of aquaculture. As noted previously, aquacultural development is the result of individuals making personal commitments of scarce resources and sustaining those commitments in order to bring the farming of aquatic animals to a more advanced state. To help individuals make the correct decision regarding their commitment, and to help them sustain that commitment, it is important to know something of their individual culture.

While culture is a characteristic of individuals, the interaction between individuals and their cultures result in effects that are extremely important in development. For example, Schwartz et al. (1988) describe how efforts to introduce aquaculture in Panamanian villages were affected by politicians who lived there. The problems encountered in promoting development in those villages were different from those encountered in villages without local politicians. The presence or absence of elected "Honorable Representatives" living in a community had a pronounced effect on the expression of the response of individuals to the introduced fish-farming technology. These same authors also described how cultural history affected the culture of individuals and, in turn, the effectiveness of their participation in the development of integrated fish farming in Panama. The people in one province had Hispanic cultural traditions, a more egalitarian ideology, and an active opposition to central government. The people in this province imposed their ideas on change agents and were resistant to "top-down" development projects. In an adjoining province, people more readily accepted change agents because they viewed them as potential patrons. In a more general sense, Lewis (1982) concluded that there is a strong correlation between culture and economic behavior or that "society's values, priorities, and attributes importantly condition the performance of its enterprise."

### *Sociological Characteristics and Aquacultural Development*

The food that we eat is part of our culture (Steinberg, 1980). The methods we use to hunt, gather, or produce it also are part of our culture. Aquaculture is part of our culture. It is a part of our effort to manage or work within our environment to provide for one of our basic needs — food. If we are to bring the culture of aquatic animals to a more advanced state (development), either by changing existing aquaculture or by introducing it into areas where it has been practiced little or not at all, we have to do it within the boundaries imposed by our culture(s). To develop aquaculture, we must change some aspects of existing cultures. And if we are to be successful in the development of aquaculture, we must thoroughly understand the nature of culture, what it represents, and how it is functionally related to the environment that shaped it.

There are several characteristics of culture that are important in this process:

1. *Differences in cultures.*
2. *The problem of cultural change.*
3. *Ethnocentricity.*
4. *Dysfunctional bureaucracy.*
5. *Conflict and power.*

**Differences in Cultures --** As suggested before, culture in the general sense is shaped or determined by environment. Because there are different environments in the world, there are different cultures. Obviously, there can be important cultural differences between regions in a country or between countries. For example, Sanoff and Golden (1989), summarizing information from historian David Hackett Fischer's book, *Albion's Seed*, suggest that there are seven regional cultures in the United States. They suggest that these are a result of four different waves of early immigrants from different regions of England in the 17th and 18th centuries which have co-mingled with later immigrations from other countries.

Differences in culture are especially important now when so much money and effort are being expended to help the developing countries of the world improve their food-producing systems or to improve the profitability of their agricultural sectors. It is especially important in any situation where a member of one society (people who share a common culture) is involved in any way in assisting the members of another society with the development process. Unless we understand thoroughly the cultural characteristics of those we want to help, we certainly cannot understand the environment in which we must work, and our chances for success are small.

Understanding the differences in cultures is important especially if the development effort involves moving an "artifact" of one culture to another. For example, efforts to introduce channel catfish farming into Rwanda in Central Africa would almost certainly result in failure. Channel catfish farming is a cultural artifact of a relatively specific environment primarily found in the southern United States and of the major river valleys in that region. Some of the characteristics of this cultural artifact were described is a preceding section. The Rwandan environment is so dissimilar that it is highly unlikely that catfish farming could be established there.

While efforts to transfer catfish farming to Rwanda would likely fail, they would likely succeed in introducing it onto a farm in Humphries County, Miss., when an adjacent farmer and many farmers in the county already are producing catfish. There are minor environmental differences from one farm to another or from one county to another in the same region, but generally these are not great enough to markedly influence the success of transferring this cultural artifact. Similarly, transferring some improved technological innovation, such as a new feed or new type of aerator, from one farm to another also would likely be successful because of the similarity of the environments on adjacent farms or in adjacent counties. In the development of aquaculture through the transfer of technology (a cultural artifact), it is important to remember that some cultural differences may essentially preclude this approach. Consequently, it is essential that the change agency or agent proposing the transfer understand the nature of the culture and the environment of the area that is to receive the new technology. Of equal importance is understanding the nature of the culture and the environment from where it is being transferred. One cannot predict the likelihood of successfully transferring technology to a new environment until the functional characteristics of that technology in the old environment are known, as well as how that particular environment shaped the cultural artifact in question. For example, one cannot expect to be successful in transferring channel catfish farming to another environment until it is understood why and how it is successful in Alabama, Mississippi, and Arkansas.

**The Problem of Cultural Change --** It requires a change in culture to develop aquaculture either through changing existing aquaculture or introducing the practice into new areas. Remember, I have suggested that the food we eat and the way we obtain it is part of our culture. Unfortunately, one characteristic of a society is that its shared means of coping with its environment -- its culture -- changes slowly. This phenomenon probably is a result, historically at least, of the fact that environments changed slowly. Remember, however, that in reality, it is the culture of individuals which changes slowly. As noted previously, Sanoff and Golden's (1989) article on the book *Albion's Seed* described seven regional cultures in the United States. These seven resulted from a co-mingling of four different early immigrations of people from four different regions of England with later immigrations from other countries. According to the book, these regional differences in cultures in England during the 17th and 18th centuries were so strong that they withstood the rigors of immigration to a new land and were strong enough to persist at least to the beginning of the 21st century.

While culture changes slowly, its material component (physical objects) can be changed much more rapidly than its non-material component (abstract human creations) (Robertson, 1987). Apparently, people are more willing to accept change that involves "feeling" and "seeing" physical objects than changes in the mental processing of information regarding abstract creations. This can be an important consideration in aquacultural development, especially when a change agency is promoting change.

In planning for the development of aquaculture, it is essential that the extent of cultural change required be determined, as well as whether material culture, non-material culture, or both must be changed to achieve development. It also is important to understand the cultural changes that will be required of each individual. This is especially important when aquaculture is being introduced to an area where it has not been practiced before. The material culture change required to grow channel catfish in Israel would be rather insignificant compared to the non-material culture changes because of the Jewish belief that scaleless fish are unclean. That belief is such a strong and important part of their culture that attempts to develop catfish aquaculture there would lead to certain failure.

In a similar sense, it would be difficult to develop the commercial culture of the common carp in the United States because most Americans do not like the boniness of that species. Most food fish native to the United States are relatively bone-free or free of the intramuscular bones found in the carp. The material culture change required to grow carp would be readily acceptable.

Another important factor to note in planning a strategy for aquacultural development is that if the plan is successful, it will likely result in irreversible cultural changes for the individuals involved. While change agencies strive for these to be positive changes, this is not the case in too many situations. The development of shrimp farming along the coasts of many tropical countries has resulted in significant cultural changes in those communities. Those new farms represent a moderate stage of aquacultural development with a substantial level of capital intensiveness.

Bailey (1988) described how the development of shrimp farming in mangrove habitat has resulted in the transformation of a multi-use/multi-user coastal resource into a privately owned, single-purpose resource. Individuals who used those resources as fishermen or lower-stage aquaculturists generally are no longer able to fish and farm in areas where they had traditional use rights. Rather than benefiting directly from resource utilization, they must depend on indirect utilization by working as field laborers and in other, often low-wage jobs on the shrimp farms. Saclauso (1989) reported that conversion of mangrove swamps to ponds in the Philippines for the culture of the tiger prawn (*Penaeus monodon*) forced similar changes on the culture of local people.

In increasing the level of intervention in shrimp aquaculture in those tropical coastal communities, the human culture was irreversibly changed. In many situations and for many individuals, the changes have not been positive. History is replete with examples where development resulted in at least temporary negative cultural change. For example, the "Luddite Movement" in England, shortly after the beginning of the 19th century, was a revolution against cultural changes perceived to be caused by the use of new technology. The Luddites staged a series of destructive attacks on machines alleged to be depriving men of their jobs. In fact, such examples are so common that it seems that this is just one of the costs that societies must pay for development. However, because of the increasing interaction and interdependence of societies and cultures on a worldwide scale, it is no longer wise or prudent to accept this conclusion. We must be more careful in designing development projects to fully understand the extent of both positive and negative cultural changes that will result from their implementation. It is common in development to calculate an economic cost/benefit ratio. It might be wise and prudent to determine a cost/benefit ratio for cultural change as well.

**Ethnocentricity --** Sociologists define ethnocentrism as the tendency to judge other cultures by the standards of one's own culture (Robertson, 1987). As a child, I can remember adults around me commenting from time to time that "what we believe about others is based on what we know about ourselves." Essentially, ethnocentrism implies that we have a reasonable idea of the ways in which we cope with our environment (culture) and that we assume that other people must adapt to their environments in a similar manner. In a sense, every person is ethnocentric. Because they cannot enter the personal environment or consciousness of another, they have little choice but to assume other cultures are similar to their own. Probably the more widely these individual environments and cultures diverge, the more extreme ethnocentrism is likely to become.

The development of aquaculture, as noted in a preceding section, involves some change in culture. To bring the culture of aquatic animals to a more advanced state, the ecosystem must be dealt with in a different manner than before. It is possible to develop aquaculture by changing the culture of only a single person. A man living alone near a tidal swamp and tending a small, dammed tidal stream pond might invent a better way of allowing larval shrimp into the pond while preventing the entry of predatory fish. This invention should result in the higher production of shrimp. His aquaculture would be changed to a more advanced state. In most cases, however, the development of aquaculture involves the interaction of two or more people and two or more cultures. The development of the channel catfish industry in Mississippi involved the interaction of many individuals and cultures.

Ethnocentrism can be positive in that it provides faith and confidence in one's own tradition, or negative when it leads to racism, hostility, or an unwillingness to see the need for a change in his or her own culture. In the development of aquaculture, ethnocentrism can be quite important, especially when a change agent (extension agent) is attempting to help individuals change their culture through the adoption of new technology. Changing their way of culturing aquatic animals always requires the committing of scarce resources. Unless the agents are thoroughly familiar with the local culture and empathetic with the individuals, they may encourage them to make poor decisions. Under these conditions, ethnocentricity can lead either to encouraging people to adopt inappropriate technology or to being unable to sell a technology that is needed. Without a doubt, much of the failure of development efforts around the world has been the result of ethnocentrism -- well-intentioned, well-financed efforts to change cultures in far-away lands with little appreciation for those cultures. Worse still, some change agents have assumed that those people would respond to preferred change in the same manner as the agent's next door neighbor.

There are few effective rules for completely eliminating the negative effects of ethnocentrism. Certainly an awareness of the culture of potential technology adopters is essential. Also, it is helpful for change agents to fully understand the nuances of their own cultures before trying to change the cultures of others.

There also can be a problem with becoming too empathetic with the cultures of other people. Remember that ethnocentrism can lead to rejection of change even when it is needed. It is possible for change agents to become so empathetic that they cannot bring themselves to promote beneficial change.

**Dysfunctional Bureaucracy --** Robertson (1987) defined "Sociocultural Evolution Theory" as suggesting that societies gradually develop from simple to more complex forms: hunters and gatherers — pastoral — horticultural — agricultural — industrial — postindustrial. "Modern Evolutionary Theory" is defined as suggesting that societies tend to move from small-scale, single forms to large-scale, complex forms. In other words, there is the tendency for culture to become more complicated with time.

As the complexity of societies increases, the need for formal organizations also increases. As complexity increases, "traditional, spontaneous, rule of thumb methods ... are replaced by abstract, explicit, carefully calculated rules and procedures." The simple organization is replaced by a "hierarchical authority structure that operates under explicit rules and procedures" — a bureaucracy.

Robertson (1987) quotes Max Webber regarding the nature of bureaucracy:

> *The passion for bureaucracy is enough to drive one to despair ... The great question is ... not how we can promote and hasten it, but what can we oppose to this machinery in order to keep a portion of man-kind free from this parcelling out of the soul, from this supreme mastery of the bureaucratic way of life.*

Buchanan (1987), in his foreword to Tullock's *The Politics of Bureaucracy*, comments that "Tullock makes no attempt to conceal from view his opinion that large hierarchical structures are, with certain explicit exceptions, unnecessary evils, that these are not appropriate parts of a good society ... The bureaucratic world which Tullock pictures for us is not an attractive one, even when its abstract character is recognized, and even if the referenced politician of that world is not assigned the dominant role in real life."

Although terms like "red tape," "runarounds," and "petty regulations" are generally conceived to be synonymous with inefficiency and bureaucracy, bureaucracies exist and continue to grow and thrive simply because they are the most effective means yet devised to make large, complex, formal organizations work. As culture becomes more complex, bureaucracy becomes an indispensable element, although often an almost unmanageable element. The growth of government usually associated with increasing complexity may add to the difficulty of the situation. Government bureaucracy can be even more intractable than private sector bureaucracies. This is especially true in some of the less-developed countries. Fortunately, the power of the marketplace tends to force those in the private sector to be more efficient. There is no similar mechanism to encourage efficiency in public bureaucracies.

As discussed in a preceding section, the development of aquaculture also tends to evolve through stages from simple to more complex as the degree of intervention increases. Also, aquaculture was described as an ecosystem (a web) consisting of physical, chemical, biological, psychological, sociological, and economic components. Development was defined as a dynamic process whereby all of these interacting components are changed more or less simultaneously to a more advanced state. Given the dimensions of this ecosystem, it is inevitable that the development process will result in multiple encounters with a large number and broad range of bureaucracies regardless of the country involved (Fitzgerald, 1987). Unfortunately, there is usually a separate bureaucracy and sometimes overlapping bureaucracies for virtually every input required for the development of aquaculture. Permits that must be obtained from various bureaucracies before beginning the production of salmon in pens limits the development of aquaculture in the United States (Stickney, 1988). Poorly capitalized farmers often have a similar problem obtaining credit in less developed countries. Purchasing spare parts for machinery can be equally difficult. There are literally thousands of little bureaucratic obstacles that can divert the impetus for the development of aquaculture.

Buchanan (1987) and Max Webber (Robertson, 1987) seem to consider that there is little redeeming value in bureaucracies. Robertson takes a different position. He seems to say that bureaucracies in and of themselves are essentially neutral elements of complex cultures, that in reality the problem is bureaucratic dysfunction usually associated with some human frailty. Included in his list of dysfunctions are the following:

*1. The anonymous, impersonal nature of the relationship between officials and "outsiders".*

*2. Inefficiency in unusual cases.*

*3. "Trained incapacity" or the blind adherence to existing rules and procedures.*

*4. Goal displacement or forgetting the goals of the organization.*

*5. Authoritarian structure.*

*6. Bureaucratic personality or the stifling of individual creativity and imagination of officials in the bureaucracy.*

All of these dysfunctions are essentially self-explanatory and require no further comment except "inefficiency in unusual cases." It has been noted that aquaculture is a relatively recent phenomenon in many countries. It also is rather unusual in a number of respects. Bureaucracies have had relatively little experience dealing with it. The resulting inefficiency in responding to development needs by bureaucracies is a major constraint to bringing aquaculture to a more advanced state. Its rate of growth and the rate of geographic diffusion also are unusual and perplexing to bureaucracies.

There is one more dysfunction of bureaucracy that should be described. The impenetrability of sequential and overlapping bureaucracies is an important dysfunction. It is not included in the list given above, because it is a result of a functional weakness rather than of "human frailty" alone. A major goal of development over the past four decades has been to improve the quality of lives for poor people in less developed countries. Usually these efforts at development consisted of the government of a developed country providing some type of financial assistance to the government of the developing country. In theory, contributions (usually taxes) from citizens in the developed country were expected to move upward through multiple layers of bureaucracy, move across the gap between the two governments, and finally to trickle down through multiple layers of bureaucracy in the less developed country to reach the designated beneficiaries. Obviously, this system has not worked effectively (Paddock and Paddock, 1973; Agency for International Development, 1989; Hancock, 1989). In fact, it is surprising that it worked as well as it has (Sincere, 1990).

Moving resources through that compound maze of bureaucracies would be difficult at best and largely impossible at the worst. It is surprising that we have used this system for so long. The fact that it has persisted for 40 years suggests that bureaucracies are able to function ineffectively for many years without serious effort to make them operate more efficiently. There are some initiatives underway to bypass at least a portion of the multiple bureaucracies. Durning (1989A) describes the growing "Action at the Grassroots." With this approach, governments of developed countries are finding ways to provide support directly to grassroots organizations, thereby at least bypassing the multiple bureaucracies in the less-developed country. Unfortunately, the resources still must run the gauntlet of bureaucracies in the developed country. An even more effective procedure is the flow of resources from individual contributors (voluntary contributions) to private voluntary organizations

(PVOs) such as CARE and Save the Children. The PVOs transfer the resources directly to counterparts at the grassroots in the less-developed country. While there still is some bureaucracy involved, it is only a fraction of that involved in the "force it up and over and trickle down" method. Also, the altruistic nature of the PVOs generally provides some protection against bureaucratic dysfunction. While the relative success of the "mainlining" process utilized by PVOs to get funds to the grassroots in less-developed countries might appear to be the triumph of the common man over Max Webber's "evil empire," this is really not the case. Less-developed countries cannot become more developed without becoming more complex. This complexity cannot be managed and directed without formal organizations such as bureaucracies. Grassroots organizations can only make limited progress before higher levels of government must become involved. For example, regardless of how successful local grassroots organizations become, they cannot enact supportive agricultural policies or build roads to distant markets. Durning (1989A) summarizes the situation succinctly:

*Small may be beautiful but it can also be insignificant.*

There are few suggestions for improving the performance of bureaucracies that slow the development of aquaculture. There are so many possible problems that it is impractical to consider any of them individually. The best approach is to attempt to understand the nature of the dysfunction that is resulting in a specific problem and to try to deal with it specifically.

**Conflict and Power --** According to most sociological theories, cultures develop as a result of people adapting to their environment. There is a continuing struggle to overcome environmental resistance. Environment is the constant enemy. There are other theories that, while agreeing on this point, go further to suggest that the conflict between individuals over limited resources in the environment is also an important determinant in the development of culture. With these latter theories, an individual has two enemies, the environment and competition or conflict with his neighbor for scarce resources.

Robertson (1987) quotes Lasswell in defining politics as the process of deciding "who gets what, when and how." From the earliest times, people have competed for valued and scarce resources, and as part of the process of civilization, they invented politics as a way of resolving these disputes. This ancient solution to an ever-present problem led the philosopher Aristotle to observe that "man is a political animal." The process (politics) of deciding who gets the scarce resources is an ancient one. Equally ancient is the emergence of people who wanted to control the process -- people who wanted the power to decide who gets what, when, and how. The matter of who controls this power, how it is applied, and to what purposes it is put is the essence of political life throughout the world.

The exercise of political powers within and between nations has led to obvious inequities in the allocation of scarce resources. This really is not surprising. This is why political power was invented. There are other reasons for these inequities (resource endowments, population, system of government, etc.), but political power certainly plays a major role. In many cases these inequities have been in place for many years. They were born in conflict and, for all practical purposes, they have become institutionalized. Unfortunately, it often is difficult to redress them. They are highly resistant to change. The political power that was used to put the inequities in place to begin with is equally effective in resisting change.

One of the major objectives of much of the development effort in the last 40 years is to redress the inequities in who gets what, when, and how in the emerging nations of the world. This has been a noble goal, but it has not worked well. Development assistance provided by a donor country, because of its very nature, is a poor vehicle for attempting to redress inequities in resource allocation in developing countries when those inequities are the result of old power struggles or social conflict.

Aquaculture is not a panacea for the world's ills. The culture of aquatic animals is an important tool, when used correctly, in promoting food and economic security in virtually every country. However, it is relatively ineffectual when used as a tool in "social engineering." It is not a strong lever to be used in redressing inequities of resource allocation resulting from conflict and power.

## *Economic Dimensions*

The word "economics" is derived from the Greek "oikos" which means household and "nomics" which means management. Economics is translated as "management of the household." Economists use a more specific definition of the term:

> *Economics is the study of how individuals and societies, experiencing virtually limitless wants, choose to allocate scarce resources to satisfy their wants (Ekelund and Tollison, 1988).*

Buchanan (1987) suggests a different meaning of the term. He suggests that Adam Smith's statement in his *Wealth of Nations* concerning our "propensity to truck, barter, and exchange one thing for another" is what economics is about. Aquaculture has to do with satisfying the needs and wants of individuals and society. It also has to do with our propensity to truck, barter, and exchange. Aquaculture is a part of the household.

Although the basic meaning of the term economics indicates a broad interest in the entire household, historically economists have been more concerned with unemployment, inflation, the Gross National Product, and other elements of the money cycle (Postel, 1990). There was little concern for the utilization and management of natural resources as part of the cycle. Apparently, early economists considered natural resources (timber, fish, soil, oil, etc.) to be so abundant that notions of scarcity, depletion, and environmental damage did not become a part of their understanding of how economics functions. For example, in computing the Gross National Product, no correction is made for the loss of soil from farm lands or the over-exploitation of fish stocks. Costanza and Wainger (1992) also suggested that conventional economics distorts the value of things, because the value of natural resources is not adequately counted.

Laird (1991) suggests that "environmental accounting is an idea whose time has come" and that the time is overdue to include the costs of the destruction of nature or of increased pollution into the GNP. He concluded that we can obtain a much more accurate picture of national economic health by including the cost of natural resource degradation in the computations. Von Loesch (1991) suggests that if "environmental accounting" were considered, some resource-depleting poor countries have had a negative income for years. He further suggests that if environmental degradation is considered, fewer national development funds might be allocated to agriculture in some countries because of the poor return on investment when all of the environmental costs are considered. While he strongly supported the use of environmental accounting, he underscores the difficulty of placing a monetary value on the component parts of healthy ecosystems. Without setting a value on the healthy system, it will not be possible to determine the loss of value associated with an action that reduces its health.

***Fundamental Principles***

Over time, as economists have observed the way in which we satisfy our wants and the effects of the resulting activities on human affairs, they have suggested that there are three fundamental principles of economics. Ekelund and Tollison (1988) list two of these. I have added a third (number three in the following list) primarily based on Buchanan's (1987) work.

1. *There is no "free lunch."*
2. *People behave according to a rational self-interest.*
3. *People are led by an "invisible hand" to promote the public interest.*

**No Free Lunch --** The development of aquaculture is never a free lunch. In every effort to bring the culture of aquatic animals to a more advanced state, the decision must be made to commit scarce resources to that activity rather than to some other activity. The opportunity to practice aquaculture has a cost associated with it. When farmers in Arkansas and Mississippi decided to grow catfish, there were opportunity costs involved. They could not use the same land for cotton or soybeans and for catfish simultaneously. Similarly, when farmer-fishermen decide to dam a tidal stream in the tropics to make a brackish water pond, there is an opportunity cost involved. They have to forego the use of the stream for capture fisheries.

There is another important concept that is related to the fundamental principle of no free lunch. Development of aquaculture virtually always involves changing from one situation to another. There were costs and benefits associated with the old use of the tidal stream as a fishing ground. There will be costs and benefits associated with the use of that area as a pond for aquaculture. The important consideration in the development of this stream resource into a pond is the difference between the costs and the benefits of the old use versus the costs and benefits of the new use. There is no free lunch.

**Rational Self-Interest --** Buchanan (1987) quotes from Adam Smith's *Wealth of Nations* regarding the matter of "self-interest:"

> *It is not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest.*

A strong self-interest on the part of individuals would be a requirement for the Darwinian concept of the survival of the fittest. The strength of this characteristic in our species and the difficulty of dealing with it can be gauged by the efforts expended by the religions of the world to manage it over the last 2,000-3,000 years. The term "rational self-interest" implies that individuals do understand that, on occasion, interests of the family, the village, or even the country can supersede their individual interests. They understand that it is sometimes in their best interest not to pursue self-interest. Self-interest has played and continues to play an important role in civilization. Individuals throughout history who worked and fought harder, longer, smarter, and sometimes even cruelly and dishonestly to earn a larger, disproportionate share of available resources were indispensable in the development of new technology, commerce, statecraft, and civilization in an inhospitable environment.

Obviously, over time self-interest has been replaced to a degree with altruism or the unselfish concern for or devotion to the welfare of others. But as Desmond Morris (1967) suggests in his book, *The Naked Ape*, altruism is only a thin and often weak veneer covering the more primitive trait. Wilson (1974) uses the terms of evolution to describe altruism as the "surrendering of personal genetic fitness for the enhancement of personal genetic fitness of others." Attempting to reconcile the evolution of altruism, as opposed to the apparently more successful trait of self-interest, Wilson concluded that altruism appears or becomes more important when kinship is involved. Altruism in a family, a class, or even a village would increase the capability of the kinship group to more successfully cope with the environment.

Altruism or cooperation for the benefit of the group can be an important component of development, but it is somewhat more difficult to achieve when the investment of scarce resources (land, labor, and capital) are involved (Machan, 1989). People are naturally torn between a rational self-interest and altruism, but in the complex, rapidly changing world environment of food production, marketing, and utilization, unselfish devotion to the welfare of the entire group or industry could be extremely beneficial. Wilson's (1974) suggestion that the kinship which resulted in the development of altruism could be extended to suggest that tightly knit commodity organizations might encourage cooperation and discourage self-interest in the development of aquaculture.

An important goal in aquacultural development is to encourage self-interest so as to guarantee progress and innovation through competition. At the same time, we must encourage the altruism that is needed to develop the integration, cooperation, and communication required if an aquacultural industry is to be successful in an increasingly complex technological, regulatory, and international trade environment.

**The "Invisible Hand" --** Free and competitive trade that results from the exercise of rational self-interest leads not to chaos but to a harmony of interests. Adam Smith suggested in his *Wealth of Nations* that the process by which individual, self-interested actions result in progress rather than chaos seems to be guided by an "invisible hand." Ekelund and Tollison (1988) quote Smith regarding this concept:

> *He (every individual) generally indeed, neither intends to promote the public interest, nor knows how much he is promoting it—he is in this, as in many other cases, led by an invisible hand to promote an end which was not a part of his intention. Nor is it always the worse for the society that it was no part of it. By pursuing his own interest he frequently promotes that of society more effectively than when he really intends to promote it.*

His invisible hand is the growing efficiency of increasingly organized systems of production and marketing that result primarily from the continuous evolution of the division of labor. In a sense, the effect of Smith's invisible hand in human affairs is similar to the positive effect of polyculture in Dunseth's (1977) experimental ponds. Because of the division of labor, the "sum of the whole is greater than the sum of the parts." According to Robertson (1987), the increased efficiency in the economic life of a nation caused by the division of labor results in surplus wealth that can be used to create opportunities for artists, writers, architects, hairdressers, television repairmen, professional baseball players, used-car salesmen, and other service people.

### *Some General Applications of Economics*

It will not be the purpose of this section to attempt a discussion of the economics of aquaculture. However, there are some general applications that should be considered. These include:

*1. Demand and supply.*

*2. Elasticity.*
*3. Comparative advantage.*

These are basic concepts in the management of the household and, in turn, in the development of aquaculture. Some general comments on their relevancy in development are presented in the following sections.

**Demand --** Two of the most basic aspects of the management of the household (economics) are the demand for goods and services by individuals and efforts to supply those goods and services by other individuals. The definition of demand has become highly specific to economists. They most often use the term as part of a general statement of the relationship between prices and demand -- the "Law of Demand." According to the Law of Demand, "the price of a product or service and the amount purchased are inversely related" (Ekelund and Tollison, 1988). If the price of a product or service rises, then the quantity demanded falls; if the price falls, the quantity demanded increases, all other things being equal. The Law of Demand is one of the most powerful forces in economics. For the discussion of demand in this section, however, I will use a more general definition of the term. According to Webster's *Collegiate Dictionary, Fifth Edition*, it is the "desire to purchase a commodity accompanied by means of payment."

All living things have demands, or requirements that must be met if they are to survive. Even the autotrophic organisms, such as green, unicellular algae that manufacture their own food, require simple inorganic salts and sunlight for survival. Heterotrophic organisms, such as our species, have a much more complex and exhaustive combination of requirements. However, not all of our requirements are equally important. Maslow (1970) suggested that there is a hierarchy of needs. These include (in descending order of importance):

*1. Basic needs -- physiological and safety requirements.*
*2. Psychological needs -- belonging, love, and esteem requirements.*
*3. Self-actualization needs -- requirements for self-fulfillment and peak experiences.*

The most important or limiting of these are the physiological needs which include food, shelter, and clothing. Maslow further suggested that we are not prompted to satisfy those needs lower in the hierarchy (less important) until those higher level (more important) needs are met.

