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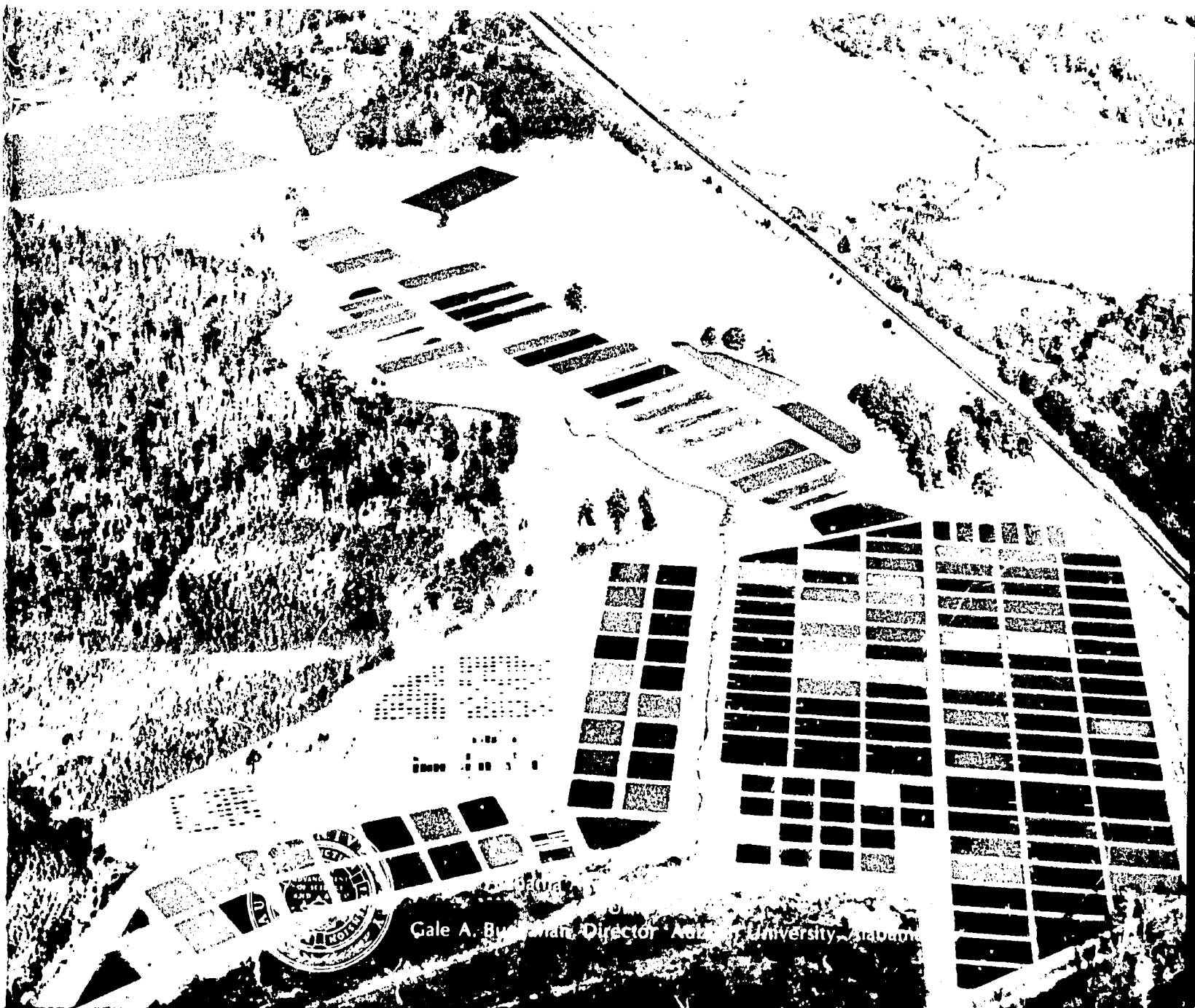

Environmental Considerations in Aquaculture

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I. INTRODUCTION

Aquaculture, the controlled production of food or other useful products in water, has received considerable interest as one possible way to better feed the world's growing population. As aquacultural development is considered both in the U.S. and overseas it is important that environmental concerns be considered in the planning and implementation of such development efforts. Such consideration is required by federal regulation where federal support is involved including where funds are used by the Agency for International Development in various foreign assistance projects.

This manual has been developed to give planners of overseas assistance projects in aquaculture a background about applications of aquaculture and the various environmental issues that should be considered is assessing project impacts. The manual has been prepared in response to a direct request from the U.S. Agency for International Development (AID) Bureau for Africa and Bureau for Science and Technology, and is principally intended for use by AID program staff in their project development efforts.

Reasons for Aquaculture

Aquaculture is the controlled management of aquatic organisms for the benefit of man. This is generally done by the controlled stocking of aquatic organisms, the addition of nutrients to increase the food supply and harvesting when the organisms are of an acceptable size.

The production of fish is a very acceptable alternative for producing animal protein. Chapman (1977) presented data showing that the yield of protein and income from the natural fishery in the flood plain lakes of Colombia is 450% greater than the yield that would be obtained if the land were drained and put into livestock production. Shpet (1972) concluded that even under natural pro-

productivity the meat production from carp is 3 times greater than that of cattle per hectare. Through intensive aquaculture fish production can be increased ten times over that obtained from natural fish production. Fish are more efficient in converting food into body tissue than farm animals because they are able to assimilate more protein per unit of caloric energy than livestock. Another favorable point for fish is that the percentage of lean meat in dressed fish is greater than beef, pork or poultry carcasses (Lovell et al. 1978).

To increase supplies of fish more emphasis is being given to aquaculture. The seas are being increasingly overfished while fuel costs for fishing and transportation continue to go up. Through aquaculture fish can be produced close to the market resulting in less transportation costs and fresher the product. Aquaculture is an important supply of fish in several countries. In India 38% of the fish harvest was from aquaculture, 22% in Indonesia and 20% in the Philippines (Anonymous 1973 FAO Aquaculture Bulletin, Vol. 5 April-July, 1973). In 1978, 56% of the total fish catch in Israel was from aquaculture (Sarig 1979).

The procedures used in aquaculture vary greatly depending on such factors as the biology of the organism, the economics and the management skills of the people involved. Because of the variety of culture methods, the effects of scale, and the uniqueness of each site, it is difficult to generalize on any environmental changes that might be brought about due to aquaculture. Each site should be looked at individually and a variety of factors must be considered.

II. PROCEDURES, METHODS AND OTHER FACTORS ASSOCIATED WITH AQUACULTURE

A. Pond Construction

Most aquaculture is done in ponds (small man-made bodies of water). Ponds may have been constructed especially for aquaculture or are built primarily for some other use and aquaculture is a secondary use. The construction of the pond is one of the most obvious effects on the environment.

The construction of ponds involves a number of steps. First is the selection of the site. One of the first considerations in selecting the site is to determine the reason for building the pond. Ponds can be built for a variety of purposes including aquaculture, irrigation, stock watering, domestic water supply and soil and water conservation. Each purpose has its particular pond design considerations.

The availability of water is a critical factor in site selection. The water must be of good quality and of an adequate volume to keep the pond full. A variety of water sources can be used for ponds including springs, wells, rainfall runoff and streams.

The soil type is another important factor in site selection. A good quality soil should be a composit of sand, silt, and clay with clay being 25-70% of the total.

The topography of the land is a very important factor determining the size and shape of a pond. A desirable site for a pond is often a gradually sloping depression between two ridges. Ponds can be built on the contours of a hill as well as level land. The location of the site is another consideration. It should be readily accessable to the farmer to facilitate fish feeding and pond management.

Normally aquaculture can be developed on marginal land not desirable for farming due to such things as being excessively eroded, having steep contours, having heavy waterlogged soils, being susceptable to flooding, the soil being highly saline etc. There are generally few competing uses for such land other than allowing it to remain undeveloped.

Once the pond site is selected it should be cleared of trees and vegetation and the topsoil removed from the dam site. It is desirable to have a drain structure in the base of the dam so that the pond can be drained completely. This is generally a pipe extending through the dam fitted with a valve or some other water regulating devise on the end. The dam is constructed by bringing in soil, compacting it, then adding more until the desired height of the dam is reached. The area disturbed by the construction is generally limited to the immediate pond site and access areas. For details on pond construction one should refer to Bard et al. 1975, Bureau of Reclamation 1965, Delmendo et al. 1970, Hepher and Pruginin 1977, Soil Conservation Service 1971, and Wheaton 1977.

B. COMMON AQUACULTURE PRACTICES

1. Introduction

It is difficult to describe general aquaculture practices. They depend on the intensity of the management, the species of fish being used, the resources available, the scale of the operation, the marketing procedures, etc.

There is a wide range in the degrees of intensity of aquacultural management. The simplest and most basic procedure is to fill the pond, stock the fish, not add any other inputs such as feed or fertilizer, then harvest several months later. This relies on the natural productivity of the environment as no fertilizer or feed is added. The yields from such a system are low (50-200 kg/ha/yr)

but on the other hand inputs are minimum. Minimum input aquaculture is an acceptable alternative only when ponds already exist and it is not possible to manage the ponds more intensively. This might occur where a large pond had been built as a water supply for a community and the concept of community pond management is not accepted. There the pond could be stocked with species of fish that will reproduce in the pond and a low level capture fishery could develop based on the natural productivity of the pond.

One should not build a pond with its primary purpose being for aquaculture and not attempt to increase the yield over that which is possible due to natural fertility. To increase the yield it is necessary to add nutrients from an outside source. This can be in the form of feed that the fish can use directly or as fertilizer to produce more food organisms in the pond which the fish can then consume.

2. Fertilization

Aquatic plants form the base of the natural aquatic food chain with fish being one of the final beneficiaries. By increasing aquatic plant production by fertilization it is possible to increase fish production.In most situations the addition of nutrients favors the development of planktonic algae (phytoplankton). This is desirable in that phytoplankton fix large amounts of energy, multiply rapidly and have a short life span. Thus the energy fixed by the phytoplankton moves rapidly up the food chain. The primary nutrients needed are nitrogen, phosphorus, potassium and carbon. These elements can be supplied through inorganic or organic fertilizers.

Inorganic fertilizers used for aquaculture are similar to commercially formulated fertilizers used in other types of agriculture, only the concentrations

of each ingredient may differ. Common fertilizer formulations used in fish culture are generally high in nitrogen and phosphorus and low in potassium (8-8-2 or 20-20-5). The numbers refer to the percentage by weight of nitrogen (N), phosphorus (as P_2O_5) and potassium (as K_2O) respectively. The amount of fertilizer required for good fish production and the frequency of its application depends on the nature of the water and the soil. A general rule of thumb is to add enough fertilizer at periodic intervals that will give the pond water a green color so that a white object can not be seen 45 cm below the water surface. A normal application rate of fertilizer might be 40-50 kg per hectare of 20-20-5 fertilizer applied at monthly intervals.

Organic fertilizers such as animal manures, grasses and agricultural by-products are effective fertilizers. Common application rates are equivalent to 1000-2000 kg/ha/month. Organic fertilizers have a distinct advantage in that they can contribute directly to several parts of the food chain. Its nutrients can be used by phytoplankton and its organic compounds used by other aquatic organisms as food. In many developing countries inorganic fertilizers may not readily available while some form of organic fertilizer may be available to the farmer.