Food, shelter, and clothing were never free. They were always scarce relative to demand. They had to be "purchased" at some price. In our pre-history, our ancient ancestors paid with muscle and sensory system "work" for hunting and gathering food, for searching for shelter in caves, and for killing animals for their pelts. For much of the time, these primitive individuals were at or near the subsistence level of livelihood. At that level, there was little relationship between their demand (needs) for food, shelter, and clothing and the prices they paid. They simply paid whatever price was necessary if they had it, and if they didn't, the chances were good that they would not survive.

With time and the effect of the invisible hand, individuals were able to move away from the subsistence level of livelihood. The evolution of the division of labor resulted in improved efficiency in the management of their households. There was surplus wealth. The same basic needs for food, shelter, and clothing were still there, but their needs were expanded to include wants. They continued to need animal protein in their diet, but they wanted it cooked and seasoned with salt and herbs. They continued to need shelter, but wanted it with doors and windows. They continued to need clothing, but wanted it with zippers.

The expansion of needs to become wants provided more strength to Adam Smith's invisible hand. The evolution of the division of labor intensified. Additional surplus wealth was created and the actions of self-interested individuals satisfying their wants recycled that wealth again and again through the economic system.

As might be expected, there is a wide range of situations regarding needs and wants. In some areas of less developed countries, people are still at the subsistence level. All too many die because they are unable to meet their basic needs for food, shelter, and clothing. For those who do survive, virtually all of their resources are required just to meet needs. In more-developed countries, individuals are able to exceed their basic needs several times over. They are more concerned with satisfying their wants. Only a small fraction of their resources are required to meet their needs.

Human needs are relatively stable. In a given environment, individuals require a basic level of food, shelter, and clothing. If forced to live very long below this level, they survive only with great difficulty. Human wants are highly volatile. The quantity they demand is dependent on the price they must pay; hence, the law of demand is where the price paid and the amount demanded are inversely related.

In February 1966, Pope Paul VI issued a decree that allowed local Catholic Bishops to end, at their discretion, the rule requiring that they not eat meat on Fridays except during Lent. This had an immediate effect on the demand for fish; prices dropped sharply for some species. Economist Frederick W. Bell (1968) studied the effect of the decree on fish prices and reported that the average decrease in price for seven species of fish averaged 12.5 percent.

The demand for fish by individual Americans has increased since 1960, but demand has increased much more rapidly since 1983 because of reports that eating more fish promotes good health. On the other hand, individuals demanded less beef because of the belief that consuming fats in beef would have a negative effect on health. Recently, there was a temporary reduction in the demand for poultry because of a general concern for the cleanliness of processed broilers. I have already discussed the effect that the development and promotion of the "blackened redfish" in restaurants had on the demand for that species.

Many factors other than price affect the wants of individuals, and it is extremely difficult to predict how any individual or the aggregate will respond to any of these factors at a given time (Buchanan, 1987). As we seek to develop aquaculture, it is important to be aware of the volatility of the demands of individuals as they attempt to satisfy their wants, as well as the sheer desperation of individuals who can barely meet their needs. It is often difficult to predict the choices individuals will make in the first case and equally difficult to provide choices for those individuals in the second. It is difficult to manage aquacultural development to accommodate such a broad range of opportunities, but these are the dimensions of the ecosystem where we must work.

Selling fresh fish in open-air markets in tropical countries provides an interesting example of the nature of the relationship between demand and prices. The seller brings a supply of fresh fish to the market, but because there is no way to keep them cold in the hot, tropical air, the quality of the fish decreases almost from the time it gets there. As quality declines, the seller is in effect putting a new product in the market almost continuously. He is in a race with time to sell his fish before the quality is so poor that no one will purchase them at any price. At any given time, if potential customers do not like the price, they can wait until the seller is forced to lower it, but potential customers are also in a race with time. They can wait for a lower price but they also may wait so long that they purchase a spoiled fish. In this situation, affluent customers come to the market when the quality of the fish and the price are highest. The poor come to market when quality and price are both low (Steet and Sullivan, 1985).

**Supply --** Webster's *Seventh New Collegiate Dictionary* defines supply as "the act or process of filling a want or need." The phenomenon of one individual supplying the needs of another is a fascinating one. This fascination stems from the fact that adults of many species of vertebrate animals supply the needs of their offspring without receiving any compensation. Birds supply their young with food and shelter until they are ready to take care of themselves. And in some of the social insects, highly specialized supply mechanisms have evolved along with a division of labor (Wilson, 1974). One would probably conclude from these observations that there is a relatively strong selection pressure in the evolutionary process for the development of a division of labor and for one individual to supply the needs of another.

Buchanan (1987) quotes Adam Smith from his *Wealth of Nations*:

> *The principle which gives rise to the division of labor, from which so many advantages are derived is not originally the effects of any human wisdom which foresaw and intends that general opulence to which it gives occasion. It is the necessary, though very slow and gradual, consequences of a certain propensity in human nature which has in view no such extensive utility; the propensity to truck (peddle), barter and exchange one thing for another.*

In quoting Smith, Buchanan seems to be suggesting that the propensity to truck, barter, and exchange is a driving force in the development of commerce and economics. Wilson (1974) suggests that barter and exchange probably appeared early in the evolution of our species. He further suggests that without this propensity to do so, division of labor would never have developed. Obviously, without a willingness to exchange one thing for another, division of labor could not exist.

Economists define supply as part of the Law of Supply: "The price of a product or service and the amount that producers are willing to offer for sale are positively related" (Ekelund and Tollison, 1988). If the price rises, then the quantity supplied rises; if the price drops, quantity supplied drops.

Of the five parts of the production of aquatic animals process -- production, harvesting, processing, marketing, and utilization -- four are included within the definition of supply. A major portion of this book is concerned with supplying aquatic animals that people need or want. It is an enigma that of the demand-supply relationship, supply requires much of the total effort. Purchasing and consuming a cultured mullet, for example, to satisfy a demand for a fish for food usually requires relatively little effort or time. Conversely, the preparation for supplying that mullet on demand may require well over a year from the time the seed is stocked into a container until it is harvested, processed, and marketed. During this period, the supplier invests an ever-increasing amount of scarce resources in the fish. These resources must be committed on credit and on the assumption that they will be redeemed when the consumer takes title of the fish. In that long interval, the supplier must assume virtually all of the risks that the fish will either not grow or that it will die. Although the supplier assumes most of the risk, the consumer also is somewhat at risk, for if the fish does not live or is not brought to market, the individual with the need or desire for the fish is the ultimate loser.

The supplier must commit scarce resources over a relatively long period of time with the hope that, when the fish is ready for the market, there will be an individual who needs or wants the fish. Unfortunately, in most cases, the supplier must wait until the very last moment to ascertain whether or not his or her hope will be realized. With so much uncertainty and potential resource loss involved, it is fascinating that there are so many individuals ready and willing to be suppliers. Adam Smith's observation of the importance of our propensity to truck, barter, or exchange one thing for another is surprising when one considers what the supplier must invest and put at risk to provide such an important service.

The demand-supply relationship is so biased against the supplier in terms of risk and uncertainty that it was inevitable that some mechanism would evolve to bring it into a more reasonable balance with demand. This bias is the primary reason for worldwide efforts to manage the supply of agricultural products available. Governments everywhere utilize direct subsidies to farmers, marketing orders, export assistance loans, price supports, acreage set-asides, and other mechanisms to manage or guarantee the supply of food (Martinez, 1987; Matsumoto, 1988; Sheeves, 1986; Martinez, 1989).

The evolution of advertising also has provided some balance for the relationship and promises to bring even more in the future. Advertising is a means of creating (engineering) wants through a process closely related to the learning through classical conditioning described in a preceding section (Kinnucan et al., 1990). Through research on the nature of the "needs-wants" phenomenon, the supplier is better able to understand the forces that drive that process. Although, as Buchanan (1987) suggested, it is difficult to predict what choices individuals will make, it is possible through psychological research to better understand the nature and sources of the uncertainty. Armed with even this limited understanding, it is possible to devise a strategy to guide the decision or wants process. Television, radio, newspapers, magazines, and billboards are replete with efforts to "program" the choice-making process of the individual. The location of items in the supermarket is not the result of the random assignment of space, but is based on a planned strategy for managing the needs-wants process. The market research and advertising campaign undertaken by the Catfish Institute (The Catfish Journal, 1989) is a good example of the efforts on the part of suppliers to remove some of the uncertainty and inequity from the demand-supply relationship.

Supply is primarily what aquaculture is about. It is a complex phenomenon, and the complexity increases as the level of intervention increases. We need to redouble our efforts to increase the efficiency and effectiveness with which we meet needs and wants of individuals. At the same time, we need to look for ways to reduce the risk and uncertainty associated with supplying those needs and wants.

**Elasticity --** According to the Law of Demand, as the price of goods or services decreases, demand tends to increase, but to what extent? A fish farmer at the market would expect to increase sales of his mullet by lowering the price, but a more practical question is how responsive will his customers be to a specific change in price? The Law of Demand does not tell him if the buyers will be relatively responsive or relatively unresponsive.

Elasticity, or more specifically "Price Elasticity of Demand," is a measure of the relative responsiveness of buyers to price changes. Price elasticity of demand is the ratio of percentage change of the quantity demanded divided by the percentage change in price (Ekelund and Tollison, 1988). If the percentage change in demand is greater than the percentage change in price (the value of the ratio is greater than 1.0), buyers are relatively responsive or there is elastic demand. If, however, the percentage change in demand is less than the percentage change in price (the value of the ratio is less than 1.0), buyers are relatively unresponsive or there is inelastic demand.

Kinnucan and Wineholt (1989) studied demand and prices in the catfish industry. They concluded that demand is price elastic at the wholesale level, or that the processors could effect demand by changing wholesale prices which they charge their customers. They further concluded that demand is price inelastic at the farm level, or that the farmer can have limited effect on the quantity of live fish that the processor will purchase by changing prices. As a result of these observations, they suggested there would be greater volatility in prices received by the farmer for his live fish than the prices received by the processor through his wholesale outlets. When the demand-price relationship is inelastic, many factors other than demand can affect price. As these factors vary in importance, prices may vary considerably with little or no change in demand.

**Comparative Advantage --** Economists have a relatively complex definition of the term "comparative advantage." For our purpose, it is acceptable to define it as "the ability of one economic entity to produce a product at a lower price than another economic entity" (Ekelund and Tollison, 1988). This advantage comes when one economic entity is better able to use available resources to produce its product than another entity, or when one entity has better access to resources. Ikerd (1989) suggests that comparative advantage essentially means doing those things you can do more efficiently than someone else, or in other words, "comparative efficiency." Crook (1990) suggests that the principle of comparative advantage "is perhaps the single most powerful idea in economics."

Recall that Shelford's Law of Tolerance suggests species of animals and specific stages of aquaculture have optimum environments or ecosystems. In this optimum environment or ecosystem, the animal or stage of aquaculture would have a comparative advantage compared to the same animal or stage of aquaculture in a less optimum environment or ecosystem.

Given sufficient resources and sufficient time, change agencies can establish some type of aquaculture in a wide range of environments. The problem is not whether it can be established, but rather, once established, whether it can be sustained. A major consideration in sustainability is whether it has a comparative advantage in the chosen area over the culture of those animals in an adjacent area. Generally, with other things being equal, the aquaculturists with the comparative advantage will be the most successful. It is important that some determination of potential comparative advantage be included in virtually all plans for developing aquaculture, especially where it has been practiced little or not at all. This determination is not simple, because it requires a substantial knowledge of the aquacultural ecosystem utilized by the competing economic entity. This difficulty generally increases as the level of intervention increases. At the lowest levels, where the animals produced are likely to be sold in the local village, competition may be between adjacent farms. However, as the level of intervention increases and the ecosystem becomes larger, the competition for sales may be between different regions or even different countries.

The channel catfish industry is an interesting study in comparative advantage. This species reproduces and lives throughout much of the eastern United States from the Gulf Coast to the Great Lakes. For profitable production, the channel catfish must be fed a prepared feed, a grain-based ration. The best source of feed grains is the Midwest, which has a comparative advantage in the production of feed grain compared to the gulf states. Also, that region is relatively close to major markets for live and processed fish in the upper Mississippi Valley. However, because this species is cold-blooded, it grows more rapidly in the warmer gulf states. The gulf states have a comparative advantage in the production of channel catfish, because the longer growing season is more important than the ready availability of feed grains and access to markets. It is cheaper to transport feed grains to the gulf states and transport fish back to the upper Mississippi Valley and Eastern Seaboard than it is to heat water in the Midwest.

While the gulf states have a longer growing season than the midwestern states, the winters are cold enough in the South so that there is little growth during three to four months in mid-winter. Mexico and Central America have a year-round growing season, and these nations also have the advantage of a less expensive labor force. But they are even farther away from the best source of feed grains and from the markets. It is not yet certain whether their longer growing season and lower labor cost is sufficient to overcome the added cost of transporting feed grains that far.

Comparative advantage is also relatively volatile. Some factors that provide an advantage today may become a disadvantage tomorrow. It is conceivable that at some future time, energy prices will reach a level where it will be more important to be near the source of feed grains and nearer the major markets. Under those conditions, it may be more energy- and cost-effective to accept the shorter growing season and the longer production cycle in the Midwest. Comparative advantage for the production of channel catfish would shift to the Midwest just as the production of feed grains did many years ago. With feed grains, the cooler climate is an advantage.

Comparative advantage is the result of many different factors and their interactions. I suspect, however, that factors such as soil, water, climate, geography, and human culture tend to provide a more permanent comparative advantage than new technology or governmental policies such as taxation and subsidies (Martinez, 1989). Those factors listed first change very slowly, if at all. Aquaculture that matches well with those natural-resource characteristics should be relatively stable and have long-term comparative advantage. The less stable factors, such as transportation, infrastructure costs, policies, and regulations, can provide a degree of comparative advantage, but it is likely to be transitory. Where there is little or no comparative advantage, attempts to develop aquaculture likely will be an exercise in market development for farmers in a different ecosystem who do enjoy a comparative advantage. For example, it is possible to grow tilapia in Alabama, but because these species cannot survive most winters in production ponds, all of the fish must be harvested in early fall. This mandatory harvest means that all of the fish would have to be processed within a few weeks during that period. The sensitivity of these fish to low water temperature limits any comparative advantage Alabama might have in their culture. As a result, any efforts to develop an industry could end in failure when another region with a year-round growing season goes into production.

## *Time as a Dimension*

> *Throughout all of man's experience, through every aspect of the world and universe he inhabits, runs the elusive entity called time ... Time governs not merely man's activities but his very being ... Time, which gives continuity and pattern to life, also brings disruption and death ... Of all the great abstractions of science, it is omnipresent time — not space or force or matter — that comes most often to our lips ... What we cannot do, oddly enough, is define it (Goudsmit and Claiborne, 1966).*

All living things exist in a matrix of time and change with time, but only humans are able to interact with it. While we cannot slow it or speed it up, we are able to manipulate our affairs so as to use it purposefully. Humankind is able with the aid of memory, writing, drawings, and pictures to recapture some aspects of the past. In this sense, we are able to go backwards in time. Also, by recapturing the past and integrating it into our consciousness, we are able to plan for the future.

A basic phenomenon of physics is the relationship between time and motion. Physicists relate the two through the use of the rate at which one changes with respect to the other:

$$Rate = Distance/Time$$

The processes of development do not obey the laws of motion in the usual sense, but changes do take place over time, so it is possible to think of them as having rates.

All processes or aspects of development are related to time. Development takes place over time, and the rate at which development changes take place vary widely. Several hundred thousand years elapsed while our ancestors were changing from hunting and gathering to farming societies. The advantages of hybrid corn were known 25 to 30 years before it was widely used in the United States. Yet only about three years were required for the widespread adoption of new pond water aeration technology by the catfish farming industry. As noted in a previous section, some aspects of culture (Material versus Non-material) change more rapidly than others.

The differing rates of change result in some difficult problems as we attempt to promote development. Often development processes with widely differing rates are linked together in change agency projects. Because of bureaucratic requirements, too little attention is given to the time required for the desired changes in the individual processes. For example, many development projects designed by change agencies have a five-year life, but in many cases, only a few of those linked processes can be completed in five years. From a project planning, implementation, and evaluation perspective, five years may be a reasonable period, but it places highly artificial and rigid restrictions on a number of complex physical, chemical, biological, psychological, sociological, economic, and political processes which are changing at their intrinsic rates.

For example, in developing aquaculture where it has not been practiced before, it is necessary to put in place production, harvesting, processing, marketing, and utilization if the effort is to be successful and aquatic animal farming is to be institutionalized. All five processes must be linked together in the development effort, but the rate at which they proceed is different. Obtaining production can be accomplished relatively quickly. Harvesting and processing proceed at even more rapid rates. But the development of markets may require a much longer period and is difficult until at least one production cycle is completed. Finally, getting people to change their food habits to include aquatic animals regularly in their diets may require many years. It would be extremely fortunate if all of these processes could be completed in five years. Probably, under even the best conditions, it would require 15-20 years to complete all of them so that aquaculture would be institutionalized.

With respect to the role of time (and rates) as a dimension of the aquaculture ecosystems, the primary limiting factor in change agency promotion of development is that the political process generally provides the funding (energy) for all of the other processes, and its rate of change may be rapid and highly variable. Often the political process in a development effort reaches an endpoint many years before the other processes are completed. When this happens, the effort will usually yield poor results and may fail completely. It would be extremely helpful if the rate of change in the political process could be reduced, or at least made more predictable. Unfortunately given the nature of the process, this is extremely difficult.

## *Effects of Aquaculture on Ecosystems*

Most of the discussion in this section has dealt with the effect that environment has on the development of aquaculture, but aquaculture also affects its environment. This perspective of the ecosystem also is important in planning development. Pillay (1992) has written a comprehensive book on this subject, so I will mention only two examples here.

When it was determined that mangrove swamps were good sites for shrimp farming ponds, investors swarmed to those areas (McClellan, 1991). With the arrival of shrimp farming, the mangroves were eliminated. By 1985, Java had lost 70 percent of its mangroves; Sulawesi, 49 percent; Sumatra, 36 percent; the Philippines, 45 percent; Thailand, 27 percent; and Malaysia, 20 percent.

The loss of mangrove breeding and growing areas for fish and shrimp reduced the availability of these animals for local fishermen who depended on them for food.

In some cases, pumping salt water into the newly developed ponds caused salinization of adjacent rice paddies, bringing further hardship to the local farmer-fishermen in those remote areas.

When aquaculture involves the use of manufactured feeds, even with the best conversion rates achievable, a high percentage of these materials remains in the water column as uneaten feed or is returned to the water as feces (Hopkins and Manci, 1989). Boyd (1990) stated that the conversion rate of dry feed to wet weight of fish presents a distorted picture of the amount of feed going into the water column as uneaten feed or feces. From 1.5 to 2.0 kilograms of dry feed are required to produce one kilogram of wet weight of fish. However, when the dry weight of fish is considered, approximately 5.4 kilograms of feed are required to produce one kilogram of fish dry weight.

If a farmer is obtaining a conversion rate of 1.5 -- allowing him to produce one kilogram of fish for each 1.5 kilograms of feed -- 1.32 kilograms of the feed becomes organic matter pollution. Each 1.32 kilograms of feed voided as feces releases into the water 51.1 grams of nitrogen, 7.2 grams of phosphorus, and 1.1 kilograms of oxygen demand. Unfortunately, the problem does not end there. Nitrogen and phosphorus released into the water by microbial decomposition of the feces leads to the production of additional organic matter through the fixing of carbon in photosynthesis.

Poor water quality in the culture pond can result in low oxygen levels, wide swings in oxygen concentrations during the diurnal cycle, and toxic levels of ammonia. If these nutrient-laden waters are released into an adjacent stream during harvesting, the water quality of the receiving water can be drastically reduced at least temporarily, depending on the volume of water in the receiving stream. If there is a concentration of aquacultural operations in a small area, the reduction in the quality of the receiving water can be severe over a long period.

Poor water quality, resulting primarily from high levels of feeding, has emerged as the most important enemy of shrimp farming worldwide (Boyd, 1989; McClellan, 1991). For example, Taiwan's regional share of shrimp production plummeted from 21 percent to 4 percent in one year when poor water quality caused so much stress on the animals that they became susceptible to a variety of viral, bacterial, and parasitic diseases. This same situation is rapidly developing in Thailand. In some areas with limited access to good water, low-quality effluent flushed from one pond is picked by the pump intake of an adjacent pond as the owner fills the container to begin a new crop. Claude Boyd (personal communication) reports that water pollution is becoming such a problem in Indonesia that shrimp growers are searching for other countries for development. Unfortunately, the so-called Taiwan disaster will be repeated over and over until feeding levels are reduced or until more efficient pond management systems can be developed to promote faster rates of organic matter decomposition in culture ponds.

# CHAPTER 10
# AQUACULTURAL DEVELOPMENT AS A PEOPLE ENTERPRISE

**Development is a "people" matter.** Development projects often are designed to deal with groups of people, such as the poor majority, the underclass, small farmers, entrepreneurs, or women. Unfortunately, the success or failure of development is not determined entirely by group action (Polk, 1991). Groups may accomplish many important things in the development process, but only after appropriate individual decisions and inputs have been made. Development is the sum of individual decisions and actions. Governments often invest large sums in development projects, such as irrigation, roads, schools, and power generation stations. However, the ultimate success or failure of those projects will depend on individual decisions on whether to invest and to sustain the investment of scarce personal resources (land, labor, or capital). Development depends on myriad decisions and the resulting actions of individual people. But the keys to success are insuring that individuals have the opportunity to participate in decisions that affect their lives, encouraging them to make the correct decisions, urging them take correct actions following their decisions, and prevailing upon them the need to sustain their commitments.

One persistent problem in promoting development has been that individuals often have limited opportunity to make decisions on matters that will significantly affect their lives. Too often decisions on what development strategy to promote and how to promote it are made far from the people who will have to make the final decisions on the commitment of scarce personal resources. With too many of the typical top-down development projects, change agencies seem to say that the poor or those who will be directly affected by the process cannot be trusted to make decisions about their own economic well-being. However, as Sincere (1990) points out, even the poorest persons, whether in New Delhi or New York, in Abidjan or Aberdeen, know how to make a choice in their best interest. In the same context, Herman (1991) suggested that the answer to failed top-down economic and social engineering could be greater participation of clients in the decision-making process. He quotes the distinguished British economist, Lord P. T. Bauer on this matter:

> *Economic responsiveness does not depend on literacy or formal education. Illiterate, uneducated people can readily recognize the extension of their opportunities. They can tell whether a change makes them better or worse off, and they can certainly tell the difference between more and less.*

In this context, Herman (1991) suggests that the answer to failed top-down economic and social engineering could be greater participation of clients in the decision-making process.

While individual decisions and actions are the basic building blocks of development, it is important to emphasize that individuals must also come together and function as a unit in most development situations. At the lowest stages of aquaculture, there might be limited need for group decisions. However, at the higher stages, group decisions are essential, for example, in passing taxes to build roads and bridges required for complex marketing systems ... in efforts to support research to develop necessary new technology ... in the formation of associations to promote the use of cultured aquatic animals ... or in the development of product quality standards to protect the viability of the industry. Individual decisions are the building blocks of development, but in many situations those decisions are less effective if they are not expressed in concert with other individuals.

It is probably appropriate to suggest that development does not really occur until individuals commit scarce resources to the process on a sustained basis. Earlier understanding of development tended to suggest that government or ruling elites were the chief sources of human progress. Now, the idea is slowly emerging that individuals working for their own economic and social improvement are the only real source of development (Agency for International Development, 1989). T.W. Schultz succinctly described this role of individual people in development:

> *The future productivity of an economy is not foreordained by space, energy, and cropland. It will be determined by the abilities of human beings. It has been so in the past and there are no compelling reasons why it will not be so in the years to come.*

There are at least three basic traits of people that must be dealt with effectively in the development process:

> *1. Individuals by nature will make decisions and take actions which they perceive will improve the quality of their lives.*
> *2. Predicting decisions that individuals will make concerning the use of their scarce personal resources is extremely difficult.*
> *3. The rate at which individuals adopt technology and the effectiveness with which they manage it vary.*

Suggesting that people have these traits is not meant to denigrate or to categorize them unfavorably. Rather, it is to suggest that these traits played important roles in humankind's long struggle against environmental resistance while trying to improve the quality of life. These traits played an important role in the development of human civilizations and continue to play central roles in their affairs today. I suggest that we can encourage and promote continued development, more specifically aquacultural development, by working within the framework of these same traits.

## *Improving Quality of Life*

As suggested above, individuals will make decisions and take actions which they perceive will improve the quality of their lives. The unrelenting pressure of the Second Law of Thermodynamics ultimately will force the evolution of energy use efficiency in all living things. I suspect that this may be one of the major driving forces of Darwinian evolution. In this sense, improving the quality of one's life would result in an improvement in the utilization of energy. Agriculture and a more predictable food supply is more energy efficient than hunting and gathering, at least for a large population of people. Improved clothing and shelter, which improve the quality of life, would also result in increased efficiency in the use of energy. While this process ultimately must move in only one direction (toward energy efficiency), there are likely to be many wide positive and negative swings in the process.

Improving the quality of one's life seems to be something everyone would want, but it is a complex phenomenon. Taking actions that may improve quality of life, almost without exception, requires the expenditure of scarce resources (land, labor, and capital). Improvement must be purchased at a price. Individuals with limited resources must be convinced beyond a reasonable doubt that the expenditure of those resources would result in a better quality of life, but these individuals are by nature conservative in making these decisions. The desire to improve the quality of life can be a powerful force. It can encourage the development of aquaculture if the individuals involved can be convinced that the investments required will really result in improvement and if they actually have the resources available to make those investments.

## *Making Decisions*

Buchanan (1987) suggests that "predictions about the behavior of individually identifiable human beings are clearly impossible except in rare instances." It is extremely difficult, if not impossible, to predict how individual farmers will respond to efforts by a change agency to promote aquacultural development, how individual consumers will respond to the introduction of a new species of aquatic animal to the market, or how they will react to an increase in the price of an animal already in the market. Some of the factors that affect decision making were discussed in this book's section on the "Psychological Dimensions of the Aquaculture Ecosystem."

While a study of past choices that individuals have made in the marketplace may provide some indications of choices they may make in the future, these indications often are little better than guesses. When the nature and the dynamic process of human consciousness (Lewin, 1988B; Myers, 1989) are taken into consideration, the difficulty of predicting behavior is to be expected.

Predicting choices that individuals will make in managing their households, satisfying their wants, and trucking, bartering, or exchanging one thing for another is extremely difficult. Further, aggregating individual uncertainties by creating an average individual for purposes of prediction does not improve the situation at all. The difficulties that economists have in attempting to predict recessions, unemployment rates, inflation rates, stock market trends, or dollar exchange rates provide ample evidence of the difficulty of aggregating unpredictable individual choices. This lesson should not be lost on those of us involved in the development of aquaculture. Regardless of how promising the advancement of the production of aquatic animals might be from our perspective, the success of our efforts will ultimately depend on individuals making decisions based on their circumstances and preferences at the moment.

## *Adopting and Managing Technology*

Individual differences make up an important aspect in the success of any development effort. In the previous section, the difficulty of predicting individual decisions was discussed. In this section, two other important characteristics of individuals relative to development will be discussed briefly.

### *Individual Variations in the Rate of Adoption of New Technology*

The rate at which acceptance of new technology takes place is dependent on personal, social, and cultural characteristics and on the economic status of individuals. These characteristics include age, education, spirit, experience, wealth, social activeness, role in the community, degree of conservatism, attitude toward change, and certain community cultural characteristics. Based on the rate at which they adopt innovation, people can be divided into five general groups:

1. *Innovators (venturesome).*
2. *Early Adopters (respectable).*
3. *Early Majority (deliberate).*
4. *Late Majority (skeptical).*
5. *Laggards (traditional).*

Maunder (1973) and Rogers (1983) describe characteristics of these five groups with reference to their perception of and response to innovation. Rogers' characteristics are shown within the parentheses. There are differences in the rates at which individuals respond to new technology. However, these differences probably are not as pronounced as the groupings would indicate, but rather a continuum of responses. Also, these group designations do not suggest that one is clearly more important than the other in the development process. All of these groups play a vital role in development. Innovators certainly are important, but they sometimes do not sustain the level of interest or commitment long enough to effectively support the development of the aquacultural ecosystem. In contrast, once the laggards do accept the new technology, they will usually remain highly supportive. Obviously the pioneers are important in the development process, but no more important than the settlers who follow.

Brown (1981) and Roling (1984) suggest that there are other factors that contribute to this range in the rate of technology adoption -- from innovators to laggards. They suggested that in too many cases being an early adopter tended to be more a function of having access to resources, while lack of access to resources tended to cause others to lag in adapting new technology. Roling further suggests that the tendency now is to substitute "system blame" for "person blame" in explaining differences in the rate of adoption of new technology. Lovshin et al. (1986) and Schwartz (1986) discuss a number of psychological, social, and cultural factors that affected the rate at which aquacultural technology was accepted by people in some rural areas of Panama. Clearly the pendulum is swinging toward blaming the system and away from personal traits of individuals as an explanation for differences in the rate of adoption of new technology. It probably is a mistake to spend too much time fixing blame in either direction.

***Differences in the Ability to Manage New Technology***

Roling (1984) notes that on the "polders," or reclaimed lands in the Netherlands, where carefully selected farmers were located on uniform tracts of land, there were large differences in the results achieved by those individuals. He suggested that these differences were the result of variation in managerial ability, entrepreneurship, and professionalism between individuals. Similar results have been reported with American farmers (Jerry Crews and Joe Yeager, personal communications).

Aquacultural development is a people business. It will not proceed without their participation. Obviously, there would be no need for it except for people. However, the nature of people and their institutions make development a difficult process to manage. Development proceeds, as suggested previously, because people want to improve the quality of their lives, yet it cannot always be advanced very efficiently because of the characteristics noted above. These characteristics of people are the basic building blocks with which we have to work in aquacultural development. They are the only game in town. Our ability to work constructively with those individual differences and responses of people will determine, to a large extent, the success of our efforts to promote the development of aquaculture.

# CHAPTER 11
# APPROPRIATE LEVELS OF INPUTS

ONCE THE GOALS OF DEVELOPMENT have been adequately defined, the next step in the process is to choose the technology that will provide the levels of intervention or stages of aquaculture required to achieve those goals. Here I am using the more general term, technology, to include any input, combination of inputs, or any stage of aquaculture that might be required in the development process (information, procedures, chemicals, tools, and machines).

In choosing activities with potential for meeting the goals in a particular situation, one must first consider whether the development involves changing existing aquaculture or introducing aquaculture where it has been previously practiced little or not at all. Each of these development situations will be considered in the following sections.

## *Changing Existing Aquaculture*

The first general environment where aquacultural development is promoted is where aquaculture already is being practiced, and the goals of development are to change some characteristics of the existing industry to bring it to a more advanced state. There are two general types of changes that can be made in existing aquaculture:

*1. Vertical Change — A change that will result in an increase in the number of units of aquatic animals produced.*

*2. Horizontal Change—A change that will result in an increase in the efficiency of the system or that will result in an increase in the rate of return on investment at a given level of production.*

These are not highly specific or mutually exclusive. In some cases, a change (a development initiative) can increase both the number of units of animals produced and the return per unit produced. However, the two general situations do provide a useful framework for considering the development of existing aquaculture. The important consideration in emphasizing these two general methods is that all development does not necessarily result in the production of more aquatic animals. Bringing out the capabilities and possibilities of aquaculture can be accomplished without an increase in production. Obviously, given the world fish supply situation, increasing total production is a major goal, but in many cases, improving the return on investment or horizontal change at a given stage of production also is important.

An example will provide a clearer differentiation of these two generalized methods of development. Fish ponds in the tropics which are stocked only with a single species of tilapia and do not receive fertilizer or feed usually contain a modest quantity of fish after one year in production. Production of green plants (algae) and, in turn, microcrustaceans, insects, and fish is dependent on the plant nutrients (nitrogen, phosphorus, potassium, etc.) in the soils surrounding the ponds. For example, van der Lingen reported (Hepher and Pruginin, 1981) that in ponds in Rhodesia stocked with *Oreochromis mossambicus* and not receiving fertilizer or feed, the carrying capacity was approximately 900 kilograms per hectare. The carrying capacity or units of fish produced in those ponds was increased to approximately 2,130 kilograms per hectare by adding inorganic fertilizers. By adding supplemental feeding plus fertilization, production was increased to 6,160 kilograms per hectare. This is an example of vertical development. By increasing the input of nutrients in an existing container, the number of units of fish produced was increased. The possibilities and capabilities of aquaculture were advanced by increasing the nutrient input in the system.

While the total weight of fish was increased in this situation, the return on investment may have increased very little. The tilapias have relatively high rates of reproduction. In ponds containing only these fish, most of them will be small because there are more individuals present than can be grown to a larger size with the natural food limitations. While there are many fish present, most of them may be too small to be of much value in the market. In some countries, people will not accept the smaller sizes of *O. aureus* for food. For example, Galbreath (personal communication) noted that the market in Ivory Coast would not accept fish less than 150-200 grams in weight. In others, the size of the fish is of little concern to consumers. They will eat any size fish available (Low, 1985). If the fish in the pond are too small, fertilization generally will not solve the problem. Although the amount of natural food will be increased as a result of fertilization, the individual fish get no larger. Instead, with more food available, more young fish are produced, and competition for food is greater.

In this case, the return on investment would be low because of the limited value of the small fish and the cost of fertilizer. A more effective solution would be to add a predatory fish such as *Cichlasoma managuense* (Dunseth, 1975; Bayne et al., 1976). The predator consumes some of the small fish after they hatch. As a result, excess *O. aureus* seed are converted into *C. managuense*. Because the number of seed are reduced, those remaining have more food available and will grow larger. Consequently, they may be much more acceptable in the market and should bring a higher price and a larger return on investment, although there would be some additional cost in stocking the predators in the pond. Ofori (1988) reported that stocking the Nile perch (*Lates niloticus*) into ponds containing three species of tilapias resulted in the higher yield of larger tilapia and a higher gross income.

In the predator-prey (polyculture) situation, total fish production in the pond may actually be lower than in the monoculture. There is inevitably a loss of energy from the system as *Oreochromis* are converted to *Cichlasoma*, as a result of the effect of the Second Law of Thermodynamics. Also in the monoculture, there were so many small fish present that virtually every natural food item (microcrustaceans and insects) was consumed almost as it was produced. There was little loss of food from the system. In the predator-prey situation, because of the reduced number of fish, some food animals would escape predation to complete their life cycles and die.

Depending on the specific situation, either "vertical" or "horizontal" development could be a more important development goal. In the following sections, both will be discussed.

***Vertical Change***

With the current status of aquaculture worldwide, increasing the quantity of aquatic animals produced is the most common of the two general types of change taking place. Generally, aquaculture is in a sellers' market phase. The demand for fish relative to supply is increasing so rapidly that virtually all the fish that can be produced can be sold at a reasonable price. Under these conditions, farmers rush to increase the number of units of animals produced rather than to be overly concerned with improving the rate of return on the individual unit.

Generally, bringing existing aquaculture to a more advanced state through vertical development involves introducing some new technology, such as a new species of fish, a better feed, improved pond aeration equipment, or a new management practice. In this process, existing aquacultural ecosystems are analyzed to determine what factor(s) or input must be altered to allow the system to be moved to the more advanced state. I have previously described a systematic procedure for identifying these bottlenecks, based on the "ladder of the intellect" of Sir Francis Bacon (Platt, 1966; Van Doren, 1991), in the book *Fish Farming Research* (Shell, 1983). While the specific procedure described in that work is most applicable to the production component of aquatic animal culture, it can be applied equally well to the other components (harvesting, processing, marketing and utilization). The general process of selecting the appropriate technology for eliminating the bottlenecks will be described in a following section.

While there is a strong tendency to emphasize vertical change in aquacultural development, it is important to remember that as production per unit of container is increased, the dimensions of the ecosystem also expand. Increasing production often requires more nutrients, more services, more equipment, and more complex marketing arrangements if the ecosystem is to remain in balance. Remember that an increase in the dimensions of the ecosystem is accompanied by an increase in its complexity.

There are several general methods for increasing the number of units of aquatic animals produced on existing farms. Included are examples, which will be discussed in the following sections:

*1. Increasing the number of production units (containers).*
*2. Upscaling the stage of aquaculture practiced.*
*3. Improving the effectiveness of individual inputs.*

**Increasing the Number of Containers --** Increasing the number of containers operated by an individual farmer is an effective vertical change tool. Experienced farmers usually are able to handle the increase relatively easily. They are familiar with all of the inputs required and where they may be obtained. They also are familiar with the problems most likely to be encountered. Obviously, it is implied that increasing the number of containers requires a commensurate increase in all of the inputs required (capital, nutrients, labor, processing, marketing, and consumption). If the farmer already is successful, usually little encouragement will be required.

Simply increasing the number of containers without adequate attention to the other inputs can lead to serious stresses in the culture ecosystem and to catastrophic failure. For example, increasing the number of units produced by increasing the number of containers in operation could lead to a serious problem for the farmer if there were not unused capacity available in processing and marketing.

One other problem should be avoided in increasing the number of containers operated by a farmer. Often the most suitable sites for containers are developed first. Subsequently, if poorer sites are developed to increase total production, serious loss of production efficiency can result. At the same time, however, adding new containers can be an advantage in the respect that mistakes made in the development of containers at an earlier time can be avoided subsequently.

**Upscaling the Stage of Aquaculture Practiced --** Moving up the scale (increasing the level of intervention) of aquacultural practice is another means of increasing the number of units of animals produced. With this method, the farmer is encouraged to move from a lower stage of aquaculture to a higher one. Generally, as the stage of aquaculture is advanced, the number of units of animals produced per unit of container increases. The upscaling of channel catfish production procedures used in Alabama in the late 1950s as recommended by Swingle (1958) and production procedures in use today (Jensen, 1981; Busch, 1985A) are an example of this method of aquacultural development. In the 1950s, the stocking rate of the containers was extremely low compared to stocking rates used today. The fish generally were fed incomplete rations. Feeding rates were kept low to prevent water quality problems. Most of the fish were sold locally. Now stocking rates are several-fold higher. Feeds have been improved significantly, and different forms of feed (floating and sinking pellets) are utilized. Aeration is used to maintain water quality when the normal photosynthesis-respiration balance in the container is seriously disrupted. Per unit production of channel catfish is increased significantly.

Upscaling or increasing intervention, while potentially leading to increased production, inherently leads to increased responsibility for management. Usually as the production rate per unit increases, the risk of catastrophic loss also increases. As the stocking rate is increased, the amount of nutrients added also must be increased. Consequently, the amount of wasted feed, feces, and other metabolic wastes that must be oxidized by the aquatic system is increased significantly (Tucker and Boyd, 1985). The oxidation of wastes leads to the release of inorganic compounds (phosphorus, nitrates, and carbon dioxide) which are utilized by algae. This process leads to the development of dense blooms of phytoplankton and to wide swings in the concentration of dissolved oxygen in the container. Under some conditions, the oxygen concentration becomes so low that all of the fish die (Boyd, 1990). As was noted previously, upscaling the stages of aquaculture usually leads to increased production, but it also leads to increased complexity.

**Improving the Effectiveness of Individual Inputs --** This general method of increasing production in existing units is utilized relatively little on a worldwide scale, although it is important in a few specific culture systems. The method involves, for example, the utilization of genetically improved seed. While current use is somewhat limited, the potential for use in the future is extremely promising. Certainly, if the experiences in production in animal agriculture are a guide, the future for the use of genetically improved aquatic animals is extremely promising. In fact, with the broad diversity of gene pools of cultured aquatic animals available in the world and unique reproductive characteristics (large eggs, external fertilization, large numbers of eggs per female, etc.), the future for the use of genetically engineered aquatic animals may be greater than for animal agriculture.

Already genetically improved rainbow trout are being utilized in the culture of that species (Ingram, 1987B), and sex-controlled individuals are being used to good advantage. Genetically improved common carp also are cultured, especially in Central Europe and Israel (McLarney, 1984). The first genetically improved channel catfish have been released to farmers by fish breeders at Auburn University, but very few of these are yet being produced for market (Dunham and Smitherman, 1985).

Another example of improving the effectiveness of individual inputs would be the use of improved feeds. In the early days of channel catfish farming, most producers utilized an incomplete ration (Welborn and Tucker, 1985), which did not meet all of the nutritional requirements of the fish. The difference between what was needed by the fish and what was supplied in the diet had to be made up by the fish foraging on natural foods in the pond. Thus, the maximum weight of fish that could be produced was determined to some extent by the availability of natural food. Changing to a complete ration limited the importance of the natural foods in the production process. Fish production on a given weight of feed, in a unit of production space, and at a given stocking rate could be increased by improving the quality of the feed.

### *Horizontal Change*

Horizontal change refers to those methods that generally do not result in the production of more units of animals, although in some cases that may happen. The emphasis is primarily on increasing the rate of return on investment at a given level of production. Usually these methods involve improving the balance of the inputs required. An example of this method was presented previously in this section by describing the stocking of a predator in a tilapia monoculture pond (Bayne et al., 1976).

Horizontal change is not yet widely used as a tool in aquacultural development. As was noted previously, aquaculture, in most cases, is in a seller phase. There is limited concern for balancing inputs and for increasing the efficiency of the production systems. However, as supply begins to overtake demand and competition in the market increases, the concern for the rate of return will inevitably increase. Sarig (1988) has questioned the relationship between maximum production and profitability on Israeli fish farms.

While there is relatively little immediate concern for balancing the inputs (horizontal change) as a development tool, it is important to have the method ready when it is needed. Farmers should be regularly reminded that horizontal development is an important concern for the long term. Those farmers who are little concerned for balance in their operations could experience serious difficulty in an increasingly competitive market. If this situation is widespread in an industry, it can lead to catastrophic financial losses and to a reduction of production while farmers struggle to cope with new realities.

Numerous input changes in aquaculture can increase return on investment but cause little or no increase in the total number or weight of animals produced. The following list includes three of those changes as examples:

1. *Change the species being cultured.*
2. *Change the timing of the production cycle.*
3. *Change the marketing strategy.*

**Change the Species Being Cultured** -- *Oreochromis mossambicus*, the so-called Java tilapia, was transported and introduced widely in the tropical developing world following World War II (Hickling, 1968). The fish were easy to reproduce, and they ate a wide variety of foods. They were an ideal culture animal except for the fact that in most situations they began to reproduce before reaching market size (Hepher and Pruginin, 1981). With the attainment of sexual maturity, growth rate slowed significantly. They essentially filled up the container with more reproduction (seed) than could be grown to a market size with the amount of natural food available. Also, these fish tend to be darkly colored and generally unattractive in the market.

More recently, other species of tilapia with most of the desirable characteristics of the Java tilapia and fewer of the undesirable ones have been collected from the wild. *Oreochromis niloticus* and *O. aureus* are being used to replace *O. mossambicus* on farms in many countries. These species grow to a larger size before becoming sexually mature, and they are much lighter in color. They are much more attractive in the market. By changing species and keeping other inputs at essentially the same level, the value of the product is increased, and the return on investment also should be increased.

Sarig (1988) reported that on Israeli fish farms, the choice of species has a major effect on farm profitability. Farms were most profitable when they stocked more mullet, compared to farms that stocked more common carp, silver carp, or tilapia. Also, replacing *O. niloticus* x *O. macrochir* hybrids with *O. niloticus* as the primary culture species in Rwanda was a primary reason for the resurgence of interest in aquaculture in that country (Hishamunda and Moehl, 1989).

**Change the Timing of the Production Cycle** -- In the usual pattern of production in the channel catfish industry, seed are stocked in February or March (Jensen, 1981). The fish are fed a prepared, complete ration until September or October when they are harvested. This system effectively utilizes the warm months of summer when the fish grow rapidly. Unfortunately, when too many farms use this particular production cycle, there is an excess of fish available from September to December and a shortage from February to April (Busch, 1985A). Fish prices tend to be lowest in the fall and highest in the spring. Farmers who can alter their production schedules so that fish are available during the period when the supply is somewhat limited can receive a higher price. Many farmers in Mississippi utilize a continuous production system so that they will have fish available for sale when the general supply of fish is at its lowest point.

**Change the Market Strategy** -- More than 90 percent of the channel catfish produced in the United States is sold to companies that both process and market them. The price paid to farmers at the pond in 1986 and 1987 ranged between 55-65 cents per pound. In some situations, farmers have a marketing alternative. The channel catfish is considered by many to be an excellent sportfish. It can be readily caught with a variety of sportfishing gear. Farmers who are near population centers have the opportunity of selling their fish to fishermen. Instead of harvesting the fish and selling them to the processor, the fish can be harvested and stocked in ponds where fishermen are permitted to remove the fish by hook and line (Prather, 1964; McLarney, 1984; Cichra and Carpenter, 1989; Engle et al., 1989). Fishermen are willing to pay a higher price for the fish than the processor. Obviously, there are limited opportunities for selling fish through fish-out compared to selling to processors. However, where the opportunity exists, the return on investment at a given level of production is much greater.

## *Introducing Aquaculture into New Areas*

The second general case of aquacultural development involves establishing the farming of aquatic animals in areas -- on individual farms, in regions, in provinces, even in countries -- where it was never practiced before or practiced only on a limited basis.

In a preceding section, it was suggested that in order to bring existing aquaculture to a more advanced state that it was generally necessary to introduce new technology into the existing aquatic animal farming ecosystem. In contrast, to introduce aquaculture to new areas, proven technology from another ecosystem generally is used.

There are two stages to the process of choosing the appropriate technology for introduction into new areas, both of which will be considered in the following sections:

*1. Defining the new environment.*
*2. Matching the technology with the environment.*

### *Defining the New Environment*

The first step in selecting the best technology to be used when establishing aquaculture in a new area is to precisely define the environment where it will be introduced. Here the term "define" means "to determine or fix the boundaries or the extent of," and the term "environment" is defined in its broadest sense as "the aggregate of surrounding things." Thus, defining the environment means to determine the boundaries of the aggregate of surrounding things where aquaculture is to be introduced, considering factors such as the area's geology, hydrology, sociology, economics, climate, transportation, and services available. The environmental requirements or inputs of aquaculture were described previously. The environment where the aquaculture is to be introduced should be defined in terms of those requirements. It is difficult to overemphasize the importance of this step. Poor definition of the total environment (ecosystem) is a primary cause of failure or poor performance of aquaculture when introduced into a new area. Poor environmental definition can lead to poor selection of a system of culture to be introduced.

Aquaculture is a chain, or series, of events (stocking, growing, harvesting, and marketing) that must take place in a relatively orderly fashion. The environmental requirements of aquaculture were listed in Chapter I in the general order in which they are needed. If one of these events does not occur more or less on schedule, the entire process of aquacultural production can quickly come to a halt. Defining the environment is a means of determining whether all of the required inputs can be reasonably expected to be available when they are needed.

There is a danger in oversimplifying the process of defining the environment.

Certainly, that is the first step in the process of introducing aquaculture, but doing it is not as easy as saying it. The human environment (people, land, climate, history, government, economics, etc.) is a complex ecosystem in which some components are constantly changing, while at the same time others are changing ever so slowly. As a result, determining the boundaries is also complex because they keep changing. From the time a decision is made to consider introducing aquaculture until it is implemented, many of the boundaries may change significantly. A once promising economic environment quickly can become a poor one.

The size of the environment to be defined also is critical in the definition process. Defining the environment for aquaculture on a single farm is obviously less complex than the process for a state, province, or country. The process becomes somewhat less overwhelming, however, when it is remembered that the introduction of aquaculture in a state or province is the sum of introductions onto a number of individual farms. But it is important to remember that the whole can be quite different than the sum of its parts.

The difficulty in defining the environment is also related to how isolated the new area is from other environments where aquaculture is practiced. It is relatively easy to define the environment for aquaculture on a farm when it is already practiced on an adjacent farm, but it is much more difficult in a province or country where the nearest aquaculture may be hundreds or even thousands of miles away.

Defining the environment should be done systematically lest some important characteristic be overlooked. The only way to adequately define the geographic, economic, climatic, and social boundaries of the environment is to prepare a list of information required before beginning the definition process. A comprehensive plan for systematically collecting the required information was described by Schmittou (personal communication) for use by Auburn University in planning aquacultural development projects in developing countries. Shang (1981) also has developed a check-list to be used in determining the suitability of a given environment for aquaculture. His list requires obtaining information on soil and water resources, environmental suitability, biological factors, market potential, economic feasibility, and institutional feasibility. He suggested that this information be collected jointly by a biologist and an economist.

Pollnac et al. (1982) suggested that there were a series of decision points that should be considered in designing development projects. These decision points, in effect, define the environment or ecosystem where aquaculture is to be introduced. Their list of decision points, which place more emphasis on the socio-economic dimensions of the environment, include the following:

1. *Assessment of consumer demand for fish.*
2. *Availability of fresh fish in the market.*
3. *Potential to increase availability of fresh fish from a capture fishery.*
4. *Evaluation of natural resource inputs.*

5. *Cost/benefit analysis of aquaculture versus other animal protein sources.*
6. *Assessment of infrastructure.*
7. *Biosocioeconomic cost/benefit analyses.*
8. *Attitudes toward proposed aquacultural systems.*
9. *Availability of skilled personnel.*
10. *Assessment of capital distribution.*

***Matching the Technology to the Environment***

Once the environment in question is adequately defined, the next step is to determine which stage of aquaculture a particular environment can support. The range of aquacultural stages and the environmental requirements of each stage were discussed in a preceding section.

In some situations, selection of a system or a stage of aquaculture for introduction is relatively simple. In the area around Yazoo City, Mississippi, where a high percentage of the catfish in the United States is produced, selecting a system for introduction on a new farm requires nothing more than defining the details of the system already in use throughout the area. The environment is relatively homogenous, and the stage of culture in use is relatively well standardized. Choosing the system for an additional farm is a simple matter.

In contrast to the situation in Mississippi, selecting a stage of aquaculture for introduction in the Piedmont region of east Alabama is more complex. There are no processing plants operating in that area. Harvesting, processing, and marketing must be done by the individual fish farmer. Also, some of the other environmental requirements (inputs) are more difficult to obtain and more expensive. Water availability is quite different in the Piedmont than in the Delta in Mississippi.

Selecting an aquacultural system for some regions of Central and South America presents an even greater problem than in the Piedmont area, because there is at least a rapidly growing catfish farming industry in west-central Alabama. Some of those experiences are transferrable from west to east, and technology transfer (information) systems are effective. In some regions of Central and South America, there is little or no history of aquaculture in an entire country. Consequently, there are few experiences on which to base the selection of a system for introduction.

In selecting a stage of aquaculture for introduction where there is little experience to serve as a guide, there are some general principles that can be followed. For example, it is essential that all of the input requirements must be met if the introduction is to be successful. These requirements form a kind of chain of events. If a single link is available in limited quantity, it will seriously jeopardize the success of the introduction. Remember that Liebig's Law of the Minimum also applies to these situations; the level of success will be determined by the level of the required input available in the most limited quantity.

In addition, not only must all of the requirements (links) be available in an environment, but a rather specific combination of levels of the requirements also must be available. Shelford's Law of Tolerance seems to apply to these complex ecosystems as well as to the simpler ecosystems. For example, introducing an intermediate stage of aquaculture when only a low level of marketing is available would probably result in disequilibrium. Similarly, introducing a high level of intervention when using containers usually associated with the lowest stages of culture also would likely lead to considerable difficulty.

## *Suggestions for Selecting Appropriate Inputs*

In this section, I have discussed the planning of a development strategy in rather general terms, but there are some specific practical aspects that should be considered. Some of those are listed below and will be commented on in the following sections:

1. *Choose an optimum environment for introducing new technology.*
2. *Establish a critical mass.*
3. *Establish a balanced system.*
4. *Time the introduction carefully.*

### *Choose an Optimum Environment*

It is important to choose an optimum environment for the initial introduction (diffusion) of aquaculture into a new area. It is important that few, if any, efforts to develop aquaculture fail. It is especially important that few failures occur in provinces, states, or regions where it has not been practiced previously. Development efforts under these conditions are extremely fragile. A failure in this situation can make it extremely difficult to try to establish aquaculture later.

An American company attempted to establish a relatively large catfish farming enterprise in south Georgia in the United States several years before the industry began to develop in Mississippi or Alabama. This was a highly successful company in other areas of food and fiber production. It was assumed that the company would be equally successful in this endeavor. There were many flaws in the technology available to the company at that time. For that reason and several others, the enterprise had to be abandoned. As a result, it was extremely difficult to achieve even a modest growth rate for the fish-farming industry in that state for many years after the failure of the business. Even today, the development of catfish farming there lags behind Mississippi, Alabama, and Arkansas even though Georgia has good soil, water, and climate. There were other reasons for this situation, but the failure of that early attempt at development certainly had a significant effect.In wildlife management, when an effort is made to introduce an animal into a new area, every effort is made to locate a release site that has all of the environmental factors required by that particular species. It is anticipated that, once established, the introduction will spread rapidly as a result of reproduction and dispersal into adjacent areas with less than optimum conditions. In the case of the introduction of aquaculture, it also is anticipated that once established, if successful it will diffuse into surrounding areas. This principle of seeking an optimum environment for the introduction of new ideas is an ancient one. A parable recorded in the Bible admonishes the sower to sow his seeds on "good ground."

In a previous section, it was suggested that at a given stage of aquaculture there is a combination of levels of intervention for each input (containers, seed, labor, processing, etc.) that are optimum for that stage. When that stage is to be introduced into a new area, it is essential that a site be chosen that can provide all of the inputs at the required levels when they are required. If these inputs are not available in the required quality and quantity, the resulting effect of Liebig's Law of the Minimum will probably lead to the failure of the introduction.

### *Establish a Critical Mass*

In establishing an animal in a new environment, it is necessary to introduce enough individuals to create a "critical mass" or a critical population density. The number and size of largemouth bass and bluegill seed required for stocking a new pond to establish a balanced population is an example of this principle (Swingle and Smith, 1947; Swingle, 1950). In a few situations, establishing this critical mass might require the introduction of no more than a sexually mature pair. However, in most cases a larger number would be required to guarantee that reproduction will take place and that the population will become self-sustaining. Also, stocking a larger number would guarantee a much more rapid expansion of the population in the new environment.

The matter of critical mass is quite important in introducing aquaculture to a new environment. One must consider how many ponds and how much labor, credit, processing capacity, and marketing must be available at a given stage of aquaculture or would have to be made available to guarantee a self-sustaining aquacultural system. If a critical mass of these inputs is not achieved in the introduction, the probability of failure of the introduction is quite high.

Critical mass tends to change with the stage of aquaculture introduced. For example, on a dammed, tidal stream culture in which the family producing the fish and shrimp consumes the entire crop, a single farm could be self-sustaining. From its own resources, the family could provide all of the necessary inputs. The presence or absence of other similar farms would be of little consequence. Critical mass would play a role only with respect to the size of that particular aquacultural system. If the container is too small and the yield too low, the return on investment even at that stage may be too low. There are economies of scale even here. If the return on investment is too small, the family probably would not maintain the dam or manage the water level, and aquaculture would not be sustained.

In many villages in emerging nations, where the development of aquaculture would provide rich dividends for the people, too often it is difficult to make the introduction because it is not possible to establish the necessary critical mass to sustain the system. Resources may be so limited that a number of families must cooperate to provide the inputs. Unfortunately, even though production may be relatively good, it is not sufficient to provide more than a token amount for each participating family. While the return on total investment might have been relatively good, individual investments are so small that returns would be discouraging.

At the intermediate stages of aquaculture, the critical mass situation becomes more complex. For example, when production on an individual farm exceeds what the family or other families in the vicinity can consume, some processing usually is required to prepare the product for marketing away from the immediate area. The success of processing plants requires a dependable and continuous supply of product from the farms. For example, a moderately well equipped, mechanized (one band saw) processing plant for channel catfish must process approximately 3.7 million pounds of fish per year to operate profitably. Assuming a moderate rate of production of 3,000 pounds of fish per acre per year, a critical mass of approximately 1,200 acres of production would be required to sustain the plant. Without at least that many acres in production within the effective transportation range of the plant, it could not remain in operation, and without a plant the farmers cannot market their fish. In this situation, the aquacultural system would not be sustained.

Smaller, less mechanized catfish processing plants can operate efficiently and at a profit, but they probably cannot do so except when supplying fish for small and specialized markets. Where there is custom processing for local restaurants and other local customers, they usually can charge a slightly higher price. These small plants cannot compete effectively in the larger regional or national markets unless they can reach some agreement with a larger processor or broker to market their fish for them. Small operations cannot afford to provide specialized processing and packaging, refrigerated transportation, or a sales staff, which are all required in the larger markets. Even where smaller processing plants can function efficiently, there still is a critical mass requirement involved. Several small-scale catfish processing plants have failed in east and south Alabama because of a lack of fish. There simply was not a critical mass of farms and other required inputs to sustain them.