3. Use of Feeds

Feeding is the most efficient way to increase fish production. A nutrient source from outside the pond is added that the fish can utilize directly, without the nutrients first being transformed through the aquatic food chain into another form and then being eaten by fish. Fish productions can be increased 200% or more when fish receive the food directly.

Fish have similar basic needs for proteins, carbohydrates, fats, minerals, and vitamins as higher animals but the types and amounts required and the way

they are used vary. A complete feed needs to supply all the nutritional requirements of a fish while a supplemental feed would supply only part of the nutritional requirements and natural food organisms would supply the remainder. The more intensive the fish culture the greater the need for a complete feed. One of the advantages of feeding is that various sources of carbohydrates, proteins and fats which are not acceptable as human food in their present form can be transformed into an acceptable product such as fish. The feed material used depends on the fish being able to digest and utilize the feed, the availablity of the feed, its alternative uses and the costs.

Typical materials used in fish feeds are also common ingredients in livestock feeds. These ingredients include agricultural by-products of crops primarily produced for direct human use ex: various oil seed meals such as cotton seed meal, palm nut oil meal, sesame seed oil meal and caster bean meal; grain polishing such as rice bran and polishings, oat groats, wheat shorts and middlings; and meat by-products such as blood meal, bone meal and meat renderings. Other feedstuffs that are grown principally for animal or human consumption are also used as fish feeds when available ex: sorgum, millet, corn and soybean and peanut meals. In addition other feedstuffs such as fish meals, brewers wastes, yeasts, etc. are used. Green plant materials are used for some species of fish.

The amount of feed required for adequate nutrition depends on the fish species, and number and weight of fish per pond as well as the environmental quality of the pond. Fish fed a concentrated feed typically receive per day an amount of feed equivalent to 3 to 4% of the fish biomass, ex: 1000 kgs of fish fed at 3% of body weight would receive 30 kgs of feed per day. The feed is given one or more times a day generally by hand.

4. Use of Chemicals

A variety of chemicals can be used to help manage a fish pond. The specific types of chemicals used and frequency of application is often related to the intensity of the management. In many small scale aquaculture systems, particularly in the developing countries of the world, few if any chemicals are used as a part of the management program. This is due to several factors: the problems are often not severe enough to justify the use of the chemical; there are other ways to control the problem; the chemicals are not available; or the level of technology is not advanced enough so that the farmers can manage the chemicals. When chemicals are used they can be for a variety of purposes including weed control, predacious insect control, disease control, water management, pond sterilization and the control of undesirable fishes.

What chemical is used and how often depends on the circumstances, but the goal when using a chemical is to improve the environment for the fish being produced. For a list of commonly used chemicals and their application see Table 1. Several good references on the use of chemicals include Mitchell, 1974; Hoffman and Meyer 1974, Boyd 1978, Herwig 1979, Kemp et al., 1971.

5. Production Cycles

A general production cycle for pond culture would begin with preparing the empty pond for stocking. This includes making any needed repairs, poisoning of any remaining puddles of water, and perhaps spreading lime or organic manure in the pond. The drain is closed and the pond filled. An application of fertilizer is given before or soon after the fish fingerlings are stocked. The fingerlings may come from a variety of sources. They may be captured from the wild, purchased from private producers, obtained from the government or produced by the farmer on his own farm. The species used, the number stocked and the initial

Table 1

Chemicals used in Aquaculture

Chemical	Common Dosages
Weed Control	
copper sulfate	1 mg/l
simazine	0.8 - 3 mg/l
diquat	0.5 - 3 mg/l
endothall	1 - 3 mg/l
2 4-D	3 - 10 kg/ha
dalapon	10 - 30 kg/ha
Insect Control	
kerosene	16.3 l/ha
methyl parathion	0.25 - 0.5 mg/l
fenthion	2.5 mg/l
Disease Control	
formalin	15 mg/l
copper sulfate	1 mg/l
potassium permanagate	2 - 4 mg/l
malachite green	0.1 mg/l
terramycin	2 - 8 mg/kilo of feed
furacin	5 - 10 mg/kilo of feed
salt	1%
Pond Sterilization	
quick lime	1000 kg/ha
hydrated lime	1500 kg/ha
chlorine	10 mg/l
Water Management	

size stocked depends on the production system used. Typical stocking rates range from 5000 to 20,000 fish per hectare. Once stocked the pond receives periodic inputs of nutrients, either fertilizer or feeds. The fertilizer may be applied on a prescribed schedule of X number of kilos per hectare per unit of time or on an adlib basis determined by the intensity of the phytoplankton bloom. The feed is generally given on a fixed schedule.

The duration of the production period depends the time required to produce a marketable size fish. Typical production periods range from 6 months to 2 years. The production period may be divided into phases: (1) where the recently hatched fish (fry) are reared to juveniles and, (2) where the juveniles (fingerlings) are reared to adults. During the production cycle water is added to replace evaporation and seepage from the pond. Some culture systems have periodic or continuous water flow through the pond. This water exchange improves the quality of the pond environment, especially in systems where the fish are being fed heavily and there is an excessive buildup of wastes. In ponds where only fertilizer is being used, it is very desirable that there be no flow through of water in the pond thus none of the nutrients are lost.

The pond may be harvested in several manners depending on the size of the pond, the fish, the market and the equipment available. Partial harvests may be made before the pond is drained completely. This can be done by hook and line, traps, or nets during the latter part of the production cycle. Partial harvesting is an advantageous method where the size of the market is small and a complete harvest may glut the market, or where fish are needed periodically for home consumption, or when it is necessary to continue storing the water for other purposes. Complete harvesting of a pond is difficult without draining it. In a well constructed pond it may be possible to harvest 99% of some fish

species by seining, but other species such as Tilapia are more difficult to seine necessitating the pond to be drained. Not only will draining allow a complete harvest, it will help control wild fish populations which may build up in a pond and also draining will expose the pond bottom to help oxidize the sediments which may have built up there.

A variety of drain structures may be used. In some areas where the ponds are small enough (100-500 m^2) and suitable materials to make a drain structure are not available, it is common to drain the pond by digging a channel through the dam. The channel would later be refilled and packed with soil for the next production cycle. It is more desirable to have a permanent drain structure for the pond, generally a pipe through the dam with some type of valve or riser to control the flow.

The fish produced may be marketed in a variety of manners, directly on the pond bank to the consumer, sold to a middle man or vendor at the pond bank or at the market, or the producer sells them directly to the consumer at the market. Because the harvesting can be done at the discretion of the producer most of the fish reach the consumer still alive or fresh.

6. Fishes used in Aquaculture

The species of fish used in aquaculture depends on many factors including availability and response to the proposed management procedure. From the diverse fish fauna that exists in the world, several species are used world-wide while others are used within a region and others only within their natural range.

The most widely cultured fishes are carps, tilapias and trouts. Culture procedures for these species have been established in various regions of the world and have been adopted in others. There may be many fish species as suitable for aquaculture as those currently cultured but the necessary research has

not been done to identify these species and develop appropriate culture procedures. To start an aquaculture program it is necessary to begin with a proven fish species, which generally means the use of an exotic. This is similar to other types of livestock husbandry where the domesticated animals used are often not native to the country where they are being produced.

The fish species used should be matched with the availability of production inputs, the agricultural traditions and the environmental conditions. The availability and types of feeds and fertilizers need to be considered. Common carp or channel catfish are good culture species which respond best to feeding and the production is considerably less when fertilizer only is used. On the other hand tilapia respond well to feeding but also give high yields when only fertilizer is used. If feed materials are economically available and the prospective aquaculturist has a tradition for feeding animals then it may be appropriate to use a fish species and aquaculture system which requires a supplemental feed. The greatest yields of fish per unit area can be obtained by feeding but it may not be economically or socially feasible under the existing conditions in a given country. Therefore, the use of a certain species or production system may not be practical.

If aquaculture is to be developed in a region where distinct seasonal changes in temperature occur this must be taken into consideration. In equatorial areas the temperature changes related to change in elevation should be considered. The growth of tilapia is reduced below 21°C and many species of tilapia die at 10°C. Carp are more tolerant to low temperatures and trout require low temperatures and are not suitable for warm climates.

The market acceptability and preferances are other factors to consider in selecting a fish for aquaculture. In some societies scaleless fish are not accepted, in some large fish are in demand and small ones are not.

III. ENVIRONMENTAL EFFECTS OF AQUACULTURE

A. Introduction

The earlier section concentrated on familarizing the reader with aquaculture and the procedures and techniques associated with it. This section will center on specific environmental effects that need to be considered and evaluated in an environmental assessment of a project where ponds are built and used for aquaculture. The effects associated with a pond and aquaculture will be discussed as they relate to: Terrestrial Effects; Water Quality; Natural Resources; Air Quality; Economic Effects; Social and Cultural Effects. In addition to pond culture, aquaculture is practiced in a variety of other manners and the environmental considerations of some of these methods are discussed in Appendix B and C.

Ponds and their use for aquaculture will have an effect on the environment but the significance depends on the circumstances. Some effects will be directly associated with the presence of one pond and can be documented, others resulting from a large number of ponds are sometimes vague and hard to document. Some effects will be significant if only the immediate area of the pond is considered while of little importance relative to the larger environment. Other effects may not be significant when only a pond is considered but as the density of ponds increases in a region the effects may be significant. Each project is unique in some way and will have its own characteristic environmental effects. Some effects will be associated with the presence of the pond whether it is used for aquaculture or not, other effects will be more directly associated with aquaculture. The following are some of the effects that might be expected from aquacultural development.

B. Terrestrial Effects

The terrestrial effects include any changes that might occur in regard to soil type, geology, hydrology, erosion, land use patterns etc. Ponds are not permanent features in the environment and in time will disappear. But in the meantime there will be effects on the environment. The most obvious effect is that a land form has been modified into a standing body of water. This alteration is unavoidable if a pond is to be built but the degree of alteration can be kept to a minimum by proper site selection and good construction methods. The majority of the effects are local and not significant in regard to a large watershed. Zingg (1946) presents data on how 4.6 ponds per square kilometer in a 1,148 square kilometer watershed would reduce flooding 6%. He estimates that for 4.6 ponds per square kilometer, each having a drainage area of 3.2 ha, would at most modify runoff from 15% of the land area. He concludes that farm ponds will give protection from small floods in headwater drainage areas but have little effect on large rivers. Leopold (1974) had similar conclusions, stating farm ponds intercept only a small portion of the runoff of a watershed and do not contribute greatly in flood control.

Although for an entire watershed farm ponds may contribute little in flood control they do have an effect on that portion of the headwaters where they are built. They do help to reduce flooding in the immediate area. They are able to store storm runoff for other purposes that otherwise would have been lost, as well as serving as a sediment trap for some of the sediment carried in the runoff. Ponds with a riser pipe and an emergency spillway will give temporary storage to excessive runoff and continue to release it after the peak runoff has occurred.