Critical mass may be defined in terms other than the acres of farms required to maintain a processing plant. In some situations, the size and nature of the market determines it. In this case, the amount of product required to establish and maintain a specific market determines the number of processing plants and the amount of production area required. Critical mass also is affected by economies of scale of some of the required inputs. Establishing catfish farming in areas far removed from the center of the industry in southeast Arkansas, west-central Mississippi, and west-central Alabama is difficult because there are not enough farms in the beginning to obtain bulk prices for feed, seed, and other inputs. Yet price of the finished product is largely determined by the production, processing, and marketing of fish from Mississippi, where most of the catfish are produced and processed. Production costs are a function of the volume of production. In east Alabama and west Georgia, market price is essentially fixed, but production costs are higher because of the lack of a critical mass of farms and the resulting economies of scale.

There probably is a critical mass in every case where aquaculture is being introduced into a new area, regardless of the stage being introduced. Although quantities available of all of the inputs could, under some circumstances, determine the critical mass, the marketing and utilization inputs probably are most important in determining it.

### *Establish a Balanced System*

The concept of "balancing the inputs" in aquaculture was discussed previously. It was suggested that, at each stage of aquaculture and for each system established utilizing that stage, there is an optimum combination of levels of inputs, such as containers, seed, water, and nutrients. When this combination is in place, the system would be balanced for that particular environment. In introducing a system of aquaculture into an area where it has not been practiced previously, it is necessary to provide the inputs in the proper amount so that it will come into balance and remain that way.

As was noted in the previous section, mechanized processing plants and catfish production ponds must be established in a fairly specific ratio -- 1,200-1,500 acres of production units for each plant. Further, other inputs would have to be available in a relatively narrow range. For example, channel catfish fingerlings usually are stocked in production ponds at sizes ranging from five to seven inches (13-18 centimeters). To obtain fingerlings of this size, the rearing pond cannot contain more than 50,000 fish per acre (123,500 per hectare) (Busch, 1985B). If the stock density is higher, the size of the fingerlings will be smaller. Therefore, each acre of seed production pond would provide enough young fish for stocking approximately 16 acres of production ponds. Thus, 1,200 acres of production units would require approximately 75 acres of seed production ponds.

The same extrapolation used above also would apply to feed. Catfish grown under pond conditions usually add one pound of weight for each 1.7 pounds of feed consumed; 3.6 million pounds of fish (3,000 pounds per acre from 1,200 acres) would require 6.1 million pounds of feed. Similar extrapolations could be made for brood fish, credit, labor, equipment, and all other inputs required. The significance of those extrapolations is that they provide an estimate of the levels of inputs that must be put in place as part of the aquaculture being introduced if the system is to be balanced.

In introducing aquaculture in this situation, it would be necessary to plan and establish the critical mass of farms along with the processing plant to achieve a balanced, functioning system of aquaculture. Accomplishing this balanced introduction would be quite complex. Obtaining sufficient inputs and the necessary coordination to bring 1,200 acres of ponds into production in the correct sequence would be a complex but necessary management problem. Obviously, the difficulty of establishing a balanced system increases exponentially with the level of intervention.

If establishing a balanced system is difficult, maintaining it is even more difficult. When there is a change in any element of the ecosystem, there usually must be a commensurate change in some or all elements if the system is to remain balanced. For example, if new technology is developed that will double the production per acre in catfish ponds, then farming 1,200 acres of ponds would produce too many fish for the one-bandsaw processing unit. Either some ponds would have to be taken out of production, another production line would have to be added, or the plant would have to operate on a double work shift schedule. Also, additional markets would have to be found. Any of these adjustments would, in turn, result in the need to change other elements of the ecosystem.

A major difficulty with maintaining balance is a result of the fact that all of the inputs and other factors are not equal in cost (Arndt and Ruttan, 1975). For example, it might be relatively inexpensive to increase the production per acre of pond, but the changes required in creating new processing, marketing, and utilization capacity would likely be much more expensive and much more difficult to accomplish in the short term.

### *Time the Introduction Carefully*

Timing the introduction of inputs in developing aquaculture in a new area is critical. In an analogous situation, the timing of the introduction of an animal into a new habitat is critical. In introducing the animal, it is essential that it be done at a time when environmental resistance factors such as drought, floods, and predation are at a minimum level. It is essential that the availability of environmental requirements such as food and cover be at the highest level. In a similar manner, the inputs required for the successful introduction of aquaculture must be available as needed. For example, if processing and marketing capabilities are not developed by the time fish are harvested, the introduction would likely fail. Similarly, the establishment of processing facilities and the development of markets cannot be done too far in advance of beginning production. When marketing commitments cannot be kept, those markets often disappear as other suppliers are sought.

# PART 5
# IMPLEMENTING THE DEVELOPMENT PROCESS

ONCE THE GOALS FOR DEVELOPMENT have been set and the preliminary planning on the technology or aquaculture system to introduce has been completed, implementation can be initiated. However, it is important to reiterate that all of the activities are links in a chain of events. The success of implementation will depend to a large extent on planning and preliminary activities that have preceded this last step.

Implementation consists of four general processes, each of which will be discussed in a following chapter:

1. *Encouraging the appropriate participation of the public sector.*
2. *Diffusing the required technology among the target individuals or groups.*
3. *Developing new technology necessary to sustain the process.*
4. *Establishing an effective communications network that includes all elements of the development ecosystem.*

# CHAPTER 12
# APPROPRIATE PUBLIC SECTOR PARTICIPATION

UNDER EXISTING CIRCUMSTANCES, it is difficult to imagine how either industrial or agricultural development might be actively promoted or encouraged without the direct participation of the public sector. Government involvement in development probably was limited in the past, but it has become so pervasive in the modern era that few aspects of human endeavor are unaffected by it. Many people have suggested that the role government plays is too large and that it is not responsive enough to changing needs. For example, Singh (1989) comments that voluminous development literature now argues that excessive government interference in developing countries has distorted price structure, promoted inefficient resource use, and given rise to undesirable rents for influential groups. He further suggests that the Third World is being called upon to accept a development and structural adjustment model in which the government's role is drastically reduced.

In the United States, as with most industrialized countries, government is more involved in agriculture than in virtually any other sector of the economy. Production credit loans, conservation reserve, erosion control rules, marketing orders, price supports, export support loans, support for agricultural research and extension, and myriad other programs exert a degree of influence over virtually every aspect of food and fiber production. While most citizens would agree that government involvement in American agriculture is excessive, few would trust market forces alone to guide the quantity, quality, and price of food. Our psychological relationship with food, food production, and the mystique of farming and rural life will not allow these aspects of our lives to be wholly determined by the laws of supply and demand.

Obviously, government must be involved in the development of agriculture and in the development of aquaculture as well. The problem is to find the proper role for it. Government is an essential part of the ecosystem of aquaculture. It exerts a force that can be either positive or negative as do all the other elements of that ecosystem.

Determining the correct role for government in the development of agriculture will be difficult. The two are so firmly and intricately intertwined that it is difficult to fully determine where one ends and the other begins. In a sense, government is an inoperable part of agriculture. "Surgical" intervention may cause more harm than good. Government involvement in aquaculture is still severely limited, so there is still time to seek out the proper role for it and to promote its involvement in the most beneficial way. If there have been mistakes made in government involvement in agriculture, we still have some time to avoid those mistakes in aquaculture.

The optimum role of government probably changes with the level of intervention (stages of development) and whether the development effort is designed to change existing aquaculture or to introduce aquaculture into new areas. In improving existing aquaculture, direct government (change agency) participation is more important at the lower stages than at the higher stages. At the higher stages, indirect government participation is probably sufficient.

The role of government is much more critical when introducing aquaculture into new areas. Direct involvement is especially critical at the lowest stages (Annis, 1987). It is less critical at the higher stages, but still necessary if aquacultural development is to proceed smoothly toward institutionalization.

Adam Smith wrote about the role of government in his *Wealth of Nations* (The Economist, 1990) and suggested three primary roles:

> *1. Defend people from "violence and invasion by other independent societies."*
> *2. Protect every member of society from the "injustice or oppression of every other member of it."*
> *3. Provide "certain public works and certain public institutions, which it can never be for the interest of any individual or small number of individuals to erect and maintain."*

The World Bank has studied the role of government in economic development for many years. Its *World Development Report 1987* (World Bank, 1987) summarizes many of their conclusions and suggests a broader role of government than Adam Smith:

> *1. Participate directly in "running" the economy (trade policies, fiscal incentives, tax policies, price controls, investment regulations, etc.).*
> *2. Set the "rules of the game" which define the use, ownership, and conditions of transfer of physical, financial, and intellectual assets.*
> *3. Be the primary provider or guarantor of certain services, such as education and physical infrastructure (transport, communications, power systems, etc.).*
> *4. Collect and provide economic information.*
> *5. Provide for the regulation of standards and weights.*
> *6. Promote scientific and technological research.*

All of these roles for government also would be important to the development of aquaculture; while all are important, however, some are likely to be more important than others. Some of these special considerations relative to the role of government in the growth of aquaculture are discussed in the following sections.

## *Running the Economy*

It is inevitable today that governments must be involved in efforts to "run" economies by setting tax and trade policies, instituting price controls, establishing investment regulations, and providing fiscal incentives. The results of the efforts on the part of the public sector can have widely different effects depending on the orientation or purpose of those efforts. The Agency for International Development (1989) has published an excellent book on the effects of government efforts to run economies. Entitled *Development and the National Interest: U.S. Economic Assistance into the 21st century*, the book provides a wealth of information and examples on the effects of public sector involvement. The authors conclude that the lesson of the economic success and failures of development efforts over the last three decades is that some factors cannot be controlled by man while others can. Natural disasters, such as floods, earthquakes, and drought, and the wide swings in commodity prices resulting from those disasters obviously cannot be controlled. But people can control economic factors that directly affect development. And the evidence overwhelmingly suggests that efforts to encourage economic development are significantly enhanced when governments establish and sustain responsible, growth-oriented policies that encourage competitive market forces and that do not hinder the productive energy of its citizens (De Lorenzo, 1989). These same policies also serve to reduce the effects of natural disasters and to hasten recovery from them.

Governments also must follow policies that make people feel their economic system treats them fairly. This does not mean all people will receive equal benefits from participating in the system, but they must feel that they have equal opportunity to participate.

The public sector also should implement economic policies that can be maintained over relatively long periods. Development involves risks by all participants. Farmers, entrepreneurs, and even government policy makers are all involved in risk taking. Risk cannot be eliminated in development, but it can be dealt with more effectively in a relatively constant economic environment. Where there are high levels of risk involved and uncertainty about changes in economic policies, it is likely that there will be missed opportunities for development at every level of the economic system from small farmers to industrialists. Both short-term and long-term planning are essential for effective development and both are virtually impossible where there are widely fluctuating economic policies.

Economic stability is so important in development that it probably governs to a large extent the stage of aquaculture that can be developed effectively. This concept was introduced previously. In a highly unstable environment, I suspect that it would be difficult to develop and sustain other than at the lowest stages. The risk of loss of investment required for intervention at higher levels would be too great. With improved economic stability, the risks associated with higher levels of intervention can be justified. Finally, it is not likely that the highest stages of aquaculture could be developed and sustained except in countries with highly stable economic environments. There is a somewhat analogous situation in plant and animal ecology. The most complex animal and plant communities are generally associated with those areas with the most stable and hospitable environments.

Finally, the public sector must develop and promote policies that will guarantee the capture of some of the gains realized from the employment of new technology and Adam Smith's "invisible hand." It will be argued later that the continuous development and deployment of new technology are twin engines of development. Unfortunately, they cannot be highly effective in the absence of public sector policies which capture and even enhance some of those benefits. Unless government is able to capture (usually through taxes) some of those benefits and convert them into essential services, such as roads and bridges, airports, education systems, clean and dependable water systems, zoning ordinances, judicial systems, and regulatory agencies, it is questionable how far development can proceed. This is and will remain a major problem for many of the developing countries of the world.

## *Setting the Rules of the Game*

It has been suggested that the industrial revolution began in Great Britain in the late 18th and early 19th centuries. Political stability and well-established and well-understood "rules of the game" were primary factors in its beginning (Gomory and Shapiro, 1988). These rules define the use, ownership, and conditions of transfer of physical, financial, and intellectual assets (World Bank, 1987). When these rules are fair, well defined, well understood, and regularly enforced, economies run more or less smoothly. For example, a report by the World Bank (World Bank, 1991) reminds us:

> *... Competitive markets are the best way yet found for efficiently organizing the production of goods and services. Domestic and external competition provides the incentives that unleash entrepreneurship and technological progress.*

Unfortunately, these markets cannot operate without a supporting framework of laws and regulations (rules of the game) that only government can provide. Fortunately or unfortunately, because aquaculture only recently has become a significant force in economic development, the number of rules developed for it specifically is relatively limited in some cases. Of course, virtually all of the rules for the use, ownership, and transfer of assets impacting agriculture are applicable to aquaculture, but there are few special rules for growing crops in water.

A major task in setting the rules of the game for aquaculture is to have farming in water included in many of the rules that apply to agriculture. The problems and opportunities are similar for both farmers of the land and of water. Several states in the United States have amended the organic law pertaining to agriculture to include aquaculture. In 1988, New York legislators considered the omnibus "New York Aquaculture Development Act" that would have defined aquaculture, designated the Department of Agriculture and Markets as the lead state agency for aquaculture, required the purchasers of aquacultural products to comply with bonding and licensing provisions governing the sale of farm products, provided for coordination among several state agencies, provided tax incentives related to the new or reconstructed farm buildings, and included lands used to produce aquacultural products under the Agricultural Districts Law. Although the Act was not passed, it provides excellent guidelines for the rules of the game that should be established for aquacultural development.

The State of Alabama has a "Prompt Pay Law" that regulates the purchase and payment for livestock. It guarantees that the farmer will receive payment within a reasonable length of time after the sale. As catfish production developed in the state, it became obvious that fish farmers needed the same protection as livestock producers. Consequently, a bill was passed by the Legislature to provide that equity.

Another example involves the right of farmers to sell cultured catfish on their farms to recreational fishermen. Alabama law required that people, except the owner's family, fishing in a private pond had to have a recreational fishing license. Many catfish farmers market their product by allowing recreational fishermen to fish them out of the production ponds. Under the law, those fishermen had to have a recreational fishing license. Fish farmers felt that this was unfair since customers who came to the farm did not have to have a special license to purchase other farm products. Consequently, a law was passed exempting those fishing for farmed catfish in private ponds from having a license.

One of the major tasks in promoting the development of aquaculture is to bring aquaculture under the broad umbrella of the existing rules of the game and to develop new rules when necessary. This is a formidable task in some cases. Many states have onerous rules and regulations regarding the establishment of aquacultural enterprises (Stickney, 1988). These rules and regulations were established to protect aquatic environments from degradation. Some of these permitting systems are unreasonable and serve as a powerful impediment to the development of aquaculture (Fitzgerald, 1987).

The development of net pen culture of salmon in the marine waters of British Columbia, Canada, is advancing rapidly. In a relatively short period of time, salmon production has become a significant economic force and helped to breathe new life into some segments of a severely ailing commercial fishing industry. Government is actively encouraging the development of the industry there. Just south of the Canadian border, in Washington, the culture of salmon is hardly growing at all, although the aquatic environments in both areas are essentially the same. The difference is the governmental environment. Obtaining permits for the establishment of net pen farms in Washington State is time consuming and difficult (Stickney, 1988).

## *Guaranteeing Essential Services*

Educational systems, roads, telephones, television, water and sewer systems and electricity are essential components of the aquacultural ecosystem. Although they are important, the degree of importance varies with the stage of aquaculture. They are less important at the lowest stages, but become increasingly important as the level of intervention increases.

Generally, these services are more dependable and even cheaper when provided by the private sector (Quinn, 1989). However, it is difficult for the private sector to provide some of them, such as roads. Even where the private sector can provide them, they generally must be regulated by the public sector. Market forces are incapable of providing the quality and quantity required for the broad spectrum of citizens that need them.

The role of government in providing or guaranteeing these services is important, but providing or guaranteeing suitable educational systems is especially crucial. There is a need for educated people at all stages of aquaculture, but the need grows almost exponentially in both a qualitative and quantitative sense as the level of intervention is increased. In order to cope effectively with the complexity of the ecosystems at the higher stages of aquaculture, it is mandatory that a large number and broad spectrum of educated people be available. While the private sector can play an important role in some specialized aspects of the educational system, such as training production or technology support personnel, it cannot be expected to provide the breadth and depth of education required for the continuing function of the ecosystem.

## *Collecting and Providing Economic Information*

A continuing supply of good economic information is important in development. Information on current prices, demand, sales, interest rates, and supplies are essential if effective business management decisions are to be made. Weather forecasts also would have to be included in the array of information needed. Because aquaculture is a relatively small industry and because it has so recently come on the economic scene, the availability of information is relatively poor. Governments have been slow in moving to provide this information. In fact, most countries have made virtually no effort to do so. In the United States, where aquaculture is an important economic force in some areas, collection and dissemination of the information is done on an ad hoc basis. In Alabama, catfish is not even included in the agricultural commodity statistics. The value of catfish is included in the "miscellaneous" category even though it ranks in the top 10 crops in the state. There is limited effort to regularly report prices being paid to farmers or the volume of sales on a daily or even weekly basis. If aquaculture is to rapidly reach its potential for contributing to the economies of nations, governments must be encouraged to collect the important statistics and to make them available to all of those involved in the entire industry (ecosystem). Collection and dissemination of relevant information should be done even before the volume of production would seem to justify it. Providing the growing industry with needed information is a good investment in development. Encouraging government to play this important role in the development of aquaculture should be high on the agenda of all segments of the industry.

## *Regulating Standards and Weights*

Government provides an important service in regulating standards and weights. It is amazing how much mischief can be caused in an industry when the accuracy of scales or the analyses of feeds, fertilizers, and chemicals are questionable. It is difficult to imagine that aquaculture could advance rapidly under any circumstances without public sector involvement in guaranteeing standards and weights. Alabama's Department of Agriculture and Industries has the responsibility for inspecting scales used in all aspects of the food and fiber industry where the change of ownership of products is involved. Unfortunately, this responsibility did not extend to scales used in the catfish farming industry, so it was necessary to have a law passed to bring the scales used in the industry under the department's purview. Encouraging government to play this role in the development of aquaculture should also be included on the agenda of groups promoting its development.

## *Promoting Scientific and Technological Research*

Government also should play an active role in promoting scientific and technological research and in the diffusion of new technology. The importance of these aspects of aquacultural development will be discussed in detail in a following section, but some comments are needed concerning the problems in getting government to provide such support for a new industry. Governmental support for research and for the diffusion of technology is largely energized by two forces:

*1. The size of the political constituency associated with an industry or commodity.*

*2. The degree of crisis that can be attached to the need for the new technology.*

Aquaculture has a severely limited political constituency in most countries, and in the competition for available funds for research and technology transfer, this growing industry generally does not fare well. Funds available for research and technology transfer on food and fiber production are never more than barely adequate. Seldom does new funding provide opportunities for more than keeping up with inflation. In this scenario, the only realistic way to get funding for aquaculture is through the reallocation of existing funds. This process is extremely difficult, given the limited political constituency of the industry. Obviously, this constituency is growing rapidly in much of the world as aquacultural production grows. Unfortunately, this process is much too slow given the informational needs in aquaculture.

Aquaculture is outgrowing its proven information base in virtually every area. Fortunately, demand for cultured aquatic products is growing so rapidly and returns on investment are so good that mistakes or errors resulting from the lack of information can be tolerated to a degree. This situation will not always remain. As supply finally comes in line with demand, profits will be reduced, and mistakes and errors will become more important. While aquaculturists' political influence is limited in a relative sense as they work to obtain funds for research and technology transfer, they should take practical steps to maximize their effectiveness. Well-organized, hard-working commodity groups are able to exert considerable force, a force much larger than their numbers would indicate, if it is sharply focused and carefully applied.

Aquaculturists have had much better success in obtaining funding for research and technology as a direct result of the crisis in the farm sector, especially in the southern tier of states in the United States during the 1980s. Traditional agriculture and rural America took a severe beating during that period; there was a real crisis. Aquaculture was "discovered" as an alternative to traditional agriculture in some rural areas. The worldwide shortage of fish has caused crisis situations around the globe, situations that can only be alleviated only through aquaculture. Aquaculturists have not adequately articulated the contributions they can make in helping to solve those critical problems and the need for government funding for research and development to be effective.

While the World Bank Report (World Bank, 1987) cited at the beginning of this section did not specifically mention providing technology transfer as a role of government, it obviously is implied as part of the need to promote scientific and technological research. In fact, promotion of the research would be of limited value without diffusion of the results. The private sector (change agencies) does play an important role in technology transfer, but its efforts are usually related to the need to sell specific products. The private sector cannot be expected to transfer the broad array of technology that is necessary for the development of the aquacultural ecosystem. Also, private sector change agencies usually disseminate information related to the purchase and use of proprietary technology or technology on which a private company owns the patent or license. Much of the required technology, especially biological technology, is not proprietary, so the private sector has limited interest in transferring it. Government-supported change agencies must be the primary transfer sources for this technology.

Aquaculturists must maintain a continuous effort to encourage governmental actions and programs that positively affect their industry. At the same time, they must be just as diligent in getting government to stop programs and actions that have a negative effect. This is a difficult problem. In some situations, direct government participation in the production part of the process is required. For example, in many countries where aquaculture is just beginning to develop, a shortage of seed is a severely limiting factor. As a result, government is encouraged to develop hatcheries and seed-distribution systems. Usually the seed are provided at little or no cost to the farmers. As the industry grows, government is no longer able to meet the needs of the industry. Farmers develop the capability to produce seed themselves for use on their farms and for sale to their neighbors. In a situation like this, government can become a direct competitor with private enterprise. It is extremely difficult to close government hatcheries once they become well established.

# CHAPTER 13
# DIFFUSING THE REQUIRED TECHNOLOGY

THE CAPABILITIES AND POSSIBILITIES OF AQUACULTURE described previously can be realized only if there is widespread, continuous diffusion of appropriate technology. Appropriate technology must be transmitted to and adopted in areas where aquaculture is not practiced already, as well as to farmers or businesses already involved in the production of aquatic animals.

Diffusion of innovations such as aquacultural technology is a complex and exceedingly important process. Brown (1981) contends that diffusion of innovations, or the lack of it in some cases, accounts in part for the rise, relative prosperity, and fall of civilizations. Certainly, diffusion of innovations is the centerpiece of market-oriented economies throughout the world.

## *Nature of the Diffusion Process*

Most research on the diffusion of innovations or new technology has emphasized the so-called "adoption perspective" in which the central role in the process is played by the person or persons who adopt the new ideas, practices, or products (Brown, 1981). The range of individual responses to innovations ("innovators" to "laggards") discussed in a preceding section has been an important element of this perspective. The adoption perspective is used extensively in situations where an effort is being made, usually on the part of government, to encourage the diffusion of innovations. This is the primary approach taken by the Cooperative Extension Service of the U.S. Department of Agriculture to encourage farmers and their families to adopt improved practices on their farms, in their homes, and in their family life. This same approach is utilized by bilateral development agencies, such as the U.S. Agency for International Development, and multilateral agencies, such as the World Bank, to promote the diffusion of improved agricultural technology primarily in the developing countries of the world.

Obviously, the adopter does play a major role in the diffusion process, but Brown (1981) contends that the adopter perspective places too much emphasis on those individuals and groups. It is person intensive. He suggests that, with this perspective, it is too easy to place the blame for poor results or failures in development projects on the adopters rather than the promoters (change agencies). He suggests that a "market and infrastructure" perspective should be used to complement the adoption perspective. This second perspective focuses on supplying (marketing) innovations to the potential adopters, but it also takes into account the infrastructure used by change agencies in the marketing effort. The market and infrastructure perspective is people extensive. It is possible to deal with more people utilizing this perspective than with the adopter perspective.

The adoption perspective assumes that all potential adopters have equal opportunity to decide whether they wish to accept innovations. Roling (1984) describes this assumption in different terms. He suggests that the assumption is made that "the social system within which an innovation is to be diffused (is) homogeneous so that the innovation (is) equally relevant to all members of the system." From this perspective, differences in the speed with which new ideas, practices, or products are adopted are the result of characteristics of individuals. In contrast, the market and infrastructure perspective suggests that the opportunity to adopt is widely unequal -- sometimes purposefully so. Furthermore, it suggests that adoption is not a free-will process on the part of the adopter so much as it is a matter of choice that must be made within boundaries established by the change agencies. This perspective further suggests that the promoters of innovation must take these inequalities into consideration when developing the infrastructure for marketing (supplying) innovations among potential adopters.

As stated earlier, the adoption perspective places the primary responsibility of the response to innovation on the person or persons who will have the opportunity to accept or reject it. Diffusion theory developed from this perspective emphasizes that acceptance, speed of acceptance, and rejection are a function of the basic processes of learning by observation. Consequently, the basic strategy of adoption is that potential adopters can be persuaded to adopt new technology through the communications process. With the market and infrastructure perspective, diffusion becomes more a matter of logistics, distribution, and promotion rather than consumer behavior alone.

Robertson (1971) contributed to the understanding of the process by which innovation is diffused by suggesting that there are two basic types of innovation, and differences in the two affect the speed with which they are adopted:

1. *Continuous innovations.*
2. *Discontinuous innovations.*

Continuous innovations refer to those that involve the alteration of an idea, a practice, or a product already in use. Discontinuous innovations refer to those where a new idea, practice, or product is involved. These two types of innovations generally are applicable to the diffusion of aquacultural technology. There are two general situations, as suggested previously, in which the production of aquatic animals can be promoted:

1. *On farms already producing aquatic animals.*
2. *On farms, in provinces, and in countries where there is little or no aquaculture.*

On farms already producing aquatic animals, innovations according to the definition would be continuous ones, while discontinuous innovations would be diffused in situations where little or no aquaculture is being practiced. Obviously, the same innovation could be both continuous and discontinuous, depending on where it is being diffused. The important point is that the concept of whether an innovation is continuous or discontinuous depends on the point of view of the potential adopter. This is primarily of importance when implementing a strategy for promoting diffusion.

Innovations that are promoted among existing aquacultural enterprises (continuous) are of a different nature than those that are promoted where there has been no aquaculture (discontinuous). The first situation involves the introduction of relatively small "packets" of technology, such as a new feed, a new genetic strain, or a new marketing scheme. In the latter situation, entire systems of technology -- production, harvesting, processing, marketing, and utilization -- must be diffused.

## *Role of Change Agencies and Change Agents*

Theoretically, diffusion can take place without promotion or the addition of exogenous energy to the system. For example, if a single drop of a concentrated dye solution is carefully placed at the surface of a container of water, diffusion of the molecules of dye will take place away from the point of application. After a period of time, the molecules will be uniformly distributed throughout the container. Diffusion will take place as a result of the "jostling" (kinetic energy) of molecules of dye and water as they move in solution. The diffusion process can be speeded by several orders of magnitude by adding energy to the system in the form of a mechanical stirrer.

In a similar sense, it is theoretically possible for agricultural or aquacultural innovation to be diffused throughout a particular environment containing potential adopters without promotion (the addition of energy). However, the rate certainly can be increased significantly by promotional activities. Just as the diffusion of dye molecules introduced into a container of water takes place as the result of the jostling of dye and water molecules, diffusion of innovation can occur as the result of the jostling or sharing of information by neighbors who grow aquatic animals. This largely passive process of diffusion operated for thousands of years before the concept of active promotion was conceived. Roling (1984) reported, for example, that cocoa was adopted as a cash crop by thousands of small farmers in Ghana and Nigeria without the assistance or involvement of a single extension agent. However, diffusion is likely to take place much more rapidly with the addition of energy to the system in the form of marketing or promotion.

Those situations in which there is directed, positive effort to promote the spread and adoption of new technology are termed "Centralized Diffusion Systems" (Rogers, 1983). These systems require that some unit or entity, usually governmental, accepts or is assigned the responsibility of actively promoting diffusion. Such units or entities are called change agencies. The change agencies usually have the responsibility of implementing development plans and strategy by promoting the diffusion of appropriate technology. This system essentially requires a top-down process.

While the emphasis is usually placed on public sector change agencies, the private sector can play an equally important, if not greater role. Privately owned companies invest billions of dollars each year in developing new technology and in diffusing (marketing) it throughout the world. They develop and market new machines, chemicals, and materials that are important in the development process. They are more product oriented than process oriented. Their involvement generally is on a much narrower scale. It is much easier to obtain proprietary (patent) rights to products than to processes. Private companies are more likely to be able to recover their investment from development and diffusion from products rather than processes. The private sector would not be expected to become involved in the development of infrastructure such as roads, schools, or research stations, and they generally would not participate in the development of human capital.

Change agencies function in the development process in a manner somewhat analogous to the role of catalysts in certain chemical reactions. In the chemical reaction, the catalyst increases the velocity of the reaction but does not itself appear in the products of the reaction. The catalyst is unchanged chemically in the process. Also, the catalyst will increase the velocity of only those reactions that will proceed to completion without the catalyst. Catalysts will not cause reactions to take place that would not take place naturally.