Ponds are also able to release water slowly back into the stream as the water filters through the soil back into the stream channel. The water table is

also raised in the area of the pond. The raising or maintaining the water table is important where wells are the main source of drinking water. Often farm ponds are located high enough on the watershed that there is no permanent stream flowing through the pond but only an intermittent stream. The storage and slower release of storm water may make for a more permanently flowing stream. By reducing the intensity of the runoff, ponds will also help reduce the erosion in the watershed (Wood and Richardson 1975).

The volume of water released during pond draining is generally at a rate less than the maximum that the stream channel would have carried during peak runoff periods if the pond had not been there. Tackett et al. (1979) reported that the level of solids in the effluent of a catfish pond is considerably less than the amount that comes off an equivalent area of land in soybean or cotton production.

Ponds can be used to help restore a watershed, particularly one that has been overgrazed, eroded and the vegetation cut off. Without a vegetative cover rainfall will runoff rapidly, not soak in, and carry away soil. This makes it difficult to reestablish a vegetative cover. Ponds will slow down the runoff rate, reduce soil erosion and raise soil moisture. The increased soil moisture will allow a denser vegetation cover to become established. This increased cover will further reduce the runoff rate. By reducing the runoff rate the danger of flooding immediately downstream is reduced.

The danger of a dam breaking is minimal if it is properly designed, constructed and located. Ponds receiving runoff water should be located high enough on the watershed so that the amount of runoff received is not excessive and an emergency spillway should be included in the construction to protect against the abnormally heavy rainfall.

Ponds which do not depend directly on runoff water, have some different effects that should be considered. Their water supplies are typically pumped water either ground water or from a nearby stream, or by gravity from a reservoir or diverted stream. These too will help raise the water table and increase soil moisture but have less effect on the stream drainage as they are not necessarily located in a natural stream channel area. The chance of flooding is less because their water inflow is more easily controlled.

Because non-runoff water ponds are often not located in natural drainage channels the effluent during pond draining is often left to find its own course, or a drainage channel is made. This drainage channel will not be used for pond draining more than 2-3 times a year but could have a more permanent effect on the immediate area by providing a channel for adjacent land drainage.

Ponds of this type are often built on flat marginal agricultural land which may be marshy or subject to flooding. By diking a particular tract of land which had been subject to flooding previously, flood water will be diverted onto another tract of land. This is a very localized effect but could affect a more valuable tract of land. This can be of special significance where there are extensive construction of ponds in a flood plain. The dikes act to restrict the natural water flow to the stream bed and during a period of high water the water may back up on to land upstream of the ponds because of this restricted flow. This backing up of water upstream can be minimized by locating the ponds on the margins of the flood plain trying to avoid restricting the flood waters any more than necessary.

The dams of both types of ponds should be well compacted during construction with sufficient slope on the sides to control sloughing. Seepage through the dam can be reduced by not having an undisturbed soil strata in the dam and

periodically placing seep collars around pipes going through the dam. The dams should be planted in grass to control erosion. Trees should not be planted on the dam to avoid problems with the roots weakening the dam. Such precautions will reduce the danger of the dam breaking.

Even though the danger of a dam breaking is minimal, consideration should be given to what would happen if a dam did break. Downstream development should be considered as to what would be threatened if a dam broke. When a dam breaks it is often not a matter of a sudden and total collapse of the dam but more an erosion of the dam over several hours. The amount of water released can cause significant local flooding in the immediate area but the downstream effects on the larger watershed may be minimal.

In areas where there already is extensive pumping of ground water for irrigation or other uses, additional wells to supply fishponds may contribute to lowering of the water table. In the coastal areas of Jamacia it is difficult to obtain permission to drill a new well because existing wells are already heavily exploiting the aquifer and additional wells could result in salt water intrusion. Similar problems exist for artesian wells where addition wells may reduce the pressure on an aquifer so that the wells have reduced flows.

In planning an aquaculture project that would use ground water, the aquifer needs to be described in terms of its depth, volume, drawdown rate and recharge rate. Present and future demands on an aquifer need to be established. Based on this information the significance of aquaculture development on the aquifer can be determined. Aquaculture development will normally not have a significant effect on an aquifer unless there is extensive irrigation using ground water.

When using stream water adequate consideration must be given to downstream users. Generally only a portion of even a small stream's flow would be diverted

for a pond, and then only for limited periods. However, there may be downstream users which depend on the full flow of the stream. Problems can develop when a continuously flowing diversion canal diverts water from one side of a valley to the other or into another watershed. This diversion might make the water less accessable to downstream users. These problems can be avoided by recognizing the rights of the downstream users and providing for them. Efforts should be made when selecting the water supply for a pond, to identify traditional drinking water supplies and washing areas to determine the effects of pond construction on these sources. The fishpond may be the primary source of water for both drinking and washing in regions where there is a scarcity of water. In areas where springs or streams traditionally provide domestic water, the waters of a fishpond often are not used for domestic purposes unless it is a more convenient source. Efforts should be made to not detrimentally affect these traditional water sources. This would include locating the pond so the traditional water sources would not be inundated by the pond water, not filling the traditional water sources with sediment as a result of pond construction or the pond blocking access to these sources. Efforts should be made to avoid draining a pond into streams or pools of water that are used for potable water.

The effects of a pond and fish culture on the soil are generally confined to the immediate area of the pond. There will be a gradual build up of sediments on the pond bottom. The addition of lime will raise the pH of the bottom muds making for a more favorable condition for the decomposition of the organic matter. Pond muds are often high in nutrients and when the pond is drained are sometimes used as topsoil or in fertilizers for gardens.

The sediment storage by a farm pond can be significant from the watershed above the pond but relative to the large watershed it is not. However, there

can be a significant beneficial reduction in the sediment load of the streams in the area when ponds are incorporated into a larger program of soil and water conservations. The reduction of erosion and the resultant decrease in sediment loads of streams generally outweighs any benefit that would be gained by the sediments being carried downstream to be deposited in the lower floodplain or delta of a stream unless there is extensive pond development and the lower flooplain users depend on an annual replenishment of soil. Problems occur when erosion is not controlled in the watershed and the sediments are trapped in large mainstream reservoirs. The soil is lost from the land and does not reach the river delta where some benefits possibly could be gained and in some cases a delta can stop growing and actually begin to erode.

During the construction phase there will be obvious modifications of the land as trees and brush are removed, the dam built, and land flooded. Unprotected soil will be exposed and subject to erosion during construction. These are temporary effects that are associated with construction and can be minimized by clearing only the land needed for the pond area and constructing the pond during the dry season. After construction is completed the dam and other exposed soil are planted in grasses or other vegetation to prevent erosion.

The intensity of pond construction in an area depends on a number of factors including land holding patterns, the number of good construction sites available, the availability of water, accessibility of the sites, as well as socio-economic aspects of fish culture and water use development.

Where the land holdings are large the land owner may develop only a few good sites to meet his immediate needs, leaving a number of good pond sites undeveloped. Thus in a region of large land holdings the number of ponds might be small relative to the number of suitable sites available. In another area

with smaller land holdings but similar number of good pond sites, each farmer might want his own pond for fish culture or water storage, thus a larger number of potential pond sites may be developed. In regions where the land ownership is not rigid, the area nearest a village having good sites might be completely developed into fishponds while an area farther from the village with an equal number of good pond sites would not be developed. Thus the impact of pond construction in a region can be influenced by the land holding patterns.

By constructing a pond for aquaculture there will be changes in land use. Typically the construction of ponds is confined to marginal or non-agricultural land not desirable for farming due to such things as being excessively eroded, having steep contours, having heavy water logged soils, being susceptable to flooding, the soil being high in salinity, etc. There are generally few competing human uses for the land other than allowing it to remain undeveloped.

It is often difficult to determine the value of land in its undeveloped state. To a farmer who is trying to use his land to meet his economic needs, an undeveloped plot of land has no value to him other than supplying occasional amounts of firewood. He may see undeveloped land as an economic loss, a site that cannot be farmed, a place where his livestock can get lost, or where he can get snake bit. He may not associate the undeveloped land with having any value for wildlife habitat. So often there is no base line data describing any flora or fauna which might be unique to tracts of land which also could be used for fishponds. It is therefore difficult to assign a value to an undeveloped tract of land in terms of its animal and plant habitats. But it is necessary in developing a aquaculture project to consider the type and amount of land that would be developed into fishponds and determine what would be the best use of that tract of land.

The presence of a pond can affect the concept of what is acceptable agricultural land and how it can be best used. In many areas of North and South America the value of agricultural land is determined by the availability of water. In regions where water is locally available only during the rainy season it may be necessary to abandon a fertile tract of land during the dry season because no water is available for domestic use or for livestock and the soil is too dry to support a crop or forage. By storing water in ponds year round management of land may be possible.

In areas where aquaculture is well accepted and proved to be very profitable the good pond sites in marginal agricultural land may be completely developed. At that time there may be competition with other agricultural crops for land. This depends on if the farmer feels that aquaculture is a better crop than traditional crops because it is more profitable, the type of management required is more acceptable, or the supplies and inputs are more available. Much competition may occur for land that could be used for aquaculture or rice. In some areas the land may be rotated between rice and fish or both raised together.

Changes in land use are generally benefical especially when the nutritional benefits are considered. Any negative effect might be associated with changes in wildlife habitat.

C. Water Quality

Waters will change in quality as a result of being held in a pond and the aquaculture practices. The fertilizers and feeds used will add nutrients to the water. These nutrients will increase phytoplankton production which in turn contributes to greater diurnal fluctuations in dissolved oxygen, carbon dioxide and pH. There is occasionally an increase in the hardness of the pond water

during the culture period due to evaporation along with the addition of minerals in the fertilizer or feed.

During the harvesting and draining the enriched pond water will generally enter a stream. Boyd (1978) found that the effluent of an intensively managed fishpond was considerably higher in settlable solids, BOD, COD, total phosphorus and total nitrogen than the waters of adjacent streams. During draining the effluent may exist in 3 phases. The initial phase is the first water which if drawn off the bottom may be high in sediments. The second phase would be the draining of the majority of the water, which is low in sediments. The last phase is when the fish are harvested the sediments stirred up and the remaining water drained out.

The significance of the quality of the effluent depends on the frequency of draining and the nature of the receiving stream. If the receiving stream is very small then the pond effluent can be a considerable enrichment of the stream when the pond is drained. In larger streams a pond effluent is diluted considerably and its influence lessened. The frequency in which a pond is drained depends on the culture method used but rarely is it more often than once every 6 months. The time involved in draining may be a few hours up to two to three days. Thus the effect of the pond effluent is over a limited time span.

Streams in many areas vary considerably in their natural water quality throughout the year. In low flow periods the streams have certain water quality characteristics while in high flow periods there may be a considerable change in temperature, pH, total hardness, turbidity and nutrient levels. This natural variation in water quality must also be considered when discussing the effects of a pond effluent. Often any change in water quality associated with a pond effluent entering a stream is less than the natural seasonal variation.

Eutrophication due to fishpond effluents is generally not a serious problem due to the small volume of water involved, the infrequent drainings of ponds and the rapid dilution of the effluent in receiving streams.

There may be slight differences in water temperature between that of a pond and surrounding streams. This difference in temperature normally is not significant enough that the effluent of a pond would effect the quality of a receiving stream.

There are often short term changes in the pond environment as a result of the chemicals used. Copper sulfate or formalin may be used to control protozoan parasites but both chemicals also kill plankton and it will be several days before the plankton population builds back up again. In the meantime if the amount of plankton killed was excessive, its decay will use large amounts of oxygen and there is little plankton to produce more. This can result in an oxygen depletion killing the fish. Dylox is an organophosphate insecticide used to control external parasitic worms and crustacians but it also will kill free living copepods that could have been fish food. These types of effects are temporary and are confined to the pond.

The chemicals which have been approved for use in the U.S. with food fishes include: for weed control-copper sulfate, simazine, diquat, endothall, and 2, 4-D; for disease control-potassium permangate, salt and terramycin; for fish eradication rotenone; and for disinfection and pond sterilization lime and calcium hypochlorite.

The persistance of chemicals in the environment depends on the chemical and physical properties of the chemicals. Some precipitate out of solution rapidly but may remain in the soil for some time. Some biodegrade very rapidly and other

very slowly. The danger from chemical residues varies with the toxicity of the chemical and its decomposition by-products.

In assessing the environmental effects of using chemicals in aquaculture in a given country, each chemical should be looked at separately. Then it should be determined: how the chemical will be used; how often; by whom; what are the anticipated effects; is the water for multi-purpose use; does the chemical break down rapidly into a nontoxic form; does it accumulate in the food chain; and what is its toxicity to man and fish.

Any aquaculture system that requires the use of pesticides must be examined in detail, as to how the pesticide will be used and what its effects would be, to comply with AID procedures. A separate section of the Initial Environmental Examination should be written to discuss the use of pesticides (see p. 59).

In summary the effects of aquaculture on water quality are generally confined to the pond. The effluent of the pond at draining can have measurable effects on the water quality in a localized area but these effects are not usually significant relative to the larger watershed. The use of pesticides require special attention as required by the AID environmental procedures.

D. Natural Resources

There is a great difficulty in determining what effects a pond or aquaculture may have on the natural resources of an area because so often little is known about the plants and animals that may occur in an area. The effects depend on the intensity of aquaculture development in an area and how it relates to the overall animal and plant habitats of a region.

1. Plant Habitats

Generally the effects of ponds are very localized. There will be the loss of terrestrial plants from the area inside the pond as the land is cleared for

pond construction. In a forested area the addition of a pond may have an effect on the vegetation immediately below the dam as some trees are more tolerant to high moisture levels than others. In a pastured area there may be a build-up of marsh vegetation below the dam due to increased soil moisture through seepage.

The amount of clearing is generally not significant in relation to an entire watershed but it can be locally important. In a savana region the better sites for ponds are located in the headwaters of small valleys. These valleys may also contain some of the few remaining forested areas in the region. The valley nearest a village may have its sides cleared for agriculture and portions of the valley floor cleared for aquaculture. This can significantly change that particular valley but often valleys farther away from the village are not developed. Thus, overall the amount of habitat loss may be slight. It is recommended for optimum fish production that the trees be removed from the immediate area of the fishpond to increase the light available to the phytoplankton for photosynthesis. The trees and vegetation in the upper part of the valley should be left undisturbed to protect the water source. In some regions it is desirable to remove all the brush and trees around a stream that would provide habitat for tsetse flies, the vector of sleeping sickness.

There exist the possibility of introducing a new aquatic plant species when fish are transported from one region to another (Mitchell, 1974). This can occur if the plant is in the transport water or on equipment used in both areas. This can be controlled by good hatchery management.

If the pond is poorly constructed there may be extensive shallow areas which favor the growth of emergent aquatic vegetation. Also if a pond is not properly managed there can be problems with submergent, floating and or emergent aquatic plants. By deeping the edges of a pond and fertilizing the pond for

plankton production it is possible to control submergent and some emergent plants. Floating aquatics such as duck weed (Lemna sp) can be controlled by herbivorous fishes or other animals, while plants such as water hyacinth are best controlled mechanically.

Macrophytic aquatic plants are a nuisance to aquaculture as well as interfering with the control of disease vectors such as mosquitos and snails. Macrophytic plants are of less benefit to fish in the food chain than phytoplankton and also greatly interfer with the harvesting of a pond. The presence of macrophytes provide protection for mosquito larva and snails from predation by fish and other animals. The plants also offer protection for young fish from predation. This often may cause a pond to become ecologically out of balance and results in stunted fish populations. An additional effect is that emergent and floating aquatic plants increase transpiration thus increasing the amount of water lost from a pond (Mitchell 1974).

2. Animal Habitats

The increased water availability may have a variety of effects on the animal population. In semi-arid areas or in time of droughts, ponds can be points of animal concentration as they gather for water. This concentration can make a species more susceptable to predation or diseases. The year-around availability of water due to pond construction may alter the migratory patterns of animals. In areas where there is no natural scarcity of water the addition of ponds may possibly serve to disperse animals or allow the population to expand as more favorable habitats become available. These are gradual effects and are related to the overall development of water resources in the area.

In regions of intensive agriculture the areas of undisturbed natural habitat areas are greatly reduced and the undisturbed land remaining is not suitable

for most types of agriculture. This same land may be developed for aquaculture thus further reducing one type of habitat but at the same time creating a new and not necessarily inferior type of habitat.

The loss or gain of habitat is very subjective. Is one plant or animal more important than another? The issue is clearer when it concerns endangered or threatened species and their critical habitat. It is required by AID environmental procedures to recognize the value of endangered or threatened species and their critical habitat and modify or cancel projects which would threaten them. An Environmental Assessment is required to formally examine such projects that may impact on threatened or endangered species. In general the amount of a particular habitat that would be developed into aquaculture is small when compared to the amount of unaltered habitat available in a region. In most cases the habitat in question has not been adequately studied to know if any plants or animals associated with that habitat are threatened or endangered.

Reservoirs can affect the natural fish population of an area if a permanent stream is dammed. Changing the habitat from flowing water to standing water will alter the fish species composition. Some fish are especially adapted to flowing water and do not adapt well to standing water. A dam across a stream may block a migratory fish from reaching its spawning area. These effects might be expected from a reservoir but ponds are generally located high enough in the watershed or on a floodplain so that few fishes are displaced.

If an aquaculture program includes the introduction of a species then special consideration should be given to possible ecological implications. Fish have been introduced into many areas where they did not occur naturally. The results on the environment have ranged from being detrimental to being a very positive contribution. It is difficult to prevent a fish that is introduced for

aquaculture from escaping into the wild. Its success in establishing itself in the wild depends on the fish and the nature of the environment. The more complex and stable the environment the less chance the introduced fish will be a nuisance.

Common carp Cyprinus carpio was introduced into the US in 1831 with great expectations for it as a food fish. As it became established in the wild it caused adverse ecological problems under some conditions and little or no problems under others. In the northern US it has become abundant in various lakes and streams and is considered a nuisance disturbing duck habitat and competing with more desirable fish. In the southern US it has also become established in lakes and streams but its population seems to be kept in check by the various predators in the system and is not considered a significant environmental problem.

The greatest disappointment resulting from introduction of common carp was not its effect on the environment but it not being accepted by the American public as a desirable food fish.

The tilapias, panfish-like cichlids native to Africa, have been widely introduced in the tropics particularly Tilapia mossambica and T. nilotica. The impact on the native fauna has been difficult to determine because of the lack of adequate data on the native population prior to the introduction of tilapia. In many cases tilapia have become an important addition in the commercial catch (Moss 1971; Riedel 1965; Lovshin 1978).

In certain circumstances Tilapia have become overpopulated. This has occurred where there were a lack of predators to keep the Tilapia under control. Popma et al. (1979) found incidences in Colombia where unmanaged farm ponds would be initially overpopulated with T. mossambica because there was no control

on its reproduction. But when the native cichlid Cichlasoma umberifera would become established in the pond and its population increased, the T. mossambica would gradually disappear. This was because the Cichlasoma controlled the tilapia reproduction. Tilapia are able to tolerate adverse environmental conditions and will invade habitats not suitable for many other fish species thus becoming abundant. It is not uncommon to find tilapia being the predominate fish in polluted water or unstable habitats such as irrigation or drainage canals.

Islands often have limited natural freshwater fish fauna and when tilapia are introduced they become established rapidly. In Jamaica and the Philippines T. mossambica has become common in the streams and supports a fishery that did not exist before. The effects of an exotic on native species do not have to be negative. Ramos (1978) found that in ponds T. rendalli increased the production of several native species.

Trout have been introduced into many temperate areas and cool mountainous areas of the tropics with rainbow trout Salmo gairdneri being the most widely introduced. The impact of rainbow trout introductions depends on the context in which it is evaluated. It was introduced into the eastern US and has become the most important trout in the sport fishery, but has done so at the expense of the native brook trout Salvelinus fontinalus in some habitats.

After the introduction of rainbow trout into Lake Titicaca in Peru a very prosperous fishery developed but with drastic consequences for the native fish population which was reduced drastically by the predatory trout. When the lake was first studied and recommendations for the use of exotics were made, rainbow trout were not recommended because of their possible competition with the native species and the stream spawning nature of the trout. The recommendations were not followed and rainbow trout were introduced. The problems with the rainbow

trout which later developed could have been avoided if the original recommendations for introducing other species and not rainbow trout were followed.

In the last several years grass carp Ctenopharyngodon idella has been introduced to several areas of the US but its effect on the environment has not been clearly demonstrated. It has been studied intensively during that time as to its effects on the environment. The results have not been conclusive. This is a case where all the alternatives need to be examined. The grass carp is effective in controlling many aquatic weeds. In doing so it opens many areas to fishing that were formerly clogged with weeds. The removal of the aquatic weeds can help reduce mosquito larva. The use of grass carp will reduce the need for the use of herbicides and their environmental effects. But unanswered are questions of how serious is the competition between the grass carp and native species. Its introduction and use is a managerial decision based on weighing the information available.

Not only do the direct effects of the fish being introduced have to be considered but also what else would be introduced with the fish. Hoffman (1970) reports that at least 48 species of fish parasites have been transferred between countries with at least 5 of the species capable of being serious problems. Similar problems have developed with viruses as trout have been transferred from one region to another. It is important that any group of fish being introduced be carefully examined to insure that they have no signficant disease problem.

The introduction of an exotic species is a gamble. Its effect on native population can not be guaranteed. Careful study must be given to the species to be introduced as well as the environment to which it is going to be introduced. The introduction should have many positive contributions that far outweigh any negative effects that may develop. Some of the more important considerations or

questions are: that the introduced species will help meet a nutritional need; can the introduction improve the economic well being of the farmer; and does a proven technology exist for the species that is applicable under the conditions where it is to be introduced, thus reducing the number of years of research that would be necessary before the technology could be extended to the user group. Secondary benefits of aquaculture may include: more water is available as a result of pond construction that can be used for other purposes; the introduction of fish culture may serve as a catalysis for the introduction of other development programs; by providing an alternative fish supply there may be a reduction in fishing for heavily exploited stocks. The purpose for introducing a species should be realistic and clear. There should be evidence that the proposed species is capable of meeting its purpose. It should have been shown that the species has market acceptability before the fish is widely distributed within the country. Attempts under controlled conditions should be made to see if there are any obvious competition between the exotic and the important commercial species. Once the exotic is released for use in an extension program, a monitoring program should be conducted to determine if the exotic fish becomes established in the wild and what are its effects.