Deciding what technology to develop and to diffuse (market) is an awesome task and responsibility. If a private sector change agency designs and produces a new product that is over-priced, too complex, does not meet the needs of individuals, or does not function properly, it is likely efforts at marketing will fail and the investment will be lost. In this situation, the unsuitable technology would disappear from the marketplace. Unfortunately, although the technology is withdrawn, farmers who adopted it will also lose their investment. Public sector change agencies have essentially the same problem. They must design and produce a product or process and market it to individuals. If it is too costly, does not meet the needs of individuals, or is too complex, individuals will not purchase it, and the public sector change agency will lose its investment (credibility).

To preclude the loss of investment because of a lack of sales, the private sector change agency often will spend a considerable amount in market research before designing and producing new technology. In this research, the private company will try to determine the needs and wants of individuals and the likelihood of their accepting the innovations. Public sector change agencies should approach the problem of developing and diffusing technology in the same manner. Unfortunately, in too many instances, market research is not given high priority by the public sector change agencies. This phenomenon probably results from the fact that the loss of investment will have more immediate and serious consequences for the private sector than for public sector agencies. The failure of an "Edsel" automobile in the market place will be noted and steps taken to correct the mistake much more quickly than the failure of a multi-million dollar aquacultural development project. This contrast, of course, is an oversimplification. It is much more difficult to plan and implement a successful aquacultural development project than to produce and market a new product. I do suspect, however, that evaluation and accountability play a role.

Change agencies also must maintain an awareness of balance in the ecosystem in which their product is to operate and compete. For example, automobile manufacturers, as change agencies, must maintain an awareness of the quality and extent of highways and bridges, the availability and price of gasoline, the availability of mechanics and spare parts, the cost of insurance, and the cost of automobile financing. While they exert a significant degree of control only over a relatively small part of the ecosystem, they must maintain contact and communications with all the other elements and positively participate in the creation of the optimum environment for their products. Public sector change agencies should use the same approach. They must maintain a sense of the balance in the development ecosystem, be aware of changes in the system, and participate actively to the extent possible to resolve the disequilibrium.

Change agencies often play a crucial role in the development of aquaculture. Unfortunately, that role can be negative as well as positive. Simply because the change agency decides to promote the development of aquaculture does not mean that the effort will be successful. The percentage of aquacultural development projects that have failed to meet the desired goals provides ample evidence of the basic weaknesses that seem to be associated with the promotion efforts (United Nations Development Program, 1987; Hancock, 1989). Change agency failure is a two-edged sword. Because change agencies usually are publicly funded, a failed project equates to the misuse or poor use of those funds, but probably even more importantly, a failed project places a heavier burden on private sector participants or individuals who put their scarce personal resources at risk. These failed projects promoted by the change agency affect the private sector participants negatively in two ways. They (1) realize little or no return on their investment and (2) because of the poor return, they are less likely to cooperate wholeheartedly in succeeding development efforts. Because of the potential for these negative results, change agencies should choose carefully the development projects they implement, and they should make every reasonable effort to guarantee that those chosen for implementation are successful.

Change agencies employ change agents (extension agents) who are directly responsible, on a day-to-day basis, for influencing the decisions of potential adopters or clients in the direction deemed desirable by the change agency. The change agent links the change agency with clients, or the people who must make the decision whether to commit scarce resources. Generally, it is the responsibility of the change agent to influence client decisions, but the process is much more complex. Rogers (1983) suggests the following seven roles for the change agent:

*1. Help develop an awareness of the need for and benefits of change among potential adopters and investors.*
*2. Establish an information-exchange relationship.*
*3. Analyze characteristics of problems.*
*4. Motivate and encourage an interest in change.*
*5. Help translate intent into action.*
*6. Stabilize adoption and prevent discontinuances.*
*7. Achieve a terminal relationship.*

It is beyond the scope of this book to discuss the specific roles of change agents. The reader is directed to Rogers' book, as well as the publication written by Engle and Stone (1989), for this purpose.

Rogers (1983) also suggested eight factors that determine the success or failure of the change agent in carrying out or playing these seven roles:

*1. Change agent success is positively related to amount of effort spent in contacting clients.*
*2. Change agent success is positively related to client orientation rather than to their change agency orientation.*
*3. Change agent success is positively related to the degree to which the diffusion program is compatible with clients' needs.*
*4. Change agent success is positively related to empathy with clients.*
*5. Change agent success is positively related to the degree of homophily with clients.*
*6. Change agent success is positively related to credibility in the clients' eyes.*
*7. Change agent success is positively related to the extent they work through opinion leaders among clients.*
*8. Change agent success is positively related to increasing clients' capability to evaluate innovations.*

Rogers' list includes important elements of change agent success, but there is one other characteristic that should be added. The success of change agents will be proportional to their ability to work effectively with a wide range of social and economic groups. Working effectively with diverse groups is a difficult task. To begin with, because of our personal ethnocentrism, we often find it difficult to understand and appreciate other people and their cultures. It is much easier to work with those whose culture approximates our own. Also, it is only natural that we respond most positively to those who come to us for help. We tend to be more helpful to those who help themselves. It is much easier to work with farmers with good resource endowments than with those who are resource limited. As change agents, it is much easier to work with the innovators and early adopters of the world. Unfortunately, in too many cases, these groups need our help much less than the less aggressive and more conservative people who find it difficult to approach us.

## *The Flow of Innovations*

The two general ways (directions) that innovations flow will be discussed briefly: (1) a centralized diffusion system, or vertical flow; and (2) a decentralized diffusion system, or horizontal flow.

### *Centralized Diffusion System*

This system suggests by its general nature that it is a top-down system, but information can actually move in both directions. The communication of client needs and attitudes about change readily and effectively move back through the change agent to the change agency. However, even through the bi-directional flow of information does occur, the very nature of the administrative and bureaucratic process usually dictates that the strength of the downward flow is greater than the upward one. This effect is the primary disadvantage of the widely used centralized diffusion system.

There also is another weakness in the top-down flow of technology. Using this approach, it is difficult to get the appropriate technology to the lowest rungs on the ladder. It is difficult to reach people at the grass-roots. Too much of the energy in the downward thrust of diffusion is absorbed by the innovators and early adopters before it can reach the late adopters and laggards.

This discussion implies that centralized diffusion systems, or top-down systems, involve only public sector entities. This is not the case. The private sector also is heavily involved in top-down technology diffusion where change agents (salesmen or sales representatives) bridge the gap between the corporation or company that developed the technology and the clients who are to be persuaded to purchase it with scarce resources. While the principles are essentially the same, there are important differences. Usually public sector-directed diffusion is not marketing a specific product. Most often the technology involved is biological or similar technical information and is provided essentially free of charge. Private sector-directed diffusion usually markets a specific product (a new feed, a new drug, or a new pond aerator) for a price. This system also provides information, but usually it tends to be related to the operation and function of the specific item of equipment.

### *Decentralized Diffusion System*

Decentralized diffusion systems have no change agencies or change agents. There is no top-down movement of technology. Rather, in this system, the technology users themselves create and share innovations with each other. The flow of technology tends to be horizontal rather than top-down (Roling, 1984). This is the more primitive system that provided for the diffusion of technology that undergirded agricultural development from ancient times. With the horizontal flow system, there is wide sharing of power and control. It is a problem-centered approach where the technology is "pulled," rather than "pushed," in response to locally perceived needs. This system is also characterized by a high degree of local adoption and re-invention (continued change) of innovations through trial and error.

While there are a number of advantages to the decentralized system, there are disadvantages. For example, it is possible for bad innovations to diffuse through the horizontal system. With the top-down system, the change agencies and their agents exercise a degree of quality control on innovations. Those that could potentially cause more damage than good in particular situations can be discarded. Unfortunately, inappropriate technology, in too many cases, slips through the quality control screen of top-down diffusion as well. Also, decentralized systems often do not take into consideration larger social and economic issues when developing and diffusing technology. Local problems are viewed as being more important, while there might be a need to view a particular problem in a broader context.

Centralized systems function more effectively in those situations where the technology has high technical content and the clients belong to relatively homogenous groups, whereas the decentralized systems work most effectively in those situations where the technology is not highly technical and where the clients are heterogenous with respect to their particular needs (Rogers, 1983). Obviously, these two systems are on the extremes of a continuum. There are common elements to both. Both serve the same essential purpose of providing technology to meet specific needs or to remove constraints to the development process for individual clients.

Intuitively, one would expect that one of these systems might be more important than the other for diffusion of new technology in the different stages of aquaculture. At the lowest levels of intervention, the technical content of innovations is relatively low and the farmers (clients) are a heterogenous group. Many of them culture aquatic animals as a matter of convenience rather than necessity. In this situation, the horizontal diffusion system probably works more effectively. However, the effectiveness of the overall process probably would be enhanced by combining the two. Top-down diffusion could contribute to a point, but would have to be replaced by horizontal diffusion for some part of the process.

At the intermediate stages of aquaculture with moderate levels of intervention, the technical content of innovations is greater and the client's operational needs are more homogeneous. In this situation, the top-down system is clearly superior, although even here the horizontal system clearly can be used effectively to reinforce the establishment of the technology and to encourage local re-invention and adaptation.

The highest stages of aquaculture present a paradox. Intervention is at its highest level, as is the technical content of any innovations that might be needed. The degree of homogeneity of clients is only moderate. In this situation, neither system seems to work well. The need for new technology and information is so critical that neither the top-down system nor the horizontal system seems to be very effective. Rather, a peculiar private sector-horizontal system tends to develop to support these highest stages. The farmers, often investors, purchase consultants' time for information and enter into special arrangements with industry to obtain specially designed technology.

In determining a strategy for the diffusion of new technology, the change agencies must decide whether to utilize the adoption perspective, the market and infrastructure perspective, or a combination of the two. These two perspectives were discussed in some detail in a previous section. They differ primarily in whether the promotional emphasis will be focused on the personal learning characteristics of the potential adopters or on the characteristics (logistics, advertising, choices offered, etc.) of the change agencies themselves. Obviously, the best strategy is to combine the two, selecting the best characteristics from both. Diffusion strategy must take the individual psychological, social, and cultural characteristics of people into consideration, while at the same time, it cannot avoid the consideration of the procedures or the purposes employed.

## *Diffusion Strategy Applied to Aquacultural Development*

Theories concerning the diffusion of innovations were discussed at the beginning of this chapter. In the following section, concepts derived from that information will be applied in proposing a general strategy for the introduction and adoption (diffusion) of new technology into current aquacultural practice (continuous innovations) and into areas where aquaculture has not been practiced previously (discontinuous innovations). There are specific and important differences in introducing new technology, such as feeds, chemicals, equipment, and management practices, into an existing industry, as well as in introducing an entire new industry into an area unfamiliar with it. Yet the general principles that govern how target individuals or groups learn and adopt new technology are essentially the same in both situations.

The adoption of new technology follows a rather well refined process which includes the following six interrelated steps (Pollnac, 1982):

1. *Development of a package of appropriate technology that will meet development goals and that will be acceptable to potential adopters.*
2. *Communicating the technology to the target individual or group.*
3. *Perception of the technology by potential adopters.*
4. *Trial of the technology.*
5. *Adoption or rejection of the technology.*
6. *Institutionalization of the technology.*

These are arbitrary divisions in a more-or-less continuous process (Robertson, 1971). Also, listing these steps does not imply that adoption of an innovation always follows this path. In some cases, the process may well begin in the middle. Even with its obvious oversimplification, it provides a useful model for the promotion of aquacultural innovations.

The process described by Pollnac, as it applies to the diffusion of aquacultural technology, includes essentially the same elements as the more general process of technology adoption described by Maunder (1973) and Rogers (1983). He adds one additional step -- institutionalization -- that was not included in the more general discussions. This added step is quite important, as will be shown later.

The process described by Pollnac implies that a change agency (Extension Service, development agency, corporation, or company) decides what constraints are affecting the production-utilization process and determines that the problem could be solved with appropriate technology, or that the technology to remove it could be marketed for a profit. In the following sections, each of Pollnac's steps in the process of diffusing new aquacultural technology is discussed.

### *Developing a Package of Technology*

Selecting an appropriate level of an input or stage of aquaculture for promotion or diffusion was discussed in some detail, but from a broad perspective, in the preceding section. Here, the selection process is presented from a much narrower, more specific perspective.

The selection of an innovation or new technology for promotion in existing aquaculture is usually done by some change agency (Rogers, 1983). It might be a feed manufacturer developing a new product to sell to farmers, a government laboratory developing a new genetic strain of aquatic animal for release to farmers, or a variety of other private groups or public agencies seeking to promote some change in existing practice. Private sector change agencies usually provide the energy required for promoting innovations which they develop. They generally develop the innovation and promote it for profit, as in the case of the feed manufacturer, or for other private sector enterprises. Government agencies that function as change agencies often have a wide range of motives for developing innovations, such as encouraging economic development or increasing food production. The beginning point in the strategy for promoting the timely and orderly diffusion of innovations is to develop a package that likely will be acceptable and that the aquaculturists need.

This is the step in which the decision is made regarding which technology should be packaged for promotion. This is a crucial decision in the process and should be made only on the basis of a thorough knowledge of the needs of an individual or group, taking into consideration a number of factors. The decision should be based on a thorough knowledge of the dynamics of the entire production-utilization process (the ecosystem) for that particular aquacultural commodity. The general process of defining the boundaries of the ecosystem was discussed in a preceding section.

Technology should be selected for promotion that will, if adopted and utilized effectively, remove or eliminate a constraint or bottleneck in the process. Obviously this decision is not simple. Constraints or bottlenecks may vary widely in their complexity. Some may be removed by even a modest change in a procedure. Others, if they can be removed at all, may require the application of a complex series of new practices. In some cases, additional research (both basic and applied) may be required to provide information needed for the package. Even so, regardless of the complexity of the problems, decisions on which new technology to promote at any one time should be based on a thorough knowledge and understanding of that specific aquacultural ecosystem or the environment where aquaculture will be introduced.

The choice of the appropriate technology is important in all circumstances, but it becomes even more important in the case of developing countries. Resources for development often are scarce. People in those countries who must commit their limited resources to adopt and put into use new technology can be seriously hurt socially and economically if that technology is not appropriate to their needs. Baum and Tolbert (1989), writing for the World Bank, strongly encouraged developing countries to use technology appropriate to their circumstances. They noted that in many instances these countries have adopted or retained clearly unsuitable technologies. This mismatch of technology to circumstances can be a major constraint in the development process. These authors further suggest that the principle of selecting technology based on circumstances in developing countries may be difficult to apply for the following reasons:

> *1. Foreign consultants or advisors may advocate technology with which they are most familiar (ethnocentricity).*
> *2. Local decision makers, if educated abroad, may favor advanced technology that is not appropriate.*
> *3. Local decision makers may wrongly assume that what is most modern is best.*
> *4. Special interest groups may favor a particular technical approach.*
> *5. Deep-seated customs and traditions may favor certain technical solutions and make others unacceptable.*
> *6. A simple lack of knowledge or reluctance to experiment may limit the range of choice.*
> *7. External assistance may be tied to a particular technological approach so that freedom of choice is compromised.*

While the same considerations are appropriate for promoting the adoption of innovation in an existing aquacultural industry and where there is no industry, the difference of scale is quite large. In an existing industry, a package might consist of a minor change in some part of the production system. Where there is little or no industry, the innovation package consists of all components in the production and utilization process. An entire aquacultural production and utilization system is being introduced. The development of a package of technology for promotion is more critical in this situation. Implementation is much more complex. Also, the role of the target individual or group is more complex. As Robertson (1971) has suggested, the process of diffusion is much more difficult when discontinuous innovation is involved. The potential adopter has a limited frame of reference within which to consider an entire new system of food production.

***Communicating the Technology***

This is the second step of the process by which innovation is diffused. It is the step in which the specific change in aquaculture planned and packaged in Step 1 would be introduced to the potential adopters. In agriculture, this step is the extension process.

It is beyond the scope of this book to discuss the process of extension. This subject received more than adequate treatment by Maunder (1973), who wrote a practical book on this subject, presenting a large amount of information on all aspects of extension. Rogers (1983) provides a more generalized, but pertinent, discussion of the general process of diffusion. Engle and Stone (1989) discuss the process specifically from the aquacultural perspective.

Although little attention will be given to extension here, a few suggestions are appropriate. First, lack of effective extension personnel (change agents) capability is a primary constraint to the development of aquaculture worldwide. The information base on aquaculture is limited, but there is considerably more available than is being effectively diffused to potential adopters. There simply are not enough extension agents with a good working knowledge of aquaculture for the rapidly growing task. Aquaculture worldwide is probably growing at an annual rate of 7-10 percent. It is extremely difficult to maintain an equal pace with the training and deployment of change agents.

Another problem is that aquaculture changes rapidly. Much of the early development was at the less complex stages in which the level of intervention was relatively low. Limited inputs were required. However, in virtually every case, regardless of the species involved, lower stages of aquaculture are being replaced by intermediate and higher stages. This rapid development places additional pressure on change agencies and change agents to meet the rapidly changing needs for technology transfer.

The complexity of aquacultural technology also limits the effectiveness of diffusion, making it relatively difficult to communicate. Agents of change must receive training in a broad range of basic science subjects in order to understand the technology themselves. In turn, it is difficult to teach this technology to persons with an inadequate science background.

Observability is a problem in the promotion of aquacultural innovations. Production cycles of most aquatic animals are relatively long. This time period is more of a problem, because for virtually all of the production cycle, the animals cannot be observed. In agriculture, it usually is possible to observe the positive results of the use of new technology, if there are any, rather quickly. It is much more difficult when the animals cannot be easily observed.

The production of aquatic animals is relatively expensive compared to the production of most food animals on land. The containers cost more in aquaculture, and land animals do not require large quantities of water, which usually is relatively expensive. Because of the costs involved, extension agents must be especially careful with their recommendations. Implementation of some of their recommendations can be expensive, and unless there is a significant increase in production, these cannot be justified. Agents must be somewhat conservative in the technology which they extend. Target individuals or groups should not be encouraged to try new things that they cannot afford or that have limited promise to provide a reasonable return on investment.

Earlier comments regarding the communication of technology where aquaculture is already practiced also are pertinent to situations where a technology package is promoted to farms, provinces, countries where little or no aquaculture is practiced (diffusion of discontinuous innovations). There are, however, some significant differences in the communication of continuous and discontinuous innovations.

The communication process is much more difficult when promoting the adoption of aquaculture than when promoting a change in existing technology. Also, as noted before, in promoting the adoption of an entire system of aquaculture, the change agent must communicate, almost simultaneously, all aspects of the system -- production, harvesting, processing, marketing, and utilization. If any one part is omitted, the entire diffusion process can fail. The responsibilities or the difficulties faced by the change agency and, in turn, the extension agent are immense. Resistance to adoption is much greater. Complexity, compatibility, advantage, trialability, and observability exert a much greater influence (greater environmental resistance). The energy input (promotion) required by the change agencies is relatively high if they wish to achieve rapid adoption in a broad geographical area. A large investment in the number of change agents, their travel, communications equipment, and demonstration farms will be required to assure a relatively rapid rate of adoption.

The role of change agents in this situation is important. Also, the burden on the agents is much greater. They must be able to communicate a much broader range of technology and must be involved with a much broader range of adopters. Not only must they work with farmers to get them to adopt aquaculture, but they also must encourage the development of harvesting and processing capability. At the same time, marketing channels must be investigated. In fact, the agents must be involved to a degree in promoting the availability of all of those inputs listed previously. The degree of personal involvement required of the extension agents with the potential adopters is extremely high. There is simply too much detail to be dealt with to rely on more passive methods of communication. The degree of personal involvement with the promotion process in this situation would be much greater than when promoting the adoption of an innovation in an existing aquacultural industry.

Change agencies, in general, are poorly prepared for the intensity and amount of communication with potential adopters that is required to effect rapid adoption of aquaculture. Historically, the level of effort allocated to communicating technology has been positively correlated with the size of the industry. More resources are allocated to extension work in support of technology promotion and adoption in the major agricultural commodities. It is difficult for the agencies to mobilize the amount of resources necessary for a small industry such as aquaculture, although it is growing rapidly.

The agencies also have a difficult problem in attempting to reallocate resources. The extension agents themselves may not welcome moving into a new field. Many of them are not trained to quickly make such a move. Also, the representatives of other commodities themselves generally do not want to see extension support transferred.

In established agricultural industries, supporting businesses (feed, drug, and equipment companies) provide for much of the communication required to maintain the diffusion process. In the poultry industry in the United States, I suspect that these private change agencies provide for well over 75 percent of the communication of innovations required. In aquaculture, the role of the private companies in this process is still limited but is growing rapidly. As a result, public sector change agencies must accept the responsibility for a much larger share of the communication process, although under existing political and economic conditions, this is a difficult commitment to make. In spite of the difficulty, public change agencies should redouble their efforts to provide the funds required for the rapid diffusion of aquaculture. The world fish supply-demand situation will require a massive effort of technology diffusion if severe shortages are to be averted. In the remaining years of this century, the return on investment from the diffusion of aquaculture is likely to be much greater than for any agricultural technology.

### *Perception of the Technology*

Perception of an innovation by the target individual or group is generally based on the five criteria or attributes listed by Pollnac (1982): complexity, compatibility, advantage, trialability, and observability. Each of these was discussed in some detail in a previous section. Virtually all of the comments made regarding these attributes in that section also apply to the perception of innovations. It was suggested that each of these be considered because they would play a vital role in decisions of whether people will commit scarce resources to try innovations.

The process of perceiving an innovation is generally the same whether individuals in the target area already practice aquaculture or not. This is the point in the process where potential adopters must become psychologically involved (Rogers, 1983). At this point, communications by change agents are actively evaluated. Complexity, compatibility, advantage, trialability, and observability become like filters or prisms of the mental evaluation process through which characteristics of the innovation are passed. These highly personalized prisms magnify, diminish, or warp images of the innovation and project how an individual's economic, social, and cultural status might change if the innovation is adopted or rejected.

Although the perception process is generally the same in both established aquaculture and where it is being introduced for the first time, there are significant differences in scale. Adoption of a new feed requires only minor changes in the primary aspects of the existing production system. The additional commitment is relatively small. However, the perception process becomes much more rigorous when the innovation involves going into a completely new and largely unknown venture. The added economic, social, and cultural commitment that is required places a tremendous amount of pressure on the process.

The perception process is less pressured when an individual farmer considers adopting aquaculture after some of his neighbors become involved in the production of aquatic animals. Essentially the same commitment is required whether he can observe his neighbor's fish farm or he is the first in the province to adopt the technology.

As noted previously, the perception process is affected by the socio-economic status of the potential adopter and characteristics of the innovation itself (Rogers, 1983). The financial resources of the potential adopters and the stages of aquaculture being promoted also would affect the process. The effects of these two factors plus their interaction should be given careful attention by change agencies and their agents in their involvement in the perception process.

### *Trial of the Technology*

The actual trial of the recommended technology is a critical step in the diffusion process. The target individuals or groups already have satisfied themselves with regard to complexity, compatibility, and advantage, and they have made the decision that the required resources are available for a trial. At this point resources are committed. It is essential that the potential adopter be provided as much support as practical from the change agent at this point. The new technology should be put in place as it was intended. The trial should be conducted so as to provide the maximum chance for the technology to provide the results expected. It is at this point in the technology diffusion process that farming systems research (FSR) can play a crucial role. Application of the FSR approach provides the farmer with an opportunity to be directly involved in experimentation, farm trials, and extension (Molnar et al., 1987).

This step also is known as the implementation stage, wherein individuals or groups actually try the innovation or actually implement the culture of aquatic animals. This level of commitment does not guarantee final adoption or institutionalization. The innovation may be rejected after it is tried once or even a few times (Rogers, 1983).

The implementation stage is crucial in the final adoption of discontinuous innovations, such as aquaculture, where the potential adopters have never tried it before. Aquaculture is a relatively complicated system with a number of interrelated components. The entire system will not function effectively for very long unless all the components are in place and are balanced. Credit, containers, seed, nutrients, labor, processing, and marketing plus several other components, all must be put in place in the proper sequence and in proper quantity for the system to function effectively. Implementation that involves putting all of these components in place is an extremely difficult task.

The task of implementation is somewhat less difficult for farmers who are new to aquaculture if their neighbors already are involved. The horizontal diffusion process plays an important role here. In this situation, many of the components of the entire system (credit, information, processing, and marketing) already are available. Even in this situation, however, implementation is not as simple as when aquaculturists are implementing a change in an existing operation (continuous innovation).

To ensure the success of implementation or trial of the technology when aquaculture is being introduced for the first time to a province or other large area, change agencies and agents must play an extremely active role. They must provide a high level of coordination in order to get all of the components in place at the proper time. These situations almost demand that aquaculture be implemented at one of the lower stage. It is just too difficult to get all of the components in place for the higher-stage systems. Once the system is functioning properly at a lower stage, diffusion can begin through continuous innovations to raise the stage to a more suitable level.

### *Adoption or Rejection of the New Technology*

The adoption stage is reached when substantial numbers of the target group begin to use the new technology. Farmers have tried the technology and at least some of them are convinced that the return on investment is acceptable or will be acceptable within a reasonable period of time. Usually farmers will have completed several trial production cycles before they will have reached the adoption stage. However, even though they have successfully tried the technology on more than one occasion, the final step in the process, institutionalization, cannot be assured. Although substantial numbers of farmers may be involved, serious problems may develop that will halt further development. In fact, the technology may be rejected.

In the mid-1950s, Arkansas farmers began to grow a fish called the buffalo (*Ictiobus spp.*) as part of rotation of fish and rice. A number of farmers adopted the practice and produced several crops. By 1958, approximately 3,032 acres of water were devoted primarily to buffalo culture (Watson, 1979; McLarney, 1984). At one point, a processing plant for buffalo operated in the state, but after considerable initial interest, production began to decrease because, at that time, there was little market appeal for buffalo outside that area. Also, farmed fish were forced to compete in the market with wild-caught fish from the Mississippi River. Consequently, the price of the farmed fish was largely determined by the price received for the river fish. Little effort was made to locate sufficient markets outside the area to accommodate the growing production. Channel catfish farming also began to receive considerable attention about the same time and was a more profitable venture. A few buffalo still are produced for limited local consumption (Watson, 1979), but there are few fish involved. One would have to conclude that while the practice was adopted at one point, it later was essentially rejected. Certainly it was never institutionalized. By 1972, the monoculture of this species was largely non-existent in Arkansas. It was simply impractical to balance the system. Production, harvesting, and processing were implemented rather easily, but marketing and utilization could not be implemented at an acceptable level, and the technology was finally rejected.

The final decision of whether to accept or reject an aquacultural system may require considerable time, as the Arkansas experience with buffalo fish demonstrates. From the time of first trial, a period of 15-20 years elapsed before the buffalo culture system was finally rejected. Fortunately, there have been relatively few total rejections of aquacultural systems, so it is difficult to predict the time interval that might elapse before rejection would take place in other situations.

Tom Popma (personal communication) has reported an interesting phenomenon related to the rejection or adoption of aquacultural technology in Sierra Leone. In some areas of that country, the rate of abandonment of relatively successful fish ponds may reach as high as 80-90 percent. He suggested the concept of "slash-and-burn" agriculture was being applied to fish ponds. In other words, fish farmers may have felt that after a period of time, existing ponds should be abandoned.

Robertson (1971) has discussed why a new product (technology) fails when it is to be diffused in the market place. He listed six reasons for failure or lack of adoption and the percentages of total failures associated with each:

| *REASON FOR FAILURE* | *PERCENTAGE* |
|---|---|
| *1. Inadequate market analysis* | *32* |
| *2. Deficiency in the product* | *23* |
| *3. Higher production cost than anticipated* | *14* |
| *4. Poor timing of the introduction* | *10* |
| *5. Competition from similar products* | *8* |
| *6. Weakness in the marketing effort* | *3* |

While these reasons for failure were determined for specific products, I suspect that the failure to adopt new technology when it is presented would be caused by essentially the same factors.

There have been relatively few complete rejections of aquacultural systems, but re-inventions are commonplace. Re-invention is the process of change that takes place in an innovation during the implementation stage (Rogers, 1983). While an innovation may not be totally rejected, it may be rejected in its original form.

The change agency and agent play a role in final adoption of new technology. Rogers (1983) notes that stabilizing adoption and preventing discontinuation or rejections is one of their changing roles in the process. It is obvious that the agencies and their agents have played a lesser role in the diffusion of aquacultural systems in areas where they have not been utilized before. The trial and adoption of many systems have taken place with relatively little assistance from the agencies or their agents. Decentralized diffusion played a much greater role in those cases. Fortunately, in most cases the relative advantage of aquaculture has been large enough that adoption has taken place without their input.

### *Institutionalization of the Technology*

This is the final step in the diffusion process. Final adoption is complete when the technology becomes a part of the socio-cultural system (Pollnac, 1982). Rogers (1983) suggests that institutionalization has occurred when the technology becomes a regular part of the adopter's continuing operation. At this point, aquaculture has become a balanced system where all of the components (production, harvesting, processing, marketing, and consumption) at the required level are in place and functional. Another characteristic of institutionalization would be the development of aquacultural associations, or associations of producers who have joined together to promote their industry, discuss common problems, and establish a united front in dealing with change agencies, regulatory agencies, and other governmental agencies.

# CHAPTER 14
# GENERATING APPROPRIATE TECHNOLOGY

TECHNOLOGY HAS BEEN DEFINED as "the totality of the means employed to provide objects necessary for human sustenance and comfort." Lewis (1982) defines technology as "the use of knowledge to modify the physical world." From these definitions, technology would include any information, procedures, chemicals, tools, and machines necessary for the improvement of the quality of people's lives. Technology, given this broad definition, always has been important to development. Stavrianos (1971) suggested that from early history, the range of man's activities depended on the level of his technology. As his technology changed and was improved, the range of his activities was increased dramatically. Development is dependent on the generation of these new technologies that are a means of coping with resistance (bottleneck) in the environment.

There are two basic types of technology -- biological and technical. Biological technology includes factors associated with the relationships between the living dimensions of the ecosystem. For example, improved information on stocking rates, feeding practices, water quality management, and stock manipulation would be considered biological technology. Technical technology includes factors generally associated with the dimensions of the ecosystem rather than the relationships. A new strain of fish for culture, an improved feed, a new drug to be used in disease treatment, or an improved aeration device would be examples of technical technology.

The importance of these two types of technology probably shifts somewhat with the stages of aquaculture involved. Biological technology is important at all stages of development, but it probably plays a more critical role than technical technology at the lower stages. Technical technology probably plays a somewhat more important role at the more advanced stages. The importance of the differentiation between these two types of technology will be apparent in a following section.

## *Exogenous and Endogenous Technology Development*

Hayami and Ruttan (1985) have written that technical innovations or new technologies are the result of one or two general processes, an "exogenous" process and an "endogenous" one. Exogenous technology means that it is generated outside or independently of the food production research system and is related to the general progress in scientific understanding. From the beginning of recorded history, man has studied the natural order of things in an attempt to solve problems as well as to understand how things work and how to make these things work to his advantage. The process of understanding in science resulted in a spin-off of new technology that generally is unrelated to need.

The endogenous or demand process of technological innovation is the result of a dynamic response to changes in the relative costs of production inputs (resource endowments) and to growth in demand. Endogenous means that it evolves from within or is a product of the food production-utilization system. In this process, the dynamics of production factors (inputs), such as seed, nutrients, and equipment, and the demand for the products of the process induces or forces technical change. Forces within the system drive technical change. If the price of one production input, such as labor or catfish feed, increases relative to another, a sequence of technical changes is initiated that reduces the use of that input relative to the use of other inputs (Hicks' theory of induced innovation). Barriers to increased production caused by resource scarcity are cleared away by technical changes that facilitate the substitution of relatively abundant factors for relatively scarce factors. In broader economic terms, technological innovation is an endogenous process by which constraints on production imposed by inelastic supplies of land or labor are eased. In this example, a limiting supply (and the increasing cost) of labor will induce advances in mechanical, labor-saving technology, just as a limited supply of land will induce advances in biological and chemical technology to save land.

Theoretically, in the endogenous process, a price increase in feed, for example, relative to the price of other inputs results in an immediate response to develop new technology to either reduce the use of feed or reduce its price. In this situation, if private industry senses an opportunity to market a new product or new process, it moves quickly to develop, produce, and market it. This process has led to a rapid increase in the development of new technology for use in agriculture. The worldwide population explosion, which increased food demand and reduced the amount of usable land, has induced private industry to develop, produce, and market a spectacular array of new strains and breeds, new fertilizers and chemicals, and new machines.

In theory, companies that develop technology and market new products or processes are waiting expectantly for a price "signal" or an indication of a change in demand for some input. In practice, however, the system does not function exactly that way. While there are a large number of companies that develop and market technology generally in response to industry needs, they cannot wait passively for signals. They are subject to the same economic forces as farmers. In order to remain in business, they must not only respond to needs, but also they must create needs through advertising and marketing strategies. They must respond to farmers' recognized (felt) needs, but at the same time they must create an awareness of unrecognized (unfelt) needs. In this technology development and marketing environment, farmers purchase many new things that they need, as well as many new things that they want but do not really need (Easterbrook, 1985; Hadley, 1988). While this may seem to be an inefficient way to produce and market new technology, in the long term it probably is the least costly process. It allows the service companies to maintain a critical mass of development and production capacity that will be available when really critical needs for new technology arise.

The market for agricultural technology is so large that even a minor innovation can result in enormous profits for the company responsible for it. Its size, its rate of growth, and the dynamics of the prices of inputs guarantee an enormous effort on the part of private industry to produce and market a continuing flow of new technology. Many efforts to develop new technology fail, and the costs of development are lost, but because of the potential return on investment, development costs can be justified even when the outcome cannot be guaranteed.

It would be a mistake to leave the impression that new technology flows quickly and effortlessly to the marketplace in response to changes in relative factor prices (input costs) (Arndt and Ruttan, 1975). O'Connell (1989) suggests that nothing could be further from the truth. Scientific laboratories, libraries, and inventor's work benches contain countless descriptions and models of alternative technologies for producing, harvesting, processing, and marketing food and fiber. Getting those new technologies to the production sites and plants or into the hands of farmers takes an average of seven to 10 years and involves a complex sequence of activities. O'Connell (1989) further suggests that this lengthy process is the weakest link in the American economy.

This process of endogenous technological innovation is most obvious in the developed countries. There, industry responds quickly to scarcity and price fluctuation. In the poorer countries of the world, while the process works in a similar way, the response is not so rapid.

## *Bias in the Endogenous Process*

The process of endogenous technological innovation is largely market driven, thus the system can be too narrowly responsive. For example, in some cases the development of harvesting machinery in response to increasing labor scarcity can require the development of crops with less consumer appeal but that meet narrow requirements for mechanical harvesting. Currently there is concern about whether the system is providing adequate technology for smaller, family farms in the United States. Large farms produce most of the food and fiber, and the primary emphasis in technology development is in responding to the needs of these larger units. There are some studies (Chantfort, 1985; Paarlberg, 1989) which suggest that new technology, especially mechanical technology, may actually encourage the trend to fewer and larger farms. Harvey (1989) cites data indicating that the catfish industry is following the trend of other farming operations -- decreasing in number while increasing in average size. The development of new technology that results in improved economies of scale probably is at least partly responsible for this phenomenon.

Usually, almost any new technology will provide greater benefits to those who are richer in resources. Farmers usually must pay something for using new technology. Resource-rich people are generally more able to afford these costs. For example, more affluent farmers are better able to finance combines and automated milking parlors. As a result of increased productivity and the cost of the technology, these farms increase in size. The smaller farms are less able to finance the cost of the new technology. Fortunately, biological and chemical technology do not favor the larger farms over the smaller ones to the same extent as mechanical technology.

New technology also tends to favor the early adopters (Chantfort, 1985). By adopting new technology early, farmers increase profits through reduced costs per unit of output. They also tend to increase the size of their farms to pay for the technology and to take advantage of the increased productivity. As more farmers adopt the technology, with the resulting increases in production, markets become saturated and prices fall. Farmers who were late adopters or who were non-adopters may not benefit at all from the technology. In fact, its introduction may actually result in losses to them.

Similarly, the endogenous process does not work well for emerging agro-industries, such as aquaculture. While serious scarcities and input price disequilibrium exist in most types of aquaculture, market-driven technological innovation does not respond well because the market is so limited. For example, catfish farmers must contend with several extremely serious bacterial diseases. When there is a serious loss as a result of an outbreak of one of these diseases, the cost of production for that crop for that year can be extremely high. Normally in this situation, the technological innovation response process would result in the development of a number of drugs or biologics that could be used to combat the diseases. Unfortunately, the process is not responsive in this case. Potential sales are not large enough relative to the cost of developing the technology. The cost of developing and testing a new chemical for use on food fish is several million dollars. Given the size of the catfish farming industry and the incidence of disease, it would require many years of sales before a company could recover these costs and return a profit. This is an example of market failure or the inefficiency of the market in producing a socially optimal amount of a good or service (Ekelund and Tollison, 1988).

The cost of innovation and market size determines how responsive private industry will be in developing technological innovations that bring input prices back in line. While companies generally cannot afford to spend the money to develop new drugs to treat fish diseases, engineering firms and metal fabricating companies have moved quickly and forcefully to develop better pond aeration equipment. The catfish farming industry is the same size in both examples. The drug companies do not respond because of the high cost of development and the limited market; usually only a fraction of all catfish farmers have disease problems in a given year. Firms that build aerators do respond because development costs are relatively low and the market is relatively large. Virtually all catfish farmers require aeration equipment each year. Similarly, the response for developing new feeds will be relatively fast, while the response for developing new strains of catfish will be much slower.

Lack of understanding and information also limit the responsiveness of endogenous technology development to price and demand signals in aquaculture. Potential service industries know little about aquaculture or the nature of the production factors (inputs) required. As a result, even the strongest price signals from the industry are not detected. This lack of understanding probably has its most serious effect in the credit industry. The limited availability of credit is a major constraint to the development of aquaculture virtually everywhere. Also, the service industries have a limited experience base for developing new technology needed by aquaculturists. They are uncertain about the costs of development and the size of markets.

The lack of understanding and appreciation for aquaculture and its technological needs is a problem even where existing aquaculture is being expanded. In this situation, there generally are some service industries that can provide at least a limited flow of new technology. However, the problem is much more acute in situations where aquaculture is being established in new provinces or countries. The capacity for providing a flow of technology to the growing industry would have to be developed along with the capacity to deal with production, harvesting, processing, and marketing.

The capability to develop new technology generally will be induced as a result of the growth of a viable aquaculture industry. There are obvious market opportunities for new products and new equipment. As the industry grows, the demand for technology becomes so intense that existing businesses will be induced to supply it, although their response capability will be limited in the beginning. Development of a new industry -- especially if there is a strong demand pull for its products -- will not be severely constrained very long by the lack of a functioning system for providing the needed technology. In this situation, technology and equipment used in similar or even completely different industries are adapted for use in the new, rapidly growing industry. This adaptation process will not meet the needs of the industry as it matures, although adaptation will always be important in the development of appropriate technology for a new industry. Private industry has responded rapidly to provide new technology for the net pen salmon growing industry in Northern Europe. One cannot help but be impressed by the variety and sophistication of the mechanical technology being advertised for sale in trade publications, even though that industry is very young.

## *Endogenous Technology Development in the Catfish Industry*

It has been fascinating to observe the development of the capability to supply new technology to the rapidly growing catfish industry in west Alabama. There essentially was no industry there 25 years ago, and now farmers in a nine-county area produce approximately 40 million pounds of fish annually. And the industry in that area is growing at a rate of 8-10 percent a year. Two examples of the development of new technology — one to solve a production problem and the other to fill a processing need — are of special interest.

The development of equipment for pond aeration, the solution to the west Alabama production problem, is a good example of the process by which new technology is made available. As the demand for channel catfish grew, farmers increased the stocking rates and feeding rates in their ponds. With these changes, problems with dangerously low dissolved oxygen concentrations increased in frequency and severity. It soon became obvious that some means would have to be found to provide additional oxygen to the ponds, at least on an emergency basis (Tucker and Boyd, 1985).

There was some aeration equipment available from the sewage treatment industry, but it was not totally satisfactory, especially for emergency aeration. While this equipment did increase the concentration of oxygen in the immediate vicinity of the aerator, fish even a short distance away did not benefit. What was needed was a device that would add oxygen to the water and at the same time create a strong current that would move the better quality water around the pond. The affected fish could swim into the current until they reached the area near the aerator where the oxygen concentration was near saturation.

A mechanic in a welding shop in the area that serviced a wide variety of farm and forestry equipment conceived the idea of building a paddlewheel by welding flat, steel plates perpendicular to the surface, at regular intervals around the circumference of a short section of large diameter steel pipe (Figure 37). These paddlewheels were attached to the axle of a truck differential. The drive shaft to the differential was attached to the power take-off of a farm tractor. The paddlewheel was mounted on a trailer so that it could be easily moved from pond to pond. When needed, it was backed into the pond and the power take-off activated. The spinning paddlewheels throw a large volume of water into the air with considerable force, creating "curtains" of tiny droplets that absorb oxygen readily before they fall back to the surface. The force of the spinning wheels partly immersed in the water also create a strong current that carries the highly oxygenated water around the pond. The development of this aeration device designed specifically for use in pond aquacultures utilized parts and steel pipe readily available locally, and could be fabricated with technical skills available in local welding shops. Further, it could be transported and powered by a farm tractor, a piece of equipment generally available on all fish farms in the area.

Some of the technology needed to get the catfish processing industry moving in west Alabama, and the second example cited, originated in a similar manner. Equipment and pieces of equipment used for other purposes were adapted for use in fish processing. One of the most important of these adaptations to the catfish processing plant was the use of a machine that was designed to remove membranes from pork livers. The channel catfish has an extremely tough, thick skin that generally must be removed before it can be marketed. In the first processing plants, the skin was stripped off the fish using hand-held, skinning pliers. This was a tedious, labor-intensive process. Finally, someone conceived the idea of skinning fish with the machine designed for removing the membranes from pork livers. This machine

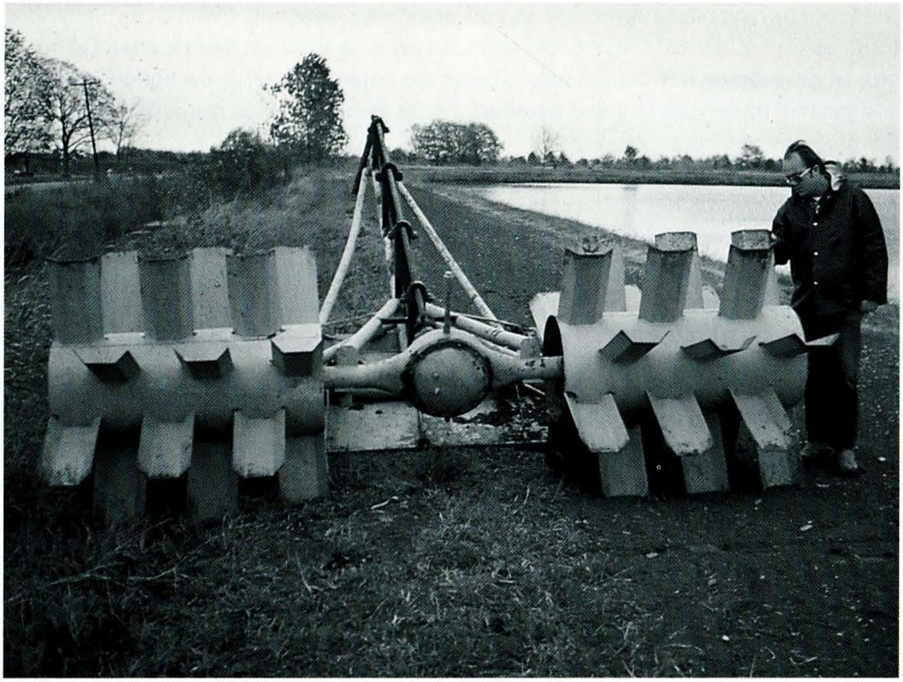


**Figure 37. Prototype paddlewheel pond aeration device.**

consists essentially of a rapidly spinning steel cylinder with knife blades mounted on the surface. The rapidly moving knives move past a fixed steel bar mounted so there is a small clearance. The liver membrane is caught in this narrow space between whirling blades and the bar. Each time a blade passes the bar, more of the membrane is pulled rapidly into the opening and past the bar.

Early attempts to use the liver skinner were failures (Chester O. Stephens, Jr., personal communications). The catfish skin would not be pulled through the narrow opening, and several hands and fingers were cut rather severely in the trial process. After many failures, it was decided that the machine simply could not be adapted for skinning catfish. Sometime later, it was decided to try the machine "just one more time." It also was decided that the blades should be sharpened. Fortunately, the man assigned the job of sharpening the blades used a coarse abrasive that dulled them rather than sharpening them. When they were put back in place, the machine functioned much better. The blades had been too sharp for the thick catfish skin. The skin was being cut rather than being pulled through the narrow opening. A redesigned machine originally built for use in pork processing plants is still used for removing the skin from most of the catfish processed in the United States (Figure 36).

Ultimately, aquaculture will be large enough so that the process of induced technological innovation will function effectively for all of the inputs required for production, harvesting, processing, and marketing (Ingram, 1987A). In the short-term, however, the responsiveness of the process will be uneven depending on the cost of developing new technology, size of the potential market for that technology, and general understanding and familiarity with the industry on the part of those who develop and market technology.

Certainly, the continuous flow of new, appropriate technology is required for the development of aquaculture. It is necessary to begin promoting the development of a responsive service industry at the same time production, harvesting, processing, and marketing components are being developed. Planning and implementing an effective strategy for its development is crucial. If this vital segment of the industry does not receive adequate attention, development of the entire industry cannot proceed very rapidly or efficiently.

## *Technology Transferability*

Developing aquaculture in the emerging nations is a special case with respect to building responsive service industries and research institutions that can provide the required technology (Steward, 1987). It will be difficult to do in most cases in the short term. There are just too many constraints to overcome for a new industry like aquaculture. In this situation, the transfer of technology is a viable solution. Because aquaculture takes place in specific containers with specific environmental characteristics and produces food animals usually for specific markets, technology provided to farmers in a given area is usually most appropriate when designed specifically for their needs (Mellor, 1989). Unfortunately, there is little choice with most emerging nations. The aquacultural technology will have to be developed someplace else and transferred.

Wortman (1980) suggested that there are differences in the transferability of technology that must be considered. Technology involving advances in physical and chemical science is more likely to be applicable in virtually any country. Technologies that involve communications, transportation, chemistry, or manufacturing also generally can be transferred rather effectively. On the other hand, technology involving the biological or social sciences has a relatively low degree of transferability (acceptance of material vs. non-material culture) (Robertson, 1987). The effectiveness of technology transfer in this case depends heavily on local ecological (climate, soils, water, pests, etc.) and social characteristics.

Developing a flow of new, appropriate technology for the lowest stages of aquaculture also is a significant problem. Often price and demand signals are so weak from these culture systems that there is limited response on the part of those businesses or institutions that could develop new technology. There are insufficient markets for new technology to encourage much interest. Also, aquaculturists at these stages usually rely on proven technology. There is little interest in experimenting. In these situations, if a flow of new technology is required, the private sector usually cannot be expected to provide it. In that case, the public sector must become involved.

## *Public Sector Development of Technology*

The private sector develops most of the new products, new equipment, and new machinery required in the advancement of agriculture and aquaculture. The public sector, especially the public-funded research institutions, such as the land-grant universities in the United States, also play a significant role in the development of new technology by conducting both basic and applied research in support of the private sector role. The public research institutions develop the basic science on which many of the new developments by private industry are based. Also, some of the institutions, especially the agricultural experiment stations, conduct important applied research on the improvement of farm practices.

The development of pond aeration equipment is a good example of the interaction between the private and public sectors in the development of new technology. The importance of aeration to catfish farming and early efforts to develop the necessary technology were described in an earlier section. The tractor-driven paddlewheel (Figure 37) played an important role in the early development of the catfish farming industry, especially for use in emergencies. It still is useful in extreme emergencies. Unfortunately, it is an inefficient method of transferring oxygen to water. Also, tractors are expensive sources of power to be used for this purpose. It is not practical to use a $40,000 farm tractor as a stationary power source.

Claude Boyd, who worked for a number of years at Auburn University in research on water quality problems in catfish production ponds, made a number of contributions (Boyd, 1979, 1990) to the understanding of the dynamics of dissolved oxygen levels in ponds. Several years ago, he became interested in the problem of the transfer of oxygen from the atmosphere to the pond water using paddlewheels. He developed a test facility and procedures for measuring the amount of oxygen being transferred and the amount of power required per unit of oxygen transferred. He also developed an adjustable, experimental paddlewheel so that he could vary the size, shape, and number of paddles, along with other characteristics. After a period of rather intense research, he developed a set of specifications that would provide for the most efficient transfer of oxygen.

Boyd publicized the results of his research in scientific journals, experiment station publications, trade publications, and presentations at meetings attended by farmers and representatives of businesses that could manufacture equipment for the catfish farming industry. Within a few months after he began to publicize his results, prototype equipment began to appear on the market. Because the research information on paddlewheel design was freely available to everyone, a number of manufacturers quickly adopted the technology and began to incorporate it into paddlewheels for the catfish farming industry. Now there are at least a dozen companies producing paddlewheels for use in the industry. There is considerable competition as these manufacturers attempt to reshape the basic Boyd technology into more marketable products (Figure 38).

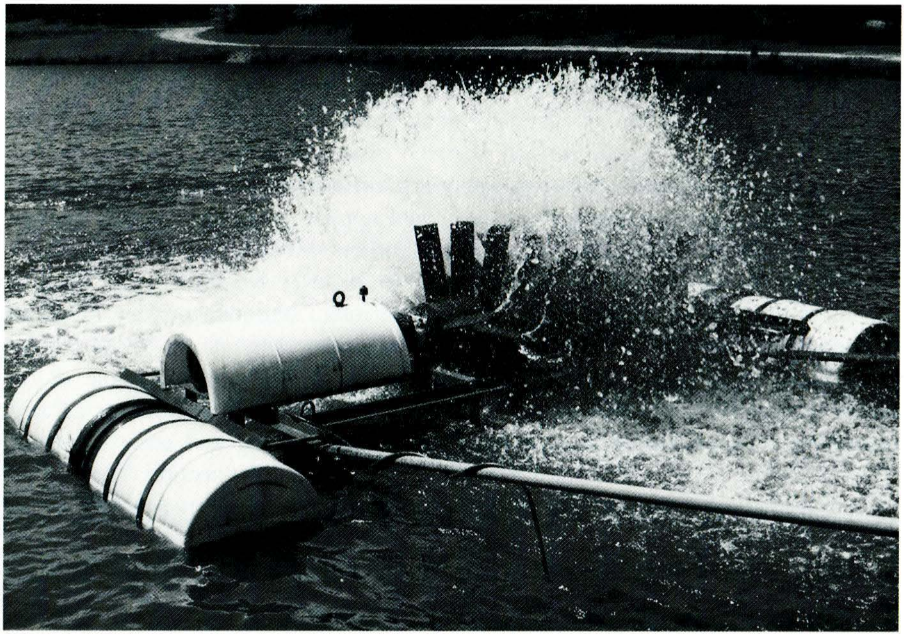


**Figure 38. Paddlewheel pond aerating device powered by an electric motor.**

The development of public research institutions is a relatively recent phenomenon, especially in agriculture. Development of new technology in farming was in the realm of the private sector, generally farmers themselves, throughout history until the mid-19th century. There are records of farmers conducting field trials to improve farming practices in England as early as the 17th century (Ruttan, 1982). These private efforts were continued through the 18th and into the 19th century. By the early 19th century, the results from the private research efforts had been successful enough to indicate that a systematic, pragmatic, problem-solving research system could provide valuable technological innovations for agricultural development. As a result of these early efforts, Great Britain was considered to be the world leader in agricultural research in the first half of the century. The first agricultural experiment station was established in England at Rothamsted in 1843. However, it was funded from private sources until the early 20th century. The first publicly funded agricultural research station was actually established in Germany at Moukern, Saxony, in 1852.

Public support for the Rothamsted Station in England was encouraged because the cost of operating it became excessive relative to the funds available from the private trust fund that had been established to sustain it. The German decision to support agricultural research from public funds seems to have been a political one (Ruttan, 1982) and was the result of a national decision to "overcome the gap in resource endowments, in industrial and agricultural technology, and in economic and political power between Germany and Great Britain." Public funding for agricultural research grew in popularity through the late 19th century. The first state agricultural experiment station in the United States was established in Connecticut in 1877. Early Japanese efforts to improve agriculture were based on the transfer of western technology. Finally, an experimental farm was set up in Japan in 1886, and a national agricultural experiment station was established in 1893. The concept of public involvement in the development of new technology for agriculture has continued to flourish in the 20th century. Now, most countries have at least a rudimentary system of publicly supported agricultural research.

As noted previously, the production of new technology is induced in private industry primarily as a result of market opportunities. Market forces, in theory, control the rate and direction of the production of new technology. Public research institutions are largely independent of these forces. Instead, farmers must somehow inform the institutions of their need for technology, and the institutions respond. This system probably works best when farmers are organized so that they are able to communicate their needs more forcefully and with a single voice (Ruttan, 1982). The effectiveness of the relationship also is strengthened if the institutions have change (extension) agents who provide a two-way, continuing communication link between farmers and scientists.

Hayami and Ruttan (1985) suggested that public funding for agricultural research resulted from the failure of market forces to induce sufficient new technology for a broad range of large and small farms. Private enterprise would be expected to emphasize the development of new products for which there would be the greatest demand and for which the return on investment would be the greatest. This approach would likely not meet the needs of all farms.

Public funding of research also was expected to correct another problem inherent in the development of new technology by private enterprise. Basic research is essential for the long-term flow of new technology (Arndt and Ruttan, 1975). Unfortunately, the results of this type of research usually cannot be protected by patents. It is generally available for everyone to exploit. Firms involved in basic research may have a difficult time earning an adequate return on their investment. In establishing public research institutions, it was expected that there would be a steady flow of basic research that private enterprise would convert into new products or new equipment that could be protected by patents. While this was obviously an effective approach to these problems, and American farmers and consumers have benefitted significantly from the technology produced by those institutions, there have been at least some indications that the state and federal agricultural research stations have not been as responsive as was initially planned. Ruttan (1982) notes that books by Rachel Carson (*Silent Spring*, 1972) and Jim Hightower (*Hard Tomatoes, Hard Times*, 1973) and the report prepared by a committee of the National Research Council, chaired by Dean Glenn S. Pound, severely criticized the quality and focus of agricultural research conducted by public institutions (Also, Budiansky, 1985). Public research institutions were created to avoid the pressures of the market. Critics of these institutions now contend that without at least some pressure, the institutions tend to "wander about aimlessly."

Also, it is difficult to change the research agenda in publicly supported research institutions. Even after farmers served by an institution no longer have a comparative advantage in producing a specific crop and are no longer competitive in an expanding world market, it is extremely difficult to reallocate those research resources to another crop. Commodity organizations, usually with political support, oppose such reallocations. Also, it is difficult to phase out programs, to abandon expensive facilities, and to terminate permanent research staff.

There is another problem with public research institutions, such as at the State Agricultural Experiment Stations in the United States. In terms of the land, labor, and capital available to them, they resemble moderately endowed farms and farmers. When most of these research stations were established, this was the predominant type of farm in the country, and for many years they produced a wealth of valuable new information and technology. However, in recent years, this moderate-sized family farm is being replaced with a smaller number of large, highly capitalized, high-technology farms and a large number of smaller farms where most of the family income is generated off the farm (Martinez, 1986A). Given the resources (funds, staff, and facilities) available to the public agricultural experiment stations, they have a difficult time meeting the applied research needs for either the small or large farms.

The public research institutions were expected to solve still a third problem. Research, especially basic research, is a stochastic process. Success cannot be predicted. Often years of research must be completed before results are obtained that can be converted into a marketable product. This unpredictability is a heavy burden for the private sector. It was envisioned that public funding would allow research to be conducted without undue pressure for immediate results. While the idea was a good one, and this system of research provided much of the information to make the American farmer the most productive in the world, there have been some problems encountered in implementing it. Ruttan (1982) suggested that 50 to 70 years of persistent effort were required to organize a productive, public-supported agricultural research and extension system in the United States. After all of these years, there is some concern whether this supposedly complementary system of private enterprise and public institutions can be effectively joined to produce the kinds of technology needed for an increasingly competitive world (Gomory and Shapiro, 1988). Wortman (1980) noted that the principal weakness of the publicly supported agricultural research network seems to be absence of acceptable procedures for involving business and industry.

Publicly funded research institutions have played a somewhat different role in the development of aquaculture than they did in the development of agriculture. Agriculture was relatively well developed throughout the world for several thousand years before the first public research institution was established. In the case of aquaculture, some public research institutions were in place before the first commercial aquaculture was established. The aquaculture research station at Auburn University (then the Alabama Polytechnic Institute) was established in 1934, some 20 years before the first commercial ventures in catfish farming were established (Swingle et al., 1936). This station was established primarily to conduct research on ponds managed for recreational fishing. While the development of the research station at Auburn predated the beginning of the catfish industry, the Research Institute for Fisheries and Hydrobiology was established at Vodnany in Czechoslovakia 800 years after the beginning of carp farming in that country (Dyk and Berka, 1988).