The use of exotic species is often the only practical alternative to begin an aquaculture program. Still it is important that careful consideration be given to the possible consequences of the introduction. To search for a native species may take years and there is no guarantee that a fish acceptable for aquaculture will be found. Likewise there is no guarantee that there will be no adverse ecological effects as a result of introducing an exotic. One can only make as thorough and complete study as possible and a decision made based on the findings, the anticipated environmental effects and the management objectives.

In summary the effects of aquaculture on natural resources can be important. In general the loss of habitat due to aquaculture is not signficiant but full consideration must be given to any threatened or endangered species in the area by conducting an Environmental Assessment. Projects that involve the introduction of exotic species should be studied in detail with regards to possible environmental consequences. In many cases relevant information regarding threatened or endangered species that might be affected by a project or the effect of an exotic species is not available. It then becomes a managerial decision as to the potential benefits of a project verses the potential threat to the natural resources.

E. Air Quality

Aquaculture has very little effect on air quality. There might be microclimatic effects in that humidity in the immediate area of the pond would be raised. There might be a slight difference in air temperature around the pond. In areas where there are extensive pond complexes, breezes may develop because of the differences in temperature of the surrounding land and the pond water. In clearing a wooded site for pond construction the area is opened up to wind action. These are very minor effects and would be difficult to document.

In intensive fish culture phytoplankton blooms of bluegreen algae occasionally develop that produce a strong musty odor which may persist for several days. This odor is short lived and may or may not be a problem depending on the view of the farmer. There are also effects that may result from spraying herbicides on emergent vegetation. The drift of the herbicides on to adjacent crops can be avoided by spraying when the wind is not blowing. Increase in noise levels would be an insignficant problem.

F. Economic Effects

The economic effects of aquaculture are both direct and indirect. One of the most obvious direct effects is the income resulting from a fish harvest. In a cash economy this money is then available for a variety of purposes. One of the reasons the farmers in Zaire are interested in aquaculture is that it provides a large sum of money at one time so that major purchases can be made or expenses paid. There aquaculture is a type of savings program where time and money are invested in the fish production and at harvest the sale of the fish provides a return of the principle with interest. The income generated by aquaculture will have effects on the farmer's lifestyle. The crop diversification by the addition of aquaculture gives added stability to the farm income.

To properly evaluate the economic effects of aquaculture, a study is needed to describe the present economic conditions before aquaculture begins. Once a program begins there may be competition for land, labor, capital and other resources. The effects of this competition must be considered. The land used for aquaculture is often undeveloped and difficult to assign a value. Similarly it may be difficult to assign a value to labor or other resources that would have gone unutilized if not used for aquaculture.

As aquaculture becomes established there may be increases in values of the resources used in aquaculture. This is particularly true for animal manures and various agricultural by-products that may not have had any former use until it became in demand for aquaculture. Before the introduction of aquaculture there may have not been much consideration given to the ownership of marginal land which could be developed for aquaculture. Once the land has been shown to have some utility it will quickly assume an economic value and its ownership may be contested. Another direct effect that could result from aquaculture is that as

the farmer realizes the profit possible from aquaculture he may devote less effort to his other crops.

In considering an aquaculture system using inorganic fertilizers there are several secondary environmental effects which should be considered. By using an inorganic fertilizer for a fishpond, will it divert fertilizer that is needed for row crops? Generally if inorganic fertilizers are available in a region then the farmers have recognized its value for row crops and their use of it for row crops would take priority over using it for aquaculture. In some countries the use of inorganic fertilizer is restricted to certain crops and not available for aquaculture. In planning a large scale aquaculture project where inorganic fertilizer is to be used, what types of changes in the supply and transport system need to occur?

There also could be competition between aquaculture and other crops for the use of organic manures. This depends on the crop, the availability of the manure, the size of the fields, and the availability of labor.

The environmental considerations relative to feeding a higher quality feed are generally secondary economic and social ones. For example does competition exist for using these feed materials for direct consumption by humans or livestock. There are several feedstuffs humans could eat directly but it is also a question would they eat it directly. An alternative is to transform these agricultural by-products and other materials into another form such as fish, cattle, hogs, chickens or other animals that are more desirable. Fish are efficient converters of feed material, for every gram of a good quality feed consumed it is possible to have 0.77 g gain in fish. This compares to 1 g of feed for 0.48 g gain in chickens, 1 g of feed for 0.31 g gain in hogs or a 0.13 g gain in cattle (Lovell, 1979).

There are a variety of other economic effects that may result from the introduction of aquaculture. In Jamaica the development of aquaculture is anticipated to have both positive and negative effects on the foreign exchange. Production materials such as feeds and fertilizers must be imported thus having a negative effect on the balance of payments. It is anticipated that this negative effect can be overcome by the reduction in the need to import fish products. A potential $8.5 to $14.5 million savings in foreign exchange is projected in a 6- year period by producing the fish in the country rather than importing them.

The economic effects resulting from aquaculture can have substantial influence on how other development programs are accepted. In several countries it has been possible to incorporate other development programs along with fish culture. As the farmers found that aquaculture was profitable then other programs suggested by an extension agent might also be initiated because fish culture stimulated the interest of the farmer toward new ideas and established the creditability of the extension agent.

In summary there can be a variety of economic effects associated with aquaculture. The possible negative effects are associated with competition for land, labor, fertilizers and feeds. The significance of these effects depend on the intensity of the competition. In the planning phase of a project these competitions need to be recognized and an aquaculture system be introduced that will keep the competition to a minimum or clearly establish that the benefits resulting from aquaculture will outweigh the effects of the competition for resources caused by an aquaculture program.

G. Social and Cultural Effects

1. Social Effects

Social effects in a community are often slow to develop and often difficult to document. This is particularly true in a community where there are many factors interacting at the same time. A community aquaculture program in Panama is a good example. The fishpond appears to have served as a focal point for bringing outlying farmers into the village. As the village increased in size the government was able to provide health and educational services that were not previously available. It also could be interpreted that the road built into the area was the catalyist point that allowed technology to come in, and the fishpond provided a food supply that permitted a concentration of people into a village social structure.

Acceptance of an innovation and the resultant improved quality of life may socially isolate a farmer from the rest of the community. Often there is peer pressure to maintain the status quo with no man working any harder than another. There have been incidents where a farmer's pond was drained or poisoned by his neighbors because of the farmer's efforts to rise above his peers. Likewise peer pressure can be a favorable point in development once enough people in a community are involved. This was the case in Central African Republic where there were often a number of fish farmers in a village and at the harvest of one farmer's pond there would be great deal of interest by the other farmers in the production obtained. If the farmer did not obtain an acceptable production in comparison to others in the village then the other farmers would be free with their advice as to what went wrong and how to improve it. If his production was above average he would be expected to explain to his peers how it was obtained. The nature of the society can have a great deal of influence on how an innovation

is accepted. In many African societies the extended family system may not give incentive for a farmer to try and improve his livelihood. The fish he produced would have to be shared with the rest of the family so that he may not feel adequately rewarded for his efforts. But if he does not share part of his production, he may become a social outcast.

The increased availability of water due to the presence of a fishpond may have significant social effects. It may alter use patterns on traditional water sources, and reduce the amount of time normally devoted to water collection. White (1977) discusses several considerations a villager may make regarding a domestic water source, they include quality, technical feasibility, economic efficiency and social effects of other people. These factors will determine if a fishpond is used as a water supply.

In some societies there may be no tradition for eating fish or perhaps even a taboo against it. Simmons et al. (1978) mentions some societies in Africa, India, and North America that have traditional feelings against eating fish. These traditions may have been established because only poor quality fish were available, but as better quality fish are available such traditions may change. In some societies the concept of fish being livestock to be managed is not readily accepted. There are sometimes stigmas against using animal manure for any type of crop. Manure is manure and fresh or dry, some people simply don't want to be associated with it. This may be particularly true when manure is used for aquaculture. The thought of fish using manure directly or indirectly may not be appealing. These stigmas are often overcome when a farmer sees the increased yields of fish that can be obtained by using manures.

The introduction of aquaculture into an area can bring about social conflicts over water rights and land use. There may have been little demand for

these resources and ownership not clearly defined prior to the development of aquaculture. Conflicts may arise in establishing ownership of these resources for use in aquaculture. These are temporary effects and generally are worked out within the community.

There needs to be an understanding of who will be affected and how by the introduction of aquaculture. Will aquaculture be regarded as a cash crop that is man's work completely or will it be that the man starts the crop but the day to day care becomes the woman's job in addition to her many other responsibilities. In some societies the production and harvesting are a man's responsibility and the marketing is the woman's while in other societies this is reversed.

The social changes brought about by development programs should be viewed from the perspective of the people to whom the program is directed. Do they see the development as an improvement or a degradation of their society? Will aquaculture bring about cultural changes, alter taboos or effect land or water usage that had been considered to be a common heritage? Such changes may not seem important to an outsider but to the family or village in the affected area these changes may be of great consequence.

2. Health Effects

The effects on human health are among the most important environmental considerations because the effects are often the most direct. The increased availability of fish and water can have both positive and negative health aspects. The nutritional benefits are a very important aspect of aquaculture. In many countries malnutrition is considered to be the most serious health problem because of the complications it makes with other diseases. It weakens a person so that he is succeptable to a variety of diseases. Malnutrition is often due to a protein shortage particularly of animal protein. It was estimated that

80% of the population in Kinshasa, Zaire, had no access to animal protein on a regular basis (Velasco 1980). Fish are very rich in protein and vitamins, and are generally one of the cheapest sources of animal protein. Thus by increasing fish production it is possible to provide an animal protein source that is more accessable to the poorer economic classes where the nutritional problems exist.

In many areas of Africa aquaculture is one of the best ways to increase the availability of animal protein. The larger wild game has been drastically reduced in many areas and only small game is available to be hunted for home use. Domesticated animals are not sufficiently available to be slaughtered on a daily basis in a village. Cattle production is limited in many areas because of various diseases. The high cost of each animal often restricts cattle production to certain economic or social classes that do not include the average villager. Small ruminants such as sheep or goats may be available but are not intensively managed. They are often considered to be a meat source only for special occasions or an income source for an emergency. Chicken production is often considered in the same way.

The increased availability of water can also be a health benefit. Water being available is an important factor in many areas with a distinct dry season. Ponds can provide a more permanent domestic water supply. They also can be used for small scale irrigation of vegetables which could improve diet.

It is important to address any negative public health effects that might result from the aquaculture practices or storage of water in ponds and consider them as they relate to the existing conditions. In most developing countries there are a variety of public health problems. Those that are associated with water or could be influenced by aquaculture practices should be identified and the potential for significant changes resulting from aquaculture development

recognized. It has been estimated that 80% of the diseases in tropical climates are water related.

As discussed earlier the practices used in aquaculture vary depending on the situation. One culture practice that often raises questions is the use of animal manures as fertilizers, however any potential public health problems associated with using the utilization of animal manures are thought to be minimal in regard to the fish produced if proper precautions are taken. Fish are "cold blooded" animals and are thought not to be good hosts for bacterial pathogens of warm blooded animals, but can be passive carriers when in contaminated water (Geldreich and Clarke 1966). The ability of fish to be carriers of viruses pathogenic to humans is unknown. Fish can serve as intermediate hosts for several animal and human parasites if fish are eaten raw.