The public research institutions have played a leading role almost from the beginning of commercial aquaculture in many countries. Much of their research has been highly applied rather than basic. Emphasis has been on solving procedural and cultural problems limiting production and profitability. Most of the institutions are experimental farms where farmer innovations are tested or practical farmer problems are investigated. While this approach has limited risk-taking by farmers to some extent, the long-term implications for the institutions are somewhat sobering. At some time they will need to devote more time and energy to basic research (Budiansky, 1985). Unfortunately, the transition from public experimental farms to research institutions will be difficult.

The public research institutions also are facing another problem related to basic research that affects their role of making knowledge available to all. Basic research today is so expensive that the public institutions have a difficult time obtaining funds for it. Often they must establish some type of partnership with the private sector to obtain the necessary funds. Unfortunately, these partnerships may lead to some restriction in the dissemination of the information obtained from the research. Businesses usually are not willing to commit resources to the partnerships unless they can recognize some return on their investment (Henkes, 1989).

# CHAPTER 15
# ESTABLISHING EFFECTIVE COMMUNICATIONS

THERE IS ONE FINAL MATTER TO CONSIDER in our discussion of the implementation of a development strategy for aquaculture: communications. I discussed how the components of the aquaculture ecosystem are related, using the analogy of the spider's web. The elements of a web are joined physically so that the impact of a fly striking any part is instantly communicated throughout the structure. While the components of aquatic animal culture are not physically connected, the same efficiency of communication is essential for the function of the aquaculture ecosystem. Some aspects of the establishment and maintenance of a communication system will be discussed in the following sections.

Using the model of animal biology again, warm-blooded animals such as rabbits and squirrels are highly successful in optimum environments. Like all similar animals, they have a relatively constant internal environment (blood pressure, blood glucose levels, blood cell counts, and respiration rates). They are able to respond effectively to changes in their external environment. They are able to obtain food, generally able to avoid danger, and able to produce young at the best time of year for survival. And they are able to cope with changes in weather from winter to summer. A primary reason for the success of these animals in rapidly changing environments is their superbly organized and efficiently functioning internal communications systems. Nervous systems and chemical (hormonal) communication systems join each cell, tissue, and organ into a unitary, highly integrated whole. This internal environment is linked to the external environment through specialized sensory receptors, such as the eyes, ears, and nose. This highly integrated system or set of systems can react quickly and effectively to changes in the external environment. For example, when the animal is faced with a dangerous situation that develops suddenly in its external environment, virtually every organ, tissue, and cell quickly become involved in a measured response to the situation.

Communication is important in the development of aquaculture, either where it is being established for the first time or where it is being expanded. This is not to suggest that the different elements of aquaculture (production, harvesting, processing, marketing, and utilization) could ever be linked in a highly integrated system such as that found in higher vertebrates. However, those highly effective systems serve as a model for communication needs in aquaculture. This model suggests that the development of aquaculture would proceed most effectively if all of its elements were linked so that changes in the environment or ecosystem in which it operates could quickly be transmitted throughout the industry for measured response.

Obviously, there already is some communication among the elements of aquaculture. Customers, for example, signal their displeasure with a cultured product by not purchasing it. The consequences of a lack of sales are transmitted from the retail outlet to the wholesaler, then to the processor, and finally to the farmer (Senauer, 1989). Similarly, the demand for a new product relative to supply is communicated throughout the industry. Farmers build more ponds. New processing plants are constructed. Additional feed processing capacity is added. Equipment manufacturers look for ways to build better equipment to capture a larger share of the expanding volume of business. This communication system is largely market driven. Prices paid and received in the market are observed by the components of the industry, and responses are undertaken based on their perception of the meaning of those signals.

Koehler et al. (1976) and Rogers and Rogers (1976) suggested that only where there is effective, interactive communication in an organization can a coordination of activities be achieved. Interactive communication is the mortar that holds organized structure together and that gives it unity and cohesion. The same authors also suggested that communication involves the continuing exchange of information, opinion, and attitudes which are required to maintain coordination within the organization and to allow it to interface effectively with its environment. It is interesting that the Koehler et al. (1976) description of the role of communications in organizational development and function parallels the description of communications among cells, tissues, organs, and systems in animals described previously.

A specific aquacultural industry is not a typical organization. There is no central, controlling authority usually found in organizations, but the industry does have one characteristic common to all organizations. That is the fact that a number of people are working toward achieving specific objectives, namely producing, harvesting, processing, marketing, and utilizing aquatic animals. Even without a central, controlling authority, the commonality of objectives suggests that the various segments of an industry could function as an organization.

Good communications would appear to be especially important in rapidly growing organizations such as aquaculture. Koehler et al. (1976) also suggest that in new organizations especially, the necessity for continuous, multi-level, multi-directional communications becomes increasingly urgent. Rapidly growing organizations, especially those involved in production of a commodity, require a continuously increasing amount of materials, technologies, processes, and ideas. Providing these necessary inputs in adequate quantity and quality and in the proper sequence cannot be achieved without some coordination, and good communications are a primary requirement for coordination.

Achieving effective communications among the disparate elements (farmers, seed producers, feed mills, credit institutions, regulatory agencies, public research agencies, processors, equipment manufacturers, wholesale markets, retail markets, and consumers) comprising an aquacultural industry is a difficult problem. Balit

(1988) has commented on the difficulty of achieving good communications in development efforts. While Balit's remarks are specifically concerned with development projects in emerging nations, the same limitations also apply to establishing effective communications in all organizations, including the aquaculture ecosystem. According to this author, difficulties with achieving effective communication include:

*1. Lack of appreciation for the importance of communications in the development process.*
*2. Incompatible communication approaches.*
*3. Differing use of language by the elements of the organization.*
*4. Divergent interests of the parties involved.*
*5. Differing perceptions of the objectives of the organization.*

Suggestions for overcoming each of these difficulties will be discussed in the following sections.

## Developing an Appreciation of Communications

Because of the results obtained from the two-way exchange of information, ideas, and opinions between change agents (extension) and farmers, there is widespread acceptance of this use of communication in some components of agriculture. Unfortunately, there is limited appreciation for the wider use of communication among all components of the entire food and fiber production ecosystems. Almost without exception, the emphasis in agricultural and aquacultural extension programs is on farmer education. Establishing and maintaining communications networks among farmers, bankers, retailers, processors, and other participants in the system receives relatively little attention. There are some communications among all of these components, but they tend to be generally passive rather than active except for contacts between the change agent and farmers. Farmers communicate with bankers when they need credit, but often these lending institutions have received relatively little information about the various components of the production, harvesting, processing, marketing, and utilization ecosystem. Bankers have limited understanding or appreciation of the factors involved that will determine whether the loan can be repaid. Farmers often have an even poorer understanding of all of the components of the ecosystem and how they interact. One can only speculate whether the crisis in agriculture in the United States in the mid-1980s could have been averted or reduced in severity if there had been better communications among all of the participants in the ecosystem.

Establishing and maintaining an effective communications network is difficult, time consuming, and expensive. At the same time, it is questionable whether agriculture or aquaculture can continue to develop and function effectively in an increasingly interdependent and competitive world without more appreciation for and more emphasis on communications within the entire ecosystem.

## *Developing Compatible Communications*

Approaches for use in agricultural extension have received considerable attention over a long period. A wide range of group and individual methods, including group discussions, result demonstrations, method demonstrations, conducted tours, personal visits to farms, and training and visit methods have been developed to communicate with farmers (Savile, 1965; Maunder, 1973; Benor and Baxter, 1984; Engle and Stone, 1989). There is considerable agreement and disagreement on the effectiveness of each of these methods. While this change agent-farmer communications relationship has received so much attention, there has been limited concern with developing effective strategies or approaches for change agents to communicate with bankers or equipment manufacturers or for farmers to communicate with consumers or legislators. Some of the so-called extension methods listed above might be effective in communications networks involving the various components of the aquacultural ecosystem, but it is likely that most would not. We will need new approaches specifically designed for communications linkages between the various components. The incompatibility of existing approaches for the broad range of network linkages is a major problem.

## *Learning a Common Language*

A difficult problem in establishing effective communications in aquaculture is language. The situation is reminiscent of the problem encountered by those attempting to construct the Tower of Babel described in the Old Testament. Only a few individuals in the aquaculture ecosystem know the languages of biology, chemistry, engineering, finance, marketing, sociology, and economics, so our ability to communicate is limited. If we are to establish effective communications networks, we must take time to learn at least some of the spectrum of languages involved.

## *Merging the Interests of Ecosystem Components*

Still another problem encountered in establishing communications networks is the divergent interests of the parties involved. For example, a fish farmer might obtain credit from a lending institution or from a group of investors. While both groups provide the same credit, they tend to have divergent interests in the production of a given crop of fish. The lending institution generally might be concerned with recovering the principal of the loan plus interest from that specific crop, while an investment group might be less concerned with short-term performance. Communications with these two groups likely would be quite different.

Similarly, scientists and farmers have divergent interests in aquaculture. Earning one's living growing fish is a different matter from researching the production of fish for a living. The interests of the two are highly divergent. A scientist might let a pond of fish die to learn something new about aquaculture. Farmers cannot afford to do this. If we are to develop effective communications networks, all parties included in the ecosystem must make an effort to reconcile the divergence of interests.

## *Sharing Perceptions of Objectives*

It is likely that most components of an aquacultural industry are not functionally aware that they are part of an organization or ecosystem. This lack of appreciation for the concept of the organization makes communication difficult. All of the components are independently owned and operated. They seldom, if ever, hold organization meetings. Yet all of them, even consumers, share some part of the same objective — to participate in a strong, vital industry that is expanding at a regular rate and provides an adequate return on investment. The long-term success of all components of the industry, including the consumer, depends on reaching this objective. It appears, however, that the various participants often have differing perceptions of the objectives of the organization.

Unfortunately, the highly competitive, market-oriented business world in which the individual enterprises (farmers, bankers, feed manufacturers, equipment dealers, etc.) operate does not encourage the participants to pursue policies or management strategies that promote the common good of the industry. The nature of current American economic environment discourages the development of the symbiotic relationships that would result in mutual benefit to all participants. Gomory and Shapiro (1988) suggested that the lack of competitiveness in American industry may result from our inability to work together or to coordinate the efforts of industry components. They further suggested that Japanese successes in economic competition worldwide are likely the result of their ability to do so. Short-term changes in interest rates, inflation rates, export opportunities, tax policies, and other government rules and regulations force participating businesses to pursue relatively narrow, short-term objectives that often are in conflict with long-term development objectives of the industry.

All of these problems that inhibit the establishment of effective communications networks in an aquacultural industry can be overcome. However, in order to do so, there must be an increased appreciation of the importance of communications among all components of the ecosystem and a major investment in developing the new approaches to ensure that farmers, bankers, processors, retailers, and consumers are hearing, speaking, and responding to the same language.

I suspect that it will be difficult for private change agencies to come together to form the necessary communications linkages that are necessary because of their narrow interests in the development process. Probably the public sector change agencies should encourage and catalyze this effort. Ideally, the proven communications network that links farmers, change agents, and scientists in public agricultural institutions could be expanded to include all other components of the industry. However, I am not sure that these institutions have the necessary flexibility to expand their programs to the degree necessary. Publicly supported change agencies in agriculture have specialized so narrowly, probably because of the legislation establishing them, that they may not be capable of dealing effectively with this larger environment. Certainly every effort should be made to encourage them to accept this expanded role of technology transfer.

# LITERATURE CITED

Agency for International Development. 1989. Development and the National Interest: U. S. Economic Interest into the 2lst Century. Washington, D.C.

Aiken, D. 1990. Shrimp Farming in Ecuador — An Aquaculture Success Story. World Aquaculture. 21(1):7-16.

Ammerman, G.R. 1985. Processing. Pages 569-620 in C.S. Tucker, ed. Channel Catfish Culture. Elsevier. New York.

Anderson, J.M. 1987. Production and Decomposition in Aquatic Ecosystems and Implications for Aquaculture. Pages 123-147 in D.J.W. Moriarty and R.S.V. Pullin, eds. Detritus and Microbial Ecology in Aquaculture. International Center for Living Aquatic Resources Management. Manila, Philippines.

Annis, S. 1987. The Next World Bank? Financing Development from the Bottom up. Grassroots Development. 11:1, 24-29. Aquaculture Digest. 1989. World Shrimp Farming 1988: The Farming Cycle. February:3-4.

Arce, R.G. and C.E. Boyd. 1980. Water Chemistry of Alabama Ponds. Ala. Agr. Exp. Sta., Auburn, Ala. Bull. 522.

Arndt, T.M. and V. Ruttan. 1975. Resource Allocation and Productivity in National and International Agricultural Research. The Agri. Dev. Council, Inc. New York.

Astatke, A., S. Bunning, and F. Anderson. 1986. Building Ponds with Animal Power in the Ethiopian Highlands. International Livestock Centre for Africa. Addis Abaja, Ethiopia.

Bailey, C. 1988. The Social Consequences of Tropical Shrimp Mariculture Development. Ocean and Shoreline Management. 11:31-44.

Baldwin, F.D. 1989. Appalachian Aquaculture: Many Streams to the Future. Appalachia. 22(3) :7-15.

Balit, S. 1988. Communication is the Message. Ceres. 21(2):13-15.

Bardach, J.E., J. H. Ryther, and W.O. McLarney. 1972. Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. Wiley-Interscience. New York.

Barnett, J. 1987. Mississippi Catfish and the Chicken Boys. Seafood Business. September/October:58-65.

Baum, W.C. and S.M. Tolbert. 1989. Lessons from World Bank Experience. World Development Forum. 7(5):2.

Bayne, D.R., D.R. Dunseth, and C.G. Ramirios. 1976. Supplemental Feeds Containing Coffee Pulp for Rearing Tilapia in Central America. Aquaculture, 7:133-146.

Beleau, M.H. 1985. High Density Culture Systems. Pages 85-105 in Tucker, C.S., ed., Channel Catfish Culture. Elsevier, New York.

Bell, F.W. 1968. The Pope and the Price of Fish. Amer. Economic Rev. 58:1346-1350.

Benor, D. and M. Baxter. 1984. Training and Visit Extension. The World Bank. Washington, D.C.

Ben-Yami, M. 1986. Aquaculture: The Importance of Knowing its Limitations. Ceres. 19(4):15-19.

Berka, R. 1986. A Brief Insight into the History of Bohemian Carp Pond Management. Pages 35-40 in R. Billard and J. Marcel, eds., Aquaculture of Cyprinids. INRA. Paris.

Beveridge, M.C.M. 1987. Cage Aquaculture. Fishing News Books Ltd. Farnham. Surrey, England.

Bheenick, R., E.G. Bonkoongou, C.B. Hill, E.M. McFarland Jr., D.N. Mokgethi, K.M. Mtawali, M.O. Schapiro, S. Wainaina, S.D. Younger, and J.B. Zongo (Contributors). 1989. Successful Development in Africa: Case Studies of Projects, Programs, and Policies. Economic Development Institute, Analytical Case Studies — Number 1. The World Bank, Washington, D.C.

Bligh, E.G. 1980. Methods of Marketing, Distribution and Quality Assurance. Pages 48-55 in Connell, J.J., ed., Advances in Fish Science and Technology.

Boyd, C.E. 1979. Water Quality in Warmwater Fish Ponds. Ala. Agri. Exp. Sta. Auburn, Ala.

Boyd, C.E. 1982. Hydrology of Small Experimental Fish Ponds at Auburn, Alabama. Transactions of the Amer. Fisheries Soc. 3:638-644.

Boyd, C.E. 1985. Hydrology and Pond Construction. Pages 107-133 in C.S. Tucker, ed., Channel Catfish Culture. Elsevier, New York.

Boyd, C.E. 1989. Water Quality Management in Shrimp Ponds. Ala. Agr. Exp. Sta. Auburn, Ala. Fisheries and Allied Aquacultures Dept. Ser. No. 2.

Boyd, C.E. 1990. Water Quality in Ponds for Aquaculture. Ala. Agr. Exp. Sta. Auburn, Ala.

Boyd, C.E. and W.D. Hollerman. 1982. Solar Radiation and Dissolved Oxygen Concentrations in Fish Ponds. Ala. Agr. Exp. Sta. Auburn, Ala. Cir. 261.

Boyd, C.E. and J.L. Shelton, Jr. 1984. Observations on the Hydrology and Morphometry of Ponds on the Auburn University Fisheries Research Unit. Ala. Agr. Exp. Sta. Auburn, Ala. Bull. 558.

Bransom, R.E. and D.G. Norvell. 1983. Introduction to Agricultural Marketing. McGraw-Hill. New York.

Brown, L.A. 1981. Innovation Diffusion. A New Perspective. Methven. New York.

Brown, L.R. 1985. Fish Farming. The Futurist. October: 18-25.

Brown, L.R. 1988. Breakthrough on Soil Erosion. World Watch. 1(3):19-25.

Buchanan, J.M., R.D. Tollison, and V.J. Vanberg, compilers. 1987. Economics: Between Predictive Science and Moral Philosophy. Texas A&M Univ. Press. College Station, Texas.

Budiansky, S. 1985. Trouble Amid Plenty. The Atlantic Monthly. January:65-69.

Bureau of Sport Fisheries and Wildlife. 1970. Report to the Fish Farmers. U.S. Dept. of the Interior. Resource Pub. 83.

Bureau of Sport Fisheries and Wildlife. 1973. Second Report to the Fish Farmers. U.S. Dept. of the Interior. Resource Pub. 113.

Burgess, G.H.O., C.L. Cutting, J.A. Lovern, and J.J. Waterman, eds. 1967. Fish Handling and Processing. Chemical Publishing Co., New York.

Burnett, J. 1989. Netting Big Profits. Neighbors, Alabama Farmers Federation. Montgomery, Ala. 14(3):8-11.

Busch, R.L. 1985A. Channel Catfish Culture in Ponds. Pages 13-84 in C.S. Tucker, ed., Channel Catfish Culture. Elsevier. New York.

Busch, R.L. 1985B. Harvesting, Grading and Transporting. Pages 543-567 in C.S. Tucker, ed. Channel Catfish Culture. Elsevier. New York.

Chantfort, E.V. 1985. Technology: The Treadmill of Agriculture. Farmline. 6(6):12-14.

Chantfort, E.V. 1988. How Will Agriculture Markets Respond to Population Doubling? Farmline. 9(7):12-13.

Chaston, I. 1983. Marketing in Fisheries and Aquacultures. Fishing News Books Ltd. Farnham. Surrey, England.

CHERFAS, J. 1990. FAO Proposes a "New" Plan for Feeding Africa. Science. 250(4982):748-749.

CICHRA, C.E. and L.T. CARPENTER. 1989. Fee Fishing as an Economic Alternative for Small Farms. Southern Rural Development Center. Miss. State Univ., Mississippi State, Miss.

COMTE, M.C., P. HENDRY, and G. THOMAS. 1984A. The New Regime for Fisheries-Prospects Policies and Practices. Ceres. 17(1):25-32.

COMTE, M.C., P. HENDRY, and G. THOMAS. 1984B. Tilting the Trade Balance. Ceres. 17(1):37-38.

CONNELL, J.J. 1980. Control of Fish Quality. Fishing News Books Ltd. Farnham. Surrey, England.

COSTA-PIERCE, B.A. 1987. Aquaculture in Ancient Hawaii. BioScience. 37(5):320-331.

COSTANZA, R., and L. WAINGER. 1992. No Accounting for Nature. Carrying Capacity Network. 1(2):5-7.

COWLEY, G. 1988. The Earth is One Big System. Newsweek. November 7:98-99.

CROOK, C. 1990. The Economics of Free Trade. The Economist. Vol. 316, No. 7673; Pages 12-19 (In a special section on world trade beginning on page 67).

DAFT, L.M. 1988. Priority Issues for a New Farm Bill. Pages 65-77 in Johnson, J.L. and R.J. Hildreth, eds. Increasing Understanding of Public Problems and Policies — 1988. Farm Foundation. Oak Brook, Ill.

DAVIS, J.T. 1986. Baitfish. Pages 149-158, in R. Stickney, ed., Culture of Nonsalmonid Freshwater Fishes. CRC Press, Inc. Boca Raton, Fla.

DE LORENZO, T.J. 1989. Why Free Trade Works. Reader's Digest. February: 119-123.

DIAMOND, J. 1989. The Great Leap Forward. Discover. 10 (5):50-60.

DICKS, M. and D. HARVEY. 1988. New Industry Fishes for Acceptance. Agr. Outlook. June:16-17.

DUNHAM, R.A. and R.O. SMITHERMAN. 1985. Improved Growth Rate, Reproductive Performance, and Disease Resistance of Crossbred and Selected Catfish from AU-M and AU-K Lines. Ala. Agr. Exp. Sta., Auburn, Ala. Cir. 279.

DUNSETH, D.R. 1975. Production of Tilapia aurea (Steindachner) in Combination with the Predator Cichlasoma managuense at Varying Stocking Rates and Ratios. M.S. Thesis. Auburn Univ., Auburn, Ala.

DUNSETH, D.R. 1977. Polyculture of Channel Catfish Ictalurus punctatus, Silver Carp Hyaophthalmichthys molitrix and Three All-Male Tilapias, Sarotheredon spp. Ph.D. Dissertation. Auburn Univ., Auburn, Ala.

DUPREE, H.K. and J.V. HUNER, eds. 1984. Third Report to the Fish Farmers. U.S. Fish and Wildlife Ser. Washington, D.C.

DURNING, A.B. 1989A. Action at the Grassroots: Fighting Poverty and Environmental Decline. Worldwatch Paper 88. The Worldwatch Institute. Washington, D.C.

DURNING, A.B. 1989B. Poverty and the Environment: Reversing the Downward Spiral. Worldwatch Paper 92. Worldwatch Institute. Washington, D.C.

DYK, V. and R. BERKA. 1988. Major Stages of Development in Bohemian Fish Pond Management. Papers of R.I.F.H. Vodnany. Research Institute of Fishery and Hydrobiology. Vodnany, Czechoslovakia. 17:1-44.

EASTERBROOK, G. 1985. Making Sense of Agriculture. The Atlantic Monthly. July:63-78.

EDWARDS, C. 1986. A Future Tied to Exports. Farmline 7(6):4-5.

EGAN, J. 1990. The Fish Story of the Decade. U.S. News and World Report. 109 (21):52-56.

EHRLICH, P.R. and A.H. EHRLICH. 1988. Population, Plenty and Poverty. National Geographic. 174(6):914-

917.

Ekelund, R.B., Jr. and R.D. Tollison. 1988. Economics. Scott, Foresman and Company. Glenview, Ill.

Engle, C.R. and N.M. Stone. 1989. A Review of Extension Methodologies in Aquaculture. Aquaculture Development and Coordination Programme. ADCP/RED/89/44. United Nations Development Programme. Food and Agr. Org. of the U.N. Rome.

Engle, C.R., U. Hatch, S. Swinton, and T. Thorpe. 1989. Marketing Alternatives for East Alabama Catfish Producers. Ala. Agr. Exp. Sta., Auburn, Ala. Bull. 596.

Evans, L.T. 1980. The Natural History of Crop Yields. American Scientist. 68:388-397.

Fentress, E.A. 1987. Ponds Linked to Water Table Drop, Official Says. The Catfish Jour. 1(7) :3.

Fitzgerald, R. 1987. Salmon, Canada's Aquacultural Gold Rush. Seafood Leader. 7(2) :138-152.

Food and Agriculture Organization of the United Nations. 1986. Programme advisory note on international technical assistance in aquaculture. ADCP/REP/1986/24. Rome.

Food and Agriculture Organization of the United Nations. 1989. Aquaculture Minutes. Inland Water Resources and Aquaculture Service. Rome. 6:5-6.

Food and Agriculture Organization of the United Nations. 1990. Aquacultural Minutes. Inland Water Resources and Aquaculture Service. Rome. 7:1.

Food and Agriculture Organization of the United Nations. 1991. Globefish Covers the Market. Ceres. 23(3) :14.

Foulke, J. 1989. Catfish Leads the Way as Aquaculture Booms. Farmline. 10(3) :8-11.

Galman, O.R., J. Moreau, and R.R. Avtalion. 1988. Breeding Characteristics and Growth Performance of Philippine Red Tilapia. Pages 169-175, in R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. MacLean, eds. The Second International Symposium on Tilapia in Aquaculture. Int. Center for Living Aquatic Resources Manag. Manila, Philippines.

Garrett, W.E. 1988. Where Did We Come From? National Geographic. 174(4) :434-435.

Gomory, R.E. and H.T. Shapiro. 1988. A Dialogue on Competitiveness. Issues in Science and Technology. Summer 1988:36-42.

Goudsmit, S.A. and R. Claiborne. 1966. Time. Life Science Library. Time Inc., New York.

Gould, S.J. and N. Eldredge. 1977. Punctuated equilibria: The Tempo and Mode of Evolution Reconsidered. Paleobiology. 3;115-151.

Grivetti, L.E. 1982. The Rationale, Promise and Realities of Aquaculture: A Cultural-Nutritional Perspective. Pages 11-20 in L.J. Smith and S. Peterson, eds., Aquaculture Development in Less Developed Countries — Social, Economic, and Political Problems. Westview Press, Inc. Boulder, Colo.

Guerrero, R.D., III. 1987. Tilapia Farming in the Philippines. National Book Store. Manila, Philippines.

Hadley, P.R. 1988. High-Tech: How Much is Too Much? World Aquaculture. 19(4) :52.

Hammond, R. 1990. How Does a Country Grow? A New Measure of Development. Development Forum. 18 (4):1.

Hancock, G. 1989. Lords of Poverty. The Atlantic Monthly Press. New York.

Handley, P. 1989. Cultural Revolution. Far Eastern Econ. Rev. October 5:96-97.

Hannan, M.T. and G.R. Carroll. 1992. Dynamics of Organizational Populations — Density, Legitimation, and Competition. Oxford Univ. Press. New York.

Harvey, D. 1988. Aquaculture: Meeting Fish and Seafood Demand. National Food Rev. 2(4):10-13.

HARVEY, D. 1989. Catfish Sales Jump 17 Percent. Agr. Outlook. April: 17-18.

HARVEY, D. 1990. Aquaculture: Situation and Outlook Report. Economic Research Service. U. S. Dept. of Agr. AQUA-4 (March). Washington, D.C.

HAYAMI, Y. and V.W. RUTTAN. 1985. Agricultural Development — An International Perspective. The Johns Hopkins University Press. Baltimore, Md.

HENKES, R. 1989. Ag Research Today: Who's Paying the Piper? The Furrow (Southern Edition). 94(3):10-13.

HEPHER, B. and Y. PRUGININ. 1981. Commercial Fish Farming: With Special Reference to Fish Culture in Israel. John Wiley and Sons. New York.

HERMAN, B. 1991. Making Foreign Aid Work. Development Forum. 19 (1):3.

HICKLING, C.F. 1968. The Farming of Fish. Pergamon Press. New York.

HISHAMUNDA, N. and J.F. MOEHL, JR. 1989. Rwanda National Fish Culture Project. International Center for Aquaculture. Ala. Agr. Exp. Sta., Auburn, Ala. Res. and Dev. Ser. No. 34.

HOPKINS, T.A. and W.E. MANCI. 1989. Feed Conversion, Waste and Sustainable Aquaculture: The Fate of Feed. Aquaculture Magazine. 15(2) :30-36.

HUNER, J.V. and H.K. DUPREE. 1984A. Methods and Economics of Channel Catfish Production and Techniques for the Culture of Flathead Catfish and Other Catfishes. Pages 44-82 in H.K. Dupree and J.V. Huner, eds., Third Report to the Fish Farmers. U.S. Fish and Wildlife Ser. Washington, D.C.

HUNER, J.V. and H.K. DUPREE. 1984B. Warmwater Fish Farming: A Thriving Industry. Pages 1-5 in H.K. Dupree and J.V. Huner, eds., Third Report to the Fish Farmers — The Status of Warmwater Fish Farming and Progress in Fish Farming Research. U.S. Fish and Wildlife Ser. Washington, D.C.

HUNER, J.V., H.K. DUPREE, and D.C. GREENLAND. 1984. Harvesting, Grading and Holding Fish. Pages 158-164 in H.K. Dupree and J.V. Huner, eds. Third Report to the Fish Farmers. Dept. of the Interior. U.S. Fish and Wildlife Ser. Washington, D.C.