The use of ponds is an effective sewage treatment. The dieoff of various pathogenic bacteria found in manure is rapid when in water (Geldreich et al. 1964; Andre et al. 1967). This is due to a variety of factors including: most pathogenic bacteria are unable to reproduce at temperatures much lower than the body temperature of the warmblooded host; a clumping and settling of the bacteria into the sediments; predation by protozoans and other aquatic organisms; lack of necessary organic sources of nutrients; adverse levels of oxygen and acidity, and exposure to sunlight and algal toxins (Gloynia 1971; Geldreich 1972; Hepher and Schroeder 1977). The fate of animal virsues in water is not well understood. Joyce and Weiser (1963) found that human enteroviruses will survive up to 10 weeks in pond water.

The extent to which a pond receives pathogenic organisms depends on the health of the animal which furnishes the manure. It is common for a low percentage of the population of animals to have a chronic disease infection.

Rothenbacker (1965) reports that approximately 13% of the cattle of the US have latent infections of Salmonellae. Chronic levels of pathogenic bacteria in manure may pose no threat but manure of animals with active infections should not be used.

It is not clear to what extent animal or humans can develop diseases as the result of drinking or contact with water that receives animal manures. Some animal disease organisms are transmitable in water but their viability depends on the organism, and the nature of the environment as well as the number of infectious units taken in. In the case of Salmonellae, 100,000 or more organisms must be ingested to cause illness while ingesting 1000 Vibrio cholerae is sufficient (Bryan 1974). The dilution of the manure in a pond and the natural dieoff of the pathogens greatly reduces the possibility that a pathogen would be at high enough concentrations to cause an infection. Another consideration when using manures in ponds is what would be the incidence of disease in the animal populations if their manure was not disposed of in ponds. The disposal of manure is a problem in some areas and its accumulation increases the incidence of both air borne and water borne diseases.

As discussed earlier, a variety of chemicals may be used in aquaculture. If these chemicals are abused this can be a problem both for man and the fish. Chemicals used with other agricultures often pose more of a danger to fish and man than the chemicals used in aquaculture do to other agricultures and man. This is a particular problem where the water supply for aquaculture is runoff or [illegible] water that may be contaminated with heavy metals or pesticides. Many agricultural pesticides are highly toxic to fish. Several types of pesticides and heavy metals can build up in the fish flesh and be passed on to humans when the fish is eaten. This can also occur when the fish feed is contaminated.

There have been cases where because of poor preservation facilities, fish in the public market have been treated with pesticides to keep away flies to give the appearance of quality fish. These abuses of chemicals exist with many agricultural products and can be controlled with a good public education program.

The pesticides normally associated with aquaculture such as the organophosphate insecticides have little residue in the aquatic environment and offer little danger to man if properly used. When an AID project involves the use of pesticides this must be addressed in detail (for content and procedures see p. 59).

In evaluating the public health aspects related to water storage it is important before a project begins to understand the human diseases in the area that are associated with water and how they are transmitted. It is also important to understand the present extent of water contact and the extent to which the water sources are contaminated.

The increased availability of water can increase the public health problems if proper controls are not taken to prevent the water from being contaminated. A number of human diseases can be transmitted through contact with water contaminated with human feces including polio, cholera, typhoid, hepetitis, various types of dysentery, schistosomiasis, dracunculosis, etc. A variety of other diseases such as malaria, yellow fever, denque fever, encephalitus, filariasis, diphyllobothriasis, fasciolopsiasis, clonorchiasis, paragonimiaseis, etc. involve aquatic organisms to complete its life cycle or to supply its vector.

Disease transmitted through contaminated water

Various viral, bacterial and parasitic diseases can be transmitted directly when a water body is contaminated with human feces. Man may come in contact with these organisms when he drinks the water or his food is prepared with it.

Geldreich (1972) reported that Salmonella typhimurium levels in runoff water were reduced 99% after the water was held 10 days. In artifically infected farm ponds Andre et al. (1967) found that Salmonellae levels were drastically reduced after 14 to 16 days. Coetzee and Fourie (1965) reported a 97.5% reduction in E. coli and a 98% reduction in Clostridium perfringen in sewage lagoons with a 20 day retention time.

Viruses do not disappear as rapidly from contaminated waters as do bacteria. Shuval (1970) found that enteroviruses were reduced 67% after 20 days in sewage stabilization ponds while there was a coliform bacteria reduction of approximately 90% during the same time period. In artifically seeded farm ponds Joyce and Wieser (1967) found measurable amounts of enteroviruses 7 weeks after seeding.

Amebiasis is also transmitted by contaminated water. The World Health Organization recognizes sewage-contaminated water supplies as the major identified source of infection in all reported outbreaks of amoebiasis (WHO 1969). Cyst of Entamobea histolytica may persist in good quality water for over 100 days but their initial density in sewage is generally low and is drastically reduced in the receiving waters by dilution and settling (Geldreich 1972).

Various helminthic infections can be acquired through contaminated waters. Ascaris eggs will remain viable in good quality water for 60 days. Man can serve as an accidental secondary host for other helminths when the eggs are

ingested by man. Most of these are limited problems as the eggs are heavier than water and quickly settle out.

Diseases in which water is necessary for part of its life cycle or its vector

Schistosomiasis:

Schistosomiasis is the infection caused by blood dwelling digentic trematodes of the genus Schistosoma. Three species S. mansoni, S. haematobium and S. japonicum are considered to be human parasites.

The basic life cycles are similar. The eggs of the parasite passes out of the host in the feces or urine and if they enter water will hatch releasing a free-swimming larva (miracida). The miracida then actively swim into the upper layers of water where they locate appropriate species of snails to act as intermediate hosts. Each Schistosoma species has its most appropriate genus and species of snail to serve as intermediate host depending on the geographical location. The miracida will enter the snail and undergo several stages of development resulting in cercaria which burrow out of the snail and become the free-swimming stage infectious to man. Infected snails live for one to two months. The number of cercaria shed varies with the species of snail and parasite and also the time of day. Cercaria of S. japonicum are most abundant during the early part of the night. Peak periods of S. mansoni cercaria release are mid-day to early afternoon.

Cercaria are free-swimming and after release move into the water strata just under the surface. The life span of the cercaria can be up to 48 hours depending on environmental conditions such as water temperature and dissolved oxygen. Maximum infections were obtained where cercaria were in waters with a velocity of about 30 cm per second and were lower at both slower and faster water flows (Webbe 1966).

Upon contact with the skin of the host, generally man, the cercaria sheds its tail, burrows its way through the tissue into a blood capillary. From there it enters the circulatory system to be carried into the hepatic portal system. S. mansoni and S. japonicum mature in the mesenteric veins of the intestine while S. haematobium develops to maturity in blood vessels in close association with the bladder. Eggs of S. mansoni and S. japonicum are extruded into the intestine and pass out with the feces. Eggs of S. haematobium penetrate through the bladder wall and pass out in the urine. Domestic animals such as pigs, cattle and horses are important reservoirs of Schistosoma japonicum. Thus the use of the manure from infected animals for aquaculture would be a public health hazard.

Man becomes infected with the disease through contact in the water. This can occur as one bathes, washes clothes or participates in any activity which puts him in water contaminated by human feces or urine. Once contracted an infection can remain active for 20 years. Children and teenagers are the most commonly infected and also the main source of transmission. There is some evidence of resistance in adults.

The vector snails can occur in fishponds and if the water supply is contaminated with Schistosoma eggs, then a pond can be a source of infection. How serious a source depends on many environmental factors. Kawata and Kruse (1966) found that miracida would survive 18 hours in tap water but only 10 hours in pond water. Snails remain infected for only 1-2 months. The water supply would need to be sufficiently contaminated so the density of miracida are high enough that some can come in contact with the appropriate snail species. The pond environment can be modified to make it less favorable to schistosomiasis transmission by reducing the abundance of snails. The habitats for snails can be

reduced by elimination of aquatic weeds. An animal which competes with or preys upon the snail can also be used. Various fish species have been found to be effective in controlling snail populations. Bard (1963) found that the African cichlid Astatoreochromis alluaudi was very effective in snail control. Lagrange (1953) found that the Central American cichlid Cichlasoma biocellatum was an effective snail predator. Jobin et al. (1977) found that a snail species which is a vector of schistosomiasis could be controlled by another species of snail. Fergusion (undated) reviews the role of biological agents for snail control and concludes that they are useful tools in a control program. In addition to biological controls temporary control can be obtained by drying the pond bottom or the use of molluscides.

The incidence of schistosomiasis and its impact on public health may vary from one region of a country to another. It is generally considered to be a chronic problem with some side effects but rarely the cause of mortality, but it is debilitating and can weaken a person's resistance to another disease.

There is little or no evidence that fishponds are or are not sources of infection for schistosomiasis. In many incidences even if a pond were a source of infection, it would be insignifcant relative to other sources of infection. In many parts of West Africa people have almost daily contact with a stream or other contaminated water supplies where they could be exposed to schistosomiasis. This should be compared to their contact with pond water which may be only once or twice in a six month production season when the pond is filled or harvested. Fishponds may become an important domestic water source in arid areas and if continually contaminated could be a source of infection. There is a need for much more investigation to determine the signficance of fishponds as sources for the transmission of schistosomiasis.

The key to the various water borne diseases is to have a water supply not contaminated with human feces. It is not the fishpond that is the source of the contamination but the water or feces entering the pond. If no new contaminated water enters a pond then the pond can purify itself. If contaminated water is unavoidable, it is no signficant problem to the fish but care must be given in the use of the water for domestic purposes. Human feces have been added directly to fishponds in the Orient for many years to improve fish production, with no apparent public health problems unique to the fishponds.

Several diseases are transmitted to humans by vectors that require an aquatic environment for part of its life cycle. Such vectors include mosquitos, and black flies. Mosquitos serve as vectors for a variety of diseases such as malaria, yellow fever, dengue fever, encephalitus and filarias.

Various species of mosquitoes are associated with specific diseases. The genus Culex are vectors for various arboviruses such as those causing encephalitus. Culex can also serve as the intermediate host for the human filarial worm Wucheriria bancrofti. The mosquito Aedes aegypti is an important vector of the viruses for yellow fever and denque. The genus Anopheles and related genera are vectors for malaria. Each species has its own preferred environment.

An aquaculture program in many areas may be an effective tool for mosquito control. The construction of ponds in poorly drained lands will help eliminate mosquito breeding areas and fish can be stocked that will control the mosquito larva in the ponds. A variety of fish are recognized as being effective in controlling mosquito larva (Gerberich and Laird 1968). Some fish such as the mosquitofish Gambusia are very effective but the juveniles of most freshwater fish are also very effective. A problem in the use of fish for mosquito control is that the fish must have access to the areas where the mosquito larva occur.