IKERD, J.E. 1989. Determining Your Competitive Advantage. Pages 62-66 in D.T. Smith, ed. Farm Management. Yearbook of Agriculture. U.S. Dept. of Agr. Washington, D.C.

INGRAM, M. 1987A. High Technology, High Return Aquaculture. Aquaculture Magazine. 13( 1) :18-20.

INGRAM, M. 1987B. The European Trout, the Swing to Larger Trout. Aquaculture Magazine. 13(6) :36-40.

JENSEN, J. 1981. Catfish Production in Ponds. Ala. Coop. Ext. Serv. Auburn, Ala. Cir. ANR-195.

JENSEN, J.W. 1989. Watershed Fish Production Ponds. Sou. Reg. Aquaculture Center Pub. No. 102.

JONES, K.D. 1988. Multi-Million Indoor System Under Construction in Virginia. Catfish News. 3(3):1-2.

KEENUM, M.E. and J.E. WALDROP. 1988. Economic Analysis of Farm-Raised Catfish Production in Mississippi. Miss. Agr. and For. Exp. Sta. Mississippi State, Miss. Tech. Bull. 155.

KEETON, W.T. 1967. Biological Science. W.W. Norton and Company, Inc. New York.

KENT, G. 1986. Aquaculture: Motivating Production for Low-Income Markets. Ceres 19 (4):23-26.

KENT, G. 1987. Fish, Food and Hunger: The Potential of Fisheries for Alleviating Malnutrition. Westview Press. Boulder, Colo.

KING, J. 1987A. Groundwater Vulnerable to Contamination by Chemicals. Farmline. 8(6) : 12-14.

KING, J. 1987B. Catfish "Feedlots" Expand Across the South. Farmline. 8(6):16-17.

KING, J. 1988. U. S. Broiler Industry is Still Expanding. Farmline. 9(3):12-15.

Kinnucan, H. and D. Wineholt. 1989. Econometric Analysis of Demand and Price-Marking Functions for Catfish at the Processor Level. Ala. Agr. Exp. Sta., Auburn, Ala. Bull. 597.

Kinnucan, H., M. Venkateswaran, and U. Hatch. 1990. Effects of Catfish Advertising on Consumers' Attitudes, Purchase Frequency, and Farmers' Incomes. Ala. Agr. Exp. Sta., Auburn, Ala. Bull. 607.

Koehler, J.W., K.W.E. Anatol, and R.L. Applbaum. 1976. Organizational Communication: Behavioral Perspectives. Holt, Rinehart and Winston. New York.

Laird, J. 1991. Environmental Accounting: Figuring in the Costs. Development Forum. 19(1):15.

Lands, W.E.M. 1989. Fish and Human Health: A Story Unfolding. World Aquaculture. 20(1):59-62.

Leopold, A. 1933. Game Management. Charles Scribner's Sons, New York.

Lewin, R. 1988A. A Revolution of Ideas in Agricultural Origins. Science. 240:984-986.

Lewin, R. 1988B. In the Age of Mankind: A Smithsonian Book of Human Evolution. Smithsonian Books. Washington, D.C.

Lewis, J.D. 1982. Technology, Enterprise and American Economic Growth. Science. 215:1204-12 11.

Lovell, R.T. 1979. Fish Culture in the United States. Science. 206:1368-1372.

Lovell, R.T. 1983. Off-Flavors in Pond-Cultured Fish. Water Sci. Tech. 15:67-73.

Lovell, R.T. 1986. Geosmin and Musty-Muddy Flavors in Pond-Raised Channel Catfish Ictalurus punctatus. Trans. Am. Fish. Soc. 115:485-489.

Lovell, R.T. 1988. Nutrition and Feeding of Fish. Van Nostrand Reinhold, New York.

Lovell, R.T. and T. Mohammed. 1988. Content of Omega-3-Fatty Acids Can Be Increased in Farm-Raised Catfish. Ala. Agr. Exp. Sta., Auburn, Ala. Highlights of Agr. Res. 35(3):16.

Lovshin, L.L., N.B. Schwartz, V.G. deCastillo, C.R. Engle, and U.L. Hatch. 1986. Cooperatively Managed Panamanian Rural Fish Ponds. Ala. Agr. Exp. Sta., Auburn, Ala. Int. Center for Aquaculture, Res. and Dev. Ser. No. 33.

Low, J.W. 1985. The Economics of Tilapia Culture in Kasai Occidental, Zaire. Cornell University, Ithaca, N. Y. Cornell Int. Agr. Mimeo. 109.

Lowe, M.D. 1988. Salmon Ranching and Farming Net Growing Harvest. World Watch. 1 (1):28-32.

Machan, T.R. 1989. We Praise Mother Teresa — Then Head for the Shopping Mall. Perspective: A Campus View. The Birmingham News, Birmingham, Ala. February 5, 1989:2C.

MacMillian, J.R. 1985. Infectious Diseases. Pages 405-496 in C.S. Tucker, ed. Channel Catfish Culture. Elsevier. New York.

Manning, E. 1988. Bugs Are Getting Hard to Kill. Progressive Farmer, Birmingham, Ala. 104(1):32-33.

Manning, E., J.T. Smith, and E. Wilborn. 1988. Requiem for a Land Bank. Progressive Farmer, Birmingham, Ala. 103 (9):32-35.

Martinez, D. 1986A. What (Exactly) is a Farm? Farmline. 7(3):4-6.

Martinez, D. 1986B. Soviet Agriculture Sluggish Despite Food Program Reforms. Farmline. 7(7):4-7.

Martinez, D. 1987. Measuring Government's Role in Agriculture. Farmline. 8(5):3-5.

Martinez, D. 1989. Freer Trade Seen as Boost to Wheat Production. Farmline. 11(1):16-18.

Maslow, A.H. 1970. Motivation and Personality. Harper and Row. New York.

Matsumoto, M. 1988. Recent Trends in Domestic Food Programs. National Food Review. 2(3):31-33.

MAUNDER, A.H. 1973. Agricultural Extension — A Reference Manual (Abridged Version). Food and Agr. Org. of the U. N. Rome.

MCCLELLAN, S. 1991. After the Gold Rush. Ceres. 23(5):17-21.

MCCOY, H.D., II. 1986. Intensive Culture Systems, Past, Present and Future, Part I. Aquaculture Magazine. 12(6):32-35.

MCCOY, H.D., II. 1987. Intensive Culture, the Past, the Present and Future, Part III. Aquaculture Magazine. 13(2): 24-29.

MCLARNEY, W. 1984. The Freshwater Aquaculture Book. Hartley and Marks, Inc. Point Roberts, Wash.

MEAD, C.L. 1988. FmHA Still Cautious on Louisiana Catfish Loans. Catfish News. 2(2) :1,14.

MEANY, T.F. 1987. Resource Rent, Common Property and Fisheries Management: An Economic Perspective. Pages 1-10 in Indo-Pacific Fishery Commission, Papers presented at the Symposium on the Exploitation and Management of Marine Resources in Southeast Asia held in conjunction with the 22nd session of the Indo-Pacific Fishery Commission, Darwin, Australia, February 16-26, 1987. RAPA/REPORT: 1987/10.

MELLOR, J.W. 1989. Agricultural Development in the Third World: The Food, Poverty, Aid, Trade Nexus. Choices. First Quarter:4-8.

MILLER, M.L. and R.C. FRANCIS. 1989. Marine Fishery Management. Pages 212-224. in F.G. Johnson and R.R. Stickney, eds. Fisheries: Harvesting Life from Water. Kendall/Hunt Publishing Co. Dubuque, Iowa.

MOEHL, J.F. Jr., K.L. VEVERICA, B.J. HANSON, and N. HISHAMUNDA. 1988. Development of Appropriate Pond Management Techniques for Use by Rural Rwandan Farmers. Pages 561-568 in R.S.V. Pullin, T. Bhukawsan, K. Tonguthai, and J.L. Maclean, eds. The Second International Symposium on Tilapia in Aquaculture. Int. Center for Living Aquatic Resources Manag. Manila, Philippines.

MOLNAR, J.J. and C.M. JOLLY. 1988. Technology Transfer: Institutions, Models, and Impacts on Agriculture and Rural Life in the Developing World. Agr. and Human Values. 5(1 & 2):16-23.

MOLNAR, J.J. and B.L. DUNCAN. 1989. Monitoring and Evaluating Aquacultural Projects. Pages 28-40 in Richard B. Pollnac, ed. Monitoring and Evaluating the Impacts of Small-Scale Fishery Projects. Int. Center for Marine Res. Dev. The Univ. of R.I., Kingston, R.I.

MOLNAR, J.J., B.L. DUNCAN, and L.U. HATCH. 1987. Fish in the Farming System: Applying the FSR Approach to Aquaculture. Res. in Rural Soc. and Dev. Vol. 3;169-193.

MOLNAR, J.J., A. RUBAGUMYA, and V.K. ADJAVON. 1990. The Sustainability of Aquaculture as a Farm Enterprise in Rwanda. Paper presented at joint meetings of the North Central Sociological Association and the Southern Sociological Society in Louisville, KY, March 21-25. Int. Center for Aquaculture. Auburn University, Ala.

MORRIS, D. 1967. The Naked Ape. McGraw-Hill Book Company, New York.

MOYLE, P.B. and J.J. CECH, Jr. 1988. Fishes — An Introduction to Ichthyology. Prentice Hall, Englewood Cliffs, N. J.

MYERS, D.G. 1989. Psychology. Worth Publishers, Inc. New York.

NATIONAL MARINE FISHERIES SERVICE. 1992. Fisheries of the United States 1989. Current Fishery Statistics No. 8900. Nat. Oceanic and Atmospheric Adm. Washington, D.C.

NATIONAL RESEARCH COUNCIL. 1989. Alternative Agriculture. National Academy Press. Washington, D.C.

NEAL, R. 1987. Fish Supply Leads Animal Protein Shortage. Agr. News and Ser. Bull. Bureau for Science and Technology. Agency for Int. Dev. Washington, D.C. Issue 5.

NEEDHAM, T. 1988. Sea Water Cage Culture of Salmonids. Page 117-154 in L. Laird and T. Needham, eds. Salmon and Trout Farming. Ellis Horwood, Ltd. Chichester, England.

NELSON, B. 1956. Propagation of Channel Catfish in Arkansas. Proceedings of the Tenth Annu. Conf., SE Assoc. of Game and Fish Comm. 10:165-168.

NIGHTINGALE, R.W. 1990. Is the World Facing a Food Crisis? Nat. Food Rev. 13(2)1:5.

O'CONNELL, P.F. 1989. Commercializing Promising Technologies: One Answer to U.S. Farm Problems. Choices. First Quarter: 26-28.

ODUM, E.P. 1983. Basic Ecology. CBS College Pub. Philadelphia, Pa.

OFORI, J.K. 1988. The Effect of Predation by Lates niloticus on Overpopulation and Stunting in Mixed Culture of Tilapia Species in Ponds. Pages 69-73 in R.S.V. Pullin, T. Bhukaswan, K. Tonguthai, and J.L. Maclean, eds. The Second International Symposium on Tilapia in Aquaculture. Int. Center for Living Aquatic Res. Manag. Manila, Philippines.

PAARLBERG, D. 1989. Marketing Agricultural Products. Proceedings of the Philadelphia Soc. for Promoting Agr., 1987-1988:28-35.

PADDOCK, W. and E. PADDOCK. 1973. We Don't Know How. Iowa State Press, Ames, Iowa.

PARKER, N.C. 1989. History, Status and Future of Aquaculture in the United States. Reviews in Aquatic Sciences. 1(1) : 97-109.

PARLETT, R.L. 1987. Food Prices in 1986 and 1987. National Food Review. United States Department of Agriculture. Winter-Spring: 5-7.

PAULY, D. and CHUA T.E. 1988. The Overfishing of Marine Resources: Socioeconomic Background in Southeast Asia. Ambio. 17(3) :200-206.

PETERSON, S. 1982. Allocation of Aquaculture Resources. Pages 21-29 in L.J. Smith and S. Peterson, eds., Aquaculture Development in Less Developed Countries: Social, Economic and Political Problems. Westview Press. Boulder, Colo.

PIERCE, J.J. 1987. Cod an Endangered Species? Prices Making it Seem So! Quick Frozen Foods Int. January:64-66.

PILLAY, T.V.R. 1973. The Role of Aquaculture in Fishery Development and Management. J. Fish. Res. Board Can. 30:2202-2217.

PILLAY, T.V.R. 1977. Planning of Aquaculture Development — An Introductory Guide. Fishing Books Limited. Farnham. Surrey, England.

PILLAY, T.V.R. 1983. Return to the Sea — Not as Hunter but As Farmer. Impact of Science on Society. 3/4;445-452.

PILLAY, T.V.R. 1992. Aquaculture and the Environment. Halsted Press. New York.

PIPER, R.G., I.B. MCELWAIN, L.E. ORME, J.P. MCCRAREN, L.G. FOWLER, and J.R. LEONARD. 1983. Fish Hatchery Management. U.S. Dept. of the Interior, Fish and Wildlife Ser. Washington, D.C.

PLATT, J.R. 1966. The Step to Man. John Wiley and Sons, Inc. New York.

POLK, P. 1991. Reckoning with the Human Factor. Ceres. 23(5) :13-17.

POLLNAC, R.B. 1982. Sociocultural Aspects of Implementing Aquaculture Systems in Marine Fishing Communities. Pages 31-44 in L.J. Smith and S. Peterson, eds., Aquaculture Development in Less Developed Countries: Social, Economic and Political Problems. Westview Press. Boulder, Colo.

POLLNAC, R.B. ed. 1989. Monitoring and Evaluating the Impacts of Small-Scale Fishery Projects. Int. Center for Marine Resource Dev. The University of R.I. Kingston, R.I.

POLLNAC, R.B., S. PETERSON, and L.J. SMITH. 1982. Elements in Evaluating Success and Failure in Aquaculture Projects. Pages 131-143 in L.J. Smith and S. Peterson, eds., Aquaculture Development in Less Developed Countries: Social, Economic, and Political Problems. Westview Press. Boulder, Colo.

Popma, T.J., F.E. Ross, B.C. Nerrie and J.R. Bowman. 1984. The Development of Commercial Farming of Tilapia in Jamaica, 1979-1983. Ala. Agr. Exp. Sta., Auburn, Ala. Int. Center for Aquaculture. Res. and Dev. Ser. No. 31.

Postel, S. 1990. Toward a New "Eco"-nomics. World-Watch. 3(5) :20-28.

Pote, J.W. , C.L. Wax, and C.S. Tucker. 1988. Water in Catfish Production: Sources, Uses and Conservation. Miss. Agr. and For. Exp. Sta. Miss. State Univ. Mississippi State, Miss. Spec. Bull. 88-3.

Prather, E.E. 1957. Annual Report of the Farm Ponds Project. Ala. Agr. Exp. Sta., Auburn, Ala.

Prather, E.E. 1958. Further Experiments on Feeds for Fathead Minnows. Proc. Annu. Conf. SE Asso. Game and Fish Comm. 12: 63-72.

Prather, E.E. 1964. Channel Catfish Shows Promise as a Sport Fish. Ala. Agr. Exp. Sta., Auburn, Ala. Highlights of Agr. Res. 2 (3).

Prather, E.E., J.R. Fielding, M.C. Johnson, and H.S. Swingle. 1953. Production of Bait Minnows in the Southeast. Ala. Agr. Exp. Sta., Auburn, Ala. Cir. 112.

Pruder, G.D. 1987. Detrital and Algal Based Food Chains in Aquaculture: A Perspective. Pages 296-308 in D.J.W. Moriarty and R.S. V. Pullin, eds., Detrital and Microbial Ecology in Aquaculture. Int. Center for Living Aquatic Res. Manag. Manila, Philippines.

Putman, J.J. 1988. The Search for Modern Humans. National Geographic. 174 (4):439-477.

Putnam, J.J. 1991. Food Consumption, 1970-90. Food Review. 14(3):2-12.

Quinn, J.B. 1989. Serving the Service Industry: Issues in Science and Technology. 5(4):74-81.

Rhodes, R.J. 1988. Status of World Aquaculture: 1988. Aquaculture Magazine, 18th Annual Buyer's Guide:6-20.

Robertson, T.S. 1971. Innovative Behavior and Communication. Holt, Rinehart and Winston, Inc., New York.

Robertson, I. 1987. Sociology. Worth Publishing, Inc. New York.

Robinson, M.H. 1992. An Ancient Arms Race Shows No Sign of Letting Up. Smithsonian. 23(1):74-82.

Robinson, E.H. and R.P. Wilson. 1985. Nutrition and Feeding. Pages 323-404 in C.S. Tucker, ed. Channel Catfish Culture. Elsevier. New York.

Rogers, E.M. 1983. Diffusion of Innovations — Third Edition. The Free Press. New York.

Rogers, E.M. and R.A. Rogers. 1976. Communication in Organizations. The Free Press. New York.

Roling, N. 1984. Appropriate Opportunities As Well As Appropriate Technology. Ceres. 17( 1) :15-19.

Roy, R.N., ed. 1984. Consultation on Social Feasibility of Coastal Aquaculture. Bay of Bengal Programme, FAO, Madras, India.

Ruttan, V.W. 1982. Agricultural Research Policy. Univ. of Minn. Press. Minneapolis, Minn.

Saclauso, C.A. 1989. Brackishwater Aquaculture: Threat to the Environment? NAGA, The ICLARM Quarterly. 12(3) :6-8.

Saint-Paul, U. 1989. Indigenous Species Promise Increased Yields. NAGA, the ICLARM Quarterly. 12(1):3-5.

Sanoff, A.P. and S.F. Golden. 1989. Remapping American Culture. U.S. News and World Report. 7(22):60-64.

SARIG, S. 1988. Is an Increase in Yield in Intensive Commercial Farming Always Accompanied by an Increase in Profitability? The Israeli Jour. of Aquaculture (Bamidgeh) 40(4) :122-124.

SASSON, A. 1983. Aquaculture: Realities, Difficulties and Outlook. Impact of Science on Society. 3/4:453-462.

SAVILE, A.H. 1965. Extension in Rural Communities. Oxford Univ. Press. New York.

SCHMITTOU, H.R., J.H. GROVER, S.B. PETERSON, A.R. LIBRERO, H.B. RABANAL, A.A. PORTUGAL, and M. ADRIANO. 1985. Development of Aquaculture in the Philippines. Ala. Agr. Exp. Sta., Auburn, Ala. Int. Center for Aquaculture. Res. and Dev. Ser. No. 32.

SCHUFTAN, C. 1991. Looking beyond the Doable. Dev. Forum. 19(1):3.

SCHWARTZ, N.B. 1986. Socioeconomic considerations. Pages 20-24, in L.L. Lovshin, N.B. Schwartz, V.G. de Castillo, C.R. Engle, and U.L. Hatch, eds., Cooperatively Managed Rural Panamanian Fish Ponds: The Integrated Approach. Ala. Agr. Exp. Sta., Auburn, Ala. Int. Center for Aquaculture. Res. and Dev. Ser. No. 33.

SCHWARTZ, N.B., J.J. MOLNAR, and L.L. LOVSHIN. 1988. Cooperatively Managed Projects and Rapid Assessment: Suggestions from a Panamanian Case. Human Org. 47(1):1-14.

SEDGWICK, S.D. 1982. The Salmon Handbook: The Life and Cultivation of Fishes of the Salmon Family. Andre Deutsch Limited. London.

SENAUER, B. 1989. Major Consumer Trends Affecting the U.S. Food System. Choices. Fourth Quarter: 18-21.

SHANG, Y.C. 1981. Aquaculture Economics: Basic Concepts and Methods of Analysis. Westview Press. Boulder, Colo.

SHEEVES, H. 1986. Japan's Fear of Food Dependence. Farmline. 8(5) :7.

SHELL, E.W. 1967. Feeds and Feeding of Warm-Water Fish in North America. Pages 310-325 in T.V.R. Pillay, ed. Proc. of the FAO World Symposium on Warm-water Pond Fish Culture. Rome. Vol. 3.

SHELL, E.W. 1969. A Review of Guyana's Program in Brackishwater and Freshwater Fisheries. Ala. Agr. Exp. Sta., Auburn, Ala.

SHELL, E.W. 1983. Fish Farming Research. Ala. Agr. Exp. Sta., Auburn, Ala.

SHELL, E.W. 1986. Tapestry of People, of Hunger and of Fishes. Proc. of the Philadelphia Soc. for Promoting Agri. 1985-1986: 48-64.

SHEPHERD, J. 1985. When Foreign Aid Fails. The Atlantic Monthly. April:41-46.

SINCERE, R.E., Jr. 1990. The Politics of AID. Vital Speeches of the Day. 56(17):519-524.

SINGH, M. 1989. Development Policy Research. Pages 11-20 in S. Fisher and D. de Troy, eds. Proc. of the World Bank Ann. Conf. on Dev. Econ. World Bank. Washington, D.C.

SMITH, R.L. 1977. Elements of Ecology and Field Biology. Harper and Row. New York.

SMITH, G.A. and G.W. KLONTZ. 1991. Organize Your Markets. Fish Farmer International File. 5(4):12-14.

SMITH, L.J. and S. PETERSON. 1982A. An Introduction to Aquaculture Development. Pages 1-10 in L.J. Smith and S. Peterson, eds., Aquaculture Development in Less Developed Countries: Social, Economic and Political Problems. Westview Press. Boulder, Colo.

SMITH, L.J. and S. PETERSON, eds. 1982B. Aquaculture Development in Less Developed Countries; Social, Economic and Political Problems. Westview Press. Boulder, Colo.

SMITHERMAN, R.O. and R.A. DUNHAM. 1985. Genetics and Breeding. Pages 283-321 in C.S. Tucker, ed. Channel Catfish Culture. Elsevier. New York.

SMITHERMAN, R.O., M.C. MOHEAD, W.G. MUSTIN, and R.K. GOODMAN. 1979. Trapping Channel Catfish from Upland Ponds. Ala. Agr. Exp. Sta., Auburn, Ala. Highlights of Agr. Res. 26(2).

STAVRIANOS, L.S. 1971. Man's Past and Present — A Global History. Prentice Hall, Inc., Englewood Cliffs, N.J.

STEINBURG, M.A. 1980. Past, Present and Future Methods of Utilization. Pages 34-48 in J.J. Connell, ed. Advances in Fish Science and Technology.

STEWARD, F. 1987. The Case for Appropriate Technology: A Reply to R.S. Eckaus. Issues. 3(4):101-109.

STICKNEY, R.R. 1986. Culture of Nonsalmonid Freshwater Fishes. CRC Press, Inc. Boca Raton, Fla.

STICKNEY, R.R. 1988. Aquaculture on Trial. World Aquaculture. 19(3):16-18.

STREET, D.R. and G.M. SULLIVAN. 1985. Equity Considerations for Fishery Market Technology in Developing Countries: Aquaculture Alternatives. Journal of the World Mariculture Society. 16:169-177.

STRIBLING, H.L. 1988. Bobwhite Quail Management. Ala. Coop. Ext. Ser., Auburn, Ala. Cir. ANR-511.

STULTS, H. 1988. There Are No World Food Problems. Farmline. 9(5):16.

SWINGLE, H.S. 1950. Relationships and Dynamics of Balanced and Unbalanced Fish Populations. Ala. Agr. Exp. Sta. Auburn, Ala. Bull. 274.

SWINGLE, H.S. 1954. Experiments on Commercial Fish Production in Ponds. Proc. of the Ann. Conf. of the SE Assoc. of Game and Fish Comm. 8:69-74.

SWINGLE, H.S. 1956. Preliminary results on the commercial production of channel catfish in ponds. Proc. of the Ann. Conf. of the SE Assoc. of Game and Fish Comm. 10:63-72.

SWINGLE, H.S. 1958. Experiments on Growing Fingerling Channel Catfish to Marketable Size in Ponds. Proc. of the Ann. Conf. of the SE Game and Fish Comm. 12:63-72.

SWINGLE, H.S., E.V. SMITH, and G.D. SCARSETH. 1936. Annual Report of the Farm Ponds Project. Ala. Agr. Exp. Sta., Auburn, Ala.

SWINGLE, H.S. and E.V. SMITH. 1947. Management of Farm Ponds. Ala. Agr. Exp. Sta., Auburn, Ala. Bull. 254.

TAVE, D. 1986. Genetics for Fish Hatchery Managers. AVI Publishing Co., Inc. Westport, Conn.

TAYLOR, C.R. and K. FROHBERG. 1989. The Effects of Multilateral Free Trade. Ala. Coop. Ext. Serv. Auburn, Ala. Ala. Agribusiness. 27(4) :2-4.

TEXAS AGRICULTURAL EXTENSION SERVICE. 1986. Red Drum Aquaculture Status. Coastal Aquaculture. The Texas A&M Univ. College Station, Texas. 3(3):1-2.

THE CATFISH JOURNAL. 1989. Institute to Promote Mississippi Fish Only. 1(7):1.

THE ECONOMIST. 1990. The Modern Adam Smith. 316(7663):11-12.

TROSCLAIR, C. 1987A. Aquaculture Must Work Itself into the Farm Credit System. Water Farming Jour. 2(6):2.

TROSCLAIR, C. 1987B. Who Will Provide Aquaculture's Expansion Dollars? Water Farming Jour. 2(6):5-8.

TUCKER, C.S. ed. 1988. Channel Catfish Culture. Elsevier, New York.

TUCKER, C.S. and C.E. BOYD. 1985. Water Quality. Pages 135-227, in C.S. Tucker, ed., Channel Catfish Culture. Elsevier, New York.

UNITED NATIONS DEVELOPMENT PROGRAMME. 1987. Thematic Evaluation of Aquaculture. Joint Study by the United Nations Development Programme, Norwegian Ministry of Development Cooperation and the Food and Agriculture Organization of the United Nations. Rome.

University Corporation for Atmospheric Research. 1989. Seafood for the Future. Ocean System Studies. NOAA/OAR Research Strategy II: The Ocean System-Use and Protection. Nat. Oceanic and Atmospheric Adm. Washington, D.C.

Van Doren, C. 1991. A History of Knowledge. Ballantine Books. New York.

Von Loesch, H. 1991. GDP and GNP on Trial. Ceres. 22(2):5-6.

Water Farming Journal. 1987A. Aquaculture Business Plan Must Cover all the Bases. 2(6):5.

Water Farming Journal. 1987B. Wall Street is Still a Dry Pond for Aquaculture Investments. 2(6):5.

Water Farming Journal. 1989. Big Bucks Lead the Way Toward Processing. 4(9):5-6, 30-31.

Watson, A.S. 1979. Aquaculture and Algae Culture — Process and Products. Noyes Data Corp. Parks Ridge, N. J.

Wax, C.L. and J.W. Pote. 1990. A Climatological Basis for Conservation of Groundwater in Aquaculture in the Southern Region. Miss. Agr. and For. Exp. Sta. Mississippi State, Miss. Tech. Bull. 169.

Wellborn, T.L. 1989. Construction of Levee-Type Ponds for Fish Production. The Ala. Coop. Ext. Ser. Auburn, Ala. Sou. Reg., Aquaculture Center Pub. No. 101.

Wellborn, T.L. and C.S. Tucker. 1985. An Overview of Commercial Catfish Culture. Pages 1-12, in C.S. Tucker, ed. Channel Catfish Culture. Elsevier. New York.

Werlin, H.H. 1987. Why Projects Fail and How They Succeed. Development Int. 1 (3):41-42.

Whitener, L.A. 1989. Needed: A Balanced Approach to Rural Development. Agr. Outlook. September: 25-27.

Wijkstrom, U. and E. Jul-Larsen. 1986. Aquaculture: Tackling the Major Constraints. Ceres 19(4):19-23.

Wilson, E.O. 1974. Sociobiology, The New Synthesis. The Belknap Press of the Harvard Univ. Press. Cambridge, Mass.

Winfree, R.A. 1989. Tropical Fish: Their Production and Marketing in the United States. World Aquaculture. 20(3):24-30.

Wohlfarth, G.W. and G. Hulata. 1987. Use of Manures in Aquaculture. Pages 353-367 in D.J.W. Moriarty and R.S.V. Pullin, eds., Detritus and Microbial Ecology in Aquaculture. Int. Center for Living Aquatic Res. Manag. Manila, Philippines.

World Bank. 1987. World Development Report. The International Bank for Reconstruction and Development. Oxford University Press. New York.

World Bank. 1991. World Development Report: The Challenge of Development. The International Bank for Reconstruction and Development. Oxford University Press. New York.

Wortman, S. 1980. World Food and Nutrition: The Scientific and Technological Base. Science. 209(4):157-164.

Young, A.A. 1988. Eliminating Hunger in America. Pages 107-111 in Johnson, J.L. and R.J. Hildreth, eds. Increasing Understanding of Public Problems and Policies — 1988. Farm Foundation. Oak Brook, Ill.