Extensive growths of aquatic plants provide protection for mosquito larva because dense plant growth may prevent fish from reaching the mosquito larva. Proper pond construction and management procedures can prevent the buildup of aquatic weeds. The areas favorable for aquatic weeds can be reduced by deeping the edges of the pond. An effective fertilization program will shade out submerged vegetation. Various herbivorious fish can also be effective in weed control. They can feed on the aquatic weeds thus making any mosquito larva that had been sheltered by the weeds exposed to predation. One could anticipate fewer problems from mosquitoes in an aquaculture program than a rice culture or perhaps an irrigation program. There exist the danger that if an aquaculture program is not well received, the ponds will be abandoned and become mosquito breeding areas.

Black flies (Simulium) are bloodsucking flies that are the vectors of river blindness caused by the nematode parasite Onchocera volvulus. The life cycle of the fly is: eggs are deposited on plants, sticks, rocks or other solid objects in water or at the surface of the water of a swift flowing stream. The larva hatch and develop in the water, attaching to solid objects in the stream, pupate there then develop into the adult fly. Horsfall (1962) mentions that the minimum stream flow required for black fly larva is 15 cm/sec. The larvae are filter feeders that rely on the water current to carry food particles to the sessile larvae. The lack of current in a fish pond makes it an unacceptable habitat for black fly larva. If the water supply is from a stream then the diversion canal from the stream to the pond may provide limited habitat. But there would be few attachment sites for the larva because of the need to keep the canal clean and free of brush and aquatic plants that would reduce the water flow to the pond.

James and Harwood (1970) mentioned that fish are effective predators on black fly larva.

The tseste fly Glossina is the vector of several Trypanosoma diseases including sleeping sickness in man. The fly is a blood sucker which transmits the disease with its bite. Its reproduction is unique in that the adult female lays one larva every 8 to 25 days. The larva is deposited in loose dry soil in such areas as under tree trunks, under overhanging rocks or in tree holes. The larva burrows into the soil where it becomes a pupa. The pupa then develop into an adult. Certain species are more characteristic of certain habitats. Of the 22 species G. palpali, G. fuscipes and G. tachinoides are waterside species and might be encountered near a fishpond. The flies require shady areas for resting and thus can be controlled by eliminating shade near the fish pond.

Another consideration in regard to tsetes flies is that because the severity of various cattle diseases transmitted by the fly there may be red meat shortages in infected areas. Fish produced in these areas can help meet these shortages of animal protein.

Fish can serve as the intermediant host for several human parasites such as the tapeworm Diphylbobthrium latum. This is a tapeworm found in the cooler and temperate zones of the world. Its life cycle is that: the eggs hatch in cool fresh water releasing free swimming embryos; these embryos are then eaten by certain species of freshwater copepods where the embryos develop into a larval stage; an infected copepod then is eaten by a fish and the larva enters the fish developing into another larval stage; then when the fish is eaten by the final host (man, dogs, bears), the adult tapeworm develops in the intestine. Another tapeworm with a similar life cycle is Ligula intestinalis with the final host normally being fish eating birds.

There are several digentic trematodes for which fish are the intermedient host. A typical life cycle would be that: the eggs of the parasite pass out in the feces and hatch in water; the free swimming larva (miracidium) enters a freshwater snail where it undergoes several larval transformations; after these transformations a free swimming larva (cercaria) is released back into the water; this larva then penetrates the flesh of a fish and becomes encysted; when the fish is eaten by the final host (man or other animals) the encysted larva is released where it develops into an adult. Such trematodes as Clonorchis, Metagonimus and Opisthorchis can infect man in this way.

These tapeworm and digentic trematode parasites are not a problem if the fish is cooked before it is eaten. The cooking will kill the larval stage of the parasite.

Several other parasitic diseases have an intermediate host in an aquatic habitat. Aquatic and semi-aquatic snails are intermediate hosts for flukes such as Fasciolopsis and Fasciola. The larva of these parasites develop in the snail then are released and encyst on vegetation. Then the final host becomes infected as it feeds on the raw vegetation. The larva then develops into an adult and later the eggs pass out in the feces. The presence of a pond may have little effect on these diseases other than perhaps reducing areas of emergent aquatic vegetation where the larva could have encysted.

In summary a wide range of public health factors that need to be considered prior to implementing an aquaculture project. The nutritional gains as the result of aquaculture can improve the public health of an area. If properly used the various chemicals associated with aquaculture do not pose significant health problems. It is AID policy that a risk benefit analysis and/or environmental assessment be prepared for programs using pesticides. There are a variety of

diseases associated with water that are public health problems. Many result from the water being contaminated with disease-bearing feces or urine. The aquatic environment of a fishpond is not favorable to the survival of bacteria and viruses of warm-blooded animals, but can be important in the life-cycle of various parasites and disease vectors.

It is important to keep in perspective the natural incidence of a public health problem and to what extent an aquaculture project would change it. In many areas where malaria is common, an aquaculture project may reduce the habitat favorable to mosquitoes. The limited amount of habitat involved generally would have little effect on the incidence of malaria. A similar case may exist with schistosomiasis. A fishpond may provide a site where man can be exposed to the disease but it could be insignificant relative to his normal day to day contact with other contaminated waters. A farmer can prevent the contamination of his private pond by using an uncontaminated water supply, not allowing anyone to defecate or urinate near his pond and controlling the public access to his pond.

Information needs to be available regarding the incidence of public health problems before the start of a project, the amount of contaminated waters presently in the project area and the normal frequency of human contact with these contaminated waters. The amount of potentially contaminated waters to be created by the aquaculture project needs to be estimated. Any changes in water use patterns because of the presence of a fishpond, needs to be projected. Based on that information one can predict the impact of the aquaculture project on the public health.

3. Cultural Effects

The cultural impacts include effects on traditional value systems, or sacred, historical or archiological sites. The most direct effects from

aquaculture would be loss or modification of culturally significant sites. Shrines or other historical or archiological sites should be identified when selecting sites for pond construction and provisions made to not alter these sites or limit access to them.

Changes in traditional values are often a long term process that will occur as a part of development. Most are socio-economic in nature as discussed earlier. The availability of fish in a region that previously had little or no fish may change dietary habits. The money generated by aquaculture may move a farmer into a different social class. There are going to be changes in culture resulting from development. Some skills subsequently will be less utilized while new ones are developed. Aquaculture is not a part of the traditional agriculture in many regions but as it becomes established then new traditions will be developed.

H. Discussion

In discussing the various areas that should be considered in regard to environmental effects it should be apparent that the amount of data needed to do a thorough job is enormous and often not available. This is particularly true in regard to what are the normal conditions before a project begins. Adequate data are rarely available to predict all the possible environmental effects. One must use what information is available, appraise its validity, examine the history of similar projects and make the best estimation possible under the circumstances. The more data available the better the estimation of the environmental effects may be, but it will not be proven right or wrong until years after the project.

Another point that must be considered is how important or significant are the effects of an action and to whom. It is often impossible to say that a

change would be statistically significant because the base for comparison is lacking. There may be a loss of habitat for a certain species but would it be significant? How much habitat must be involved? If 10 more cases of malaria appear in a village after a fishpond was built, was this due to the fishpond or a heavier than normal rainy season? A villager near a valley may see the clearing of a valley for fishponds as a significant improvement because it reduced the incidence of mosquitos while someone else may see the clearing as a detrimental loss of habitat for an animal species. Likewise some see development as a gain while others see it as a loss. In many societies the effects of an action are seen from an immediate economic viewpoint first with little significance given to long-term effects on natural resources or asthetics. The principle of managing and conserving a natural resource base can sometimes be overlooked in societies where the need for production is today. The concept of preservation of wilderness for the scenic beauty does not apply in many societies. A judgement has to be made as to the environmental significance of an action but a variety of viewpoints should be considered when making the judgement.

Scale is an important consideration. There are many significant effects resulting from the construction of a reservoir that are not significant at the scale of fishponds. Such things as flood control or sediment retention are significant effects of a large scale reservoir because they receive the runoff of a vast watershed. Ponds are generally located high on a watershed and each pond receives only the runoff of a relatively small area. Even where there is intensive pond construction there may be large amounts of a watershed, particularly in the lower portions, that would be not be overly affected. Health problems which have resulted from reservoir construction (Stanley and Alpers, 1975) are often unmanagable because of the vastness of the reservoir but can be

controlled in fishponds because they are much more managable. This same advantage can also be a disadvantage in that a single reservoir can be managed in a single coordinated effort where fishpond management must be secured by close training of a very large number of pond owners. The concept of scale also apply to habitat changes or displacement of human populations. The flooding of a valley as the result of a newly constructed reservoir will affect large tracts of land. Even if an equivalent area in water was put into fishponds the effects may be less dramatic because the ponds would have to be widely dispersed over a large area.

In determining the significance of an action both the short and long-term effects of the action should be considered. Will a short-term gain be outweighed by a long-term loss or vice versa? The short-term clearing of a site and the construction could be considered a loss but the habitats created and the fish produced would be a gain. There could also be a loss and a gain in water retention. Swamps and low lands are natural water storage areas for streams and rivers. Will the new water storage gained by pond construction offset the loss of the natural system? Frequently marshes and lowlands play an important part in the life cycle of wild fish or in wildlife, both of which are usually an important element in local diets. Will the amount of food produced by a pond offset the loss of wild food? Long-term effects could be the adoption of a new technology (aquaculture) that becomes part of the agricultural tradition. The introduction of an exotic species could be a long-term effect if it were able to establish itself in natural waters.

Another point to be considered in determining the effects of an action is whether any irreversible and irretrievable commitments of resources would be involved. This refers prinicipally to non-renewable resources such as fossil

fuels, minerals, endangered species, land, etc. Fish ponds are not permanent but have long life spans with their influence possibly passed on for several generations. The resources used in the fish production such as inorganic fertilizers may be considered non-renewable.

The alternatives to the proposed action also need to be considered. If no action were taken what would happen to the human environment? Are there any alternatives that can be pursued that will give similar benefits to the aquaculture project? The effects of these alternatives need to be compared to that of the proposed action.

AID considers certain types of projects to have significant effects on the environment. These include: river basin development projects; irrigation or water management projects including dams and impoundments; agricultural land leveling; drainage projects; large scale agricultural mechanization; new lands development; resettlement projects; penetration road building or road improvement projects; powerplants; industrial plants; potable water and sewage projects other than those that are small-scale, and any project impacting on an endangered species or its habitat. These types of projects require an Environmental Assessment or Environmental Impact Statement and an Initial Environmental Examination would not be necessary. An aquaculture project would generally not fall under any of the above headings except for extremely large projects where aquaculture is incorporated as a part of another project, or an aquaculture project which would involve conversion of land which is the habitat for an endangered or threatened species. In regard to irrigation or water management projects including dams and impoundments, this is generally refers to programs where large individual reservoirs are created or where a great many smaller reservoirs are created over a significant part of a watershed.

The impacts that might be considered significant as a result of an aquaculture project depend on the type of aquaculture, the species used, the location of the project, the scale of the project and the nature of the current environmental conditions. Some factors may result in significantly negative effects and should be examined in detail. This would include: when an exotic animal is to be introduced for a project; when an endangered or threatened species is found where the project is to be developed; where pesticides are used; when an aquaculture project would cause intense competition for available resources; or when an aquaculture project could cause an increase in the incidence of a serious public health problem. There are a number of lesser effects that can be corrected by proper site selection, consideration of other water users and using an appropriate aquaculture system.

AID considers a proposed action to have a significant effect on the environment if it does significant harm to the environment. The originator of a proposed action must decide what is significant harm. The various factors related to scale, long and short-term effects, irreversible and irretrievable commitments of resources, and alternatives must be considered when deciding what is significant harm. The originator of a proposal action is responsible for preparing the environmental statement based on his interpretation of significance. It is realized that most Missions do not have fully qualified environmental professionals on their staff to assist in preparation of these decisions. AID does have qualified professionals, both in AID and through contracts available for assistance in this area to Missions who request them. That statement should then be reviewed by interested or effected parties. Procedures for preparing environmental statements according to AID procedures are discussed in the following section.

IV. Guidelines for preparing environmental studies in accordance with AID procedures

It is a part of AID policy that environmental factors and values are considered as a part of the AID decision making process. This is done to insure that the environmental consequences of AID-financed activities are identified and considered by AID and the host country prior to a final decision to proceed and that appropriate environmental safeguards are adopted.

The first step in the AID decision making process regarding environmental concerns is the Initial Environmental Examination (IEE). It is the responsibility of the originator of the action or proposed project to prepare the IEE. An Initial Environmental Examination is a preliminary study of the reas nably foreseeable effects of the proposed action on the human environment. Its function is to provide the basis for a threshold decision as to whether an Environmental Assessment or Environmental Impact Statement will be prepared, (Positive Determination), or whether a Negative Determination is more appropriate. If an Environmental Assessment or Environmental Impact Statement is required the IEE will also provide the basis for its preparation. In the case of aquaculture projects with Positive Determinations, Environmental Assessments are the usual next step. Environmental Impact Statements would only be required if the project was to have a significant impact on the global environment. The IEE should identify and describe: (1) the nature, scope and magnitude of any reasonably foreseeable effects of an action or any part of an action on the human environment; (2) the reasonably foreseeable effects of any environmental impact on organisms in the biosphere including proposed action which should be addressed in detail in the Environmental Assessment or Environmental Impact Statement.

An IEE should include a description of the environment under present conditions, the nature of the proposed project and the proposed action to be made, the effects of the project on the environment and the alternatives available. In describing the present environmental conditions it is important to give the reader a clear understanding of the setting of the proposed project. This should include the terrestrial conditions, the water quality, atmopheric conditions as well as relevant social, economic and cultural conditions.

The project should be described in detail clearly stating the purpose and goals of the project and the methods to be used in obtaining them. All proposed modifications should be identified. The time frame and life expectancy of the project should be stated.

The environmental consequences of the project should address: any adverse environmental effects which cannot be avoided should the project be implemented; alternatives to the proposed action; the relationship between local short-term uses of a man's environment and the maintenance and irretrievable commitments of resources which would be involved in the proposed action should it be implemented. Major areas of impact that are generally considered are: Terrestrial; Water quality; Natural Resources; Atmopheric; Social; Economic; and Cultural. Each of these areas were previously discussed in the section on Environmental Effects of Aquaculture. One should refer to that section as to types of effects that may be relevant to a particular aquaculture project and may be needed to be addressed in an IEE. Each project is unique in some way and may have its own characteristic effects that should not be overlooked.

The IEE should give full consideration to alternative actions. The environmental consequences of these alternatives should be detailed. The first alternative is no action and another is to postpone action until further study.

Another alternative could be one that would have similar benefits but different actions. If the goal of the aquaculture program was to improve nutrition then an alternative would be to raise some other type of crop. In some areas rice culture might be an alternative but if the problem were a protein shortage and not a carbohydrate one, then this is not an alternative. The land used for aquaculture is generally of marginal quality and not suitable for any other alternative agriculture. The environmental effects of another type of agriculture may be similar in some regards such as land would be cleared or water diverted but different in others such as land being drained, more insecticides possibly used, etc.

Another action or alternative would be to invest the capital and labor into an unrelated activity that would generate income to purchase food. In a rural area where an aquaculture project is proposed there may not be any viable alternatives for the amount of capital or labor involved, or there may be alternative uses but the secondary benefits from the water storage would not exist.

When a proposed project involves assistance for the procurement and or use of pesticides registered with USEPA for the proposed or similar use then a separate section of the Initial Environmental Examination concerning the pesticides should be made. This section should evaluate the economic, social and environmental risks and benefits and determine whether the use of the pesticide would have a significant environmental impact.

Pesticides are used for particular functions in aquaculture when they are the safest and/or most cost effective method available. They may be suggested for use by extension agents in AID sponsored projects but most aquaculture projects would not give assistance in the procurement of pesticides. The project would be for aquaculture development and only a minor aspect would be the use of

an insecticide for insect control in a fish pond. The purpose of the project would not be to increase the use of pesticides but to develop aquaculture.

If any pesticides are to be used or procured in a project then a variety of factors must be discussed including:

1. The USEPA registration status of the requested pesticides.
2. Basis for selection of the requested pesticide.
3. The extent to which the proposed pesticide use is part of an integrated pest management program.
4. The proposed method or methods of application including availability of appropriate application and safety equipment.
5. Any acute or long-term toxicological hazards either human or environmental, associated with the proposed use and measures available to minimize such hazards.
6. The effectiveness of the requested pesticide for the proposed use.
7. Compatibility of the proposed pesticide with the target and non-target ecosystems.
8. The conditions under which the pesticide is to be used, including climate, flora, fawna, geography, hydrology and soils.
9. The availability and effectiveness of other pesticides or nonchemical control methods.
10. The requested country's ability to regulate or control the distribution, storage use and disposal of the requested pesticide.
11. The provisions made for training of users and applications.
12. The provisions made for monitoring the use and effectiveness of the pesticides.

There are some exceptions where an Initial Environmental Examination, an Environmental Assessment and Environment Impact Statement are generally not required. These are called Categorical Exclusions. Among those exclusions which might relate to aquaculture projects are educational, technical assistance or training programs except to the extent that such programs have activities directly effecting the environment ex. construction of ponds or facilities. Similarly academic or research workshops and meetings are exempted along with document and information transfers. Another type of exception is controlled experimentation exclusively for the purpose of research and field evaluations and field evaluations which are confined to small areas and are carefully monitored. This could include AID sponsored aquacultural research at an existing research station. This exception might be particularly applicable to Title-12 research projects.

It is the responsibility of the originator of a project, program or activity to determine the extent to which these exceptions relate to the activity. This determination shall be made in writing along with a supporting statement as to why, and submitted with the PID, PAIP or comparable document, for concurrence by the Bureau Environmental Officer.

The IEE will include a Threshold Decision made by the officer in the originating office who signs the PID or PAIP and concurred in by the Bureau Environmental Officer. A Threshold Decision is a formal agency decision which based on an IEE which determines whether a proposed agency action is a major action significantly affecting the environment. The decision will determine whether an Environmental Assessment or Environmental Impact Statement is required or whether Negative Determination should be prepared.

A Positive Threshold Decision is that the proposed action will have a significant effect on the environment and that an Environmental Assessment or Environmental Impact Statement should be prepared. An Environmental Assessment is a detailed study of the reasonably foreseeable significant effects both beneficial and adverse, of a proposed action on the environment of a foreign country or countries. Most aquaculture projects with Positive Determinations would fall into the Environmental Assessment category. An Environmental Impact Statement is a detailed study of the reasonably foreseeable environmental impacts both positive and negative, of a proposed AID action and its reasonable alternatives on the United States or the global environment outside the jurisdiction of any one nation.

A Negative Threshold Decision is a decision that an Environmental Assessment or Environmental Impact Statement will not be prepared.

A Negative Determination is a formal written document based on a Threshold Decision that a proposed action is not a major action which will have a significant effect on the human environment and is, therefore, an action for which an Environmental Assessment or an Environmental Impact Statement will not be required. A Negative Declaration is an official written Agency decision made by an Assistant Administrator which states that the Agency will not develop an Environmental Assessment or an Environmental Impact Statement for an action which the Agency has identified as being ordinarily covered by AID Environmental Procedures. The decision may be based on: (1) overriding considerations such as the provision of disaster relief; (2) the fact that a substantial number of Environmental Assessment or Environmental Impact Statements relating to similar activities have been prepared in the past; or (3) the fact that the Agency has previously decided to prepare a programmatic Assessment or Statement covering

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the activity in question. A Negative Determination can be the most appropriate Threshold Decision for many aquaculture projects. The negative effects are often minor and localized and are far outweighed by the positive effects.

There are cases where an Environmental Assessment is needed. This would include projects that involve the use of exotic fish. Often the Initial Environmental Examination may not be in sufficient detail to adequately determine the effect of an exotic fish on the environment and a more complete study is needed. Similarly, an Environmental Assessment is required when the IEE identifies that there will be an endangered or threatened species directly effected by the project. Another case might be where in the IEE it appears that there would be a major health problem as the result of the project. Yet another might be where the project is designed to convert all of the swamp land in the region to series of fishponds, foreclosing unidentified yet culturally important non-agricultural uses of these lands. These are issues where there is rarely adequate information and they are often not among the areas of expertise of the project originator. At that point the issues need to be clearly defined and outside help requested.

Once a positive threshold decision has been made then the originator of the project will begin the process of identifying the significant issues related to the proposed action and determining the scope of the issues to be addressed in the Environmental Assessment or Environmental Impact Statement. This scoping of the issues shall be done with the assistance of various persons having expertise relevant to the environmental aspects of the proposed action. This can include representatives of host governments, public and private institutions, the AID mission staff, REDSO and AID/W staff, and contractors.

A written statement will be prepared that determines the scope and significance of the issues to be analyzed in the Environmental Assessment or Environmental Impact Statement including direct and indirect effects of the project on the environment. For example the introduction of an exotic fish into an area might be an issue. But the issue should be limited to the introduction of a particular species into a particular region and not the issue of all the potential introductions that could be made into a broad region of the world. The statement will identify and eliminate issues that are not significant or have been covered by an earlier environmental review. Only a brief discussion of these issues will be given as to why they will not have a significant environmental effect. The atmospheric effects of aquaculture for example are minimal and would not be addressed in detail.

The statement will describe the timing of the preparation of the environmental analysis, any variation required in the format of the Environmental Assessment and the tentative planning and decision making schedule. The statement will include a description of how the analysis will be conducted and the participants in the analysis. It is the responsibility of the Bureau Environmental Officer to review and approve these statements. If as a result of the scoping process it becomes evident that the action will not have a significant effect on the environment, the Positive Threshold Decision may be withdrawn with the concurrence of the Bureau Environmental Officer.

If the PID or PAIP is approved and the Threshold Decision is positive the originator of the action will be responsible for the preparation of an Environmental Assessment or Environmental Impact Statement. The Environmental Assessment will be a full discussion of the significant environmental effects of a proposed action. It should include alternatives which would avoid or minimize

adverse effects or enhance the quality of the environment so that the expected benefits of development objectives can be weighed against any adverse impacts upon the human environment or any irreversible or irretrievable commitment of resources. The Environmental Assessment will be based on the scoping statement and should follow the following format.

1. Summary: The summary will stress the major conclusions, areas of controversy and the issues of the resolved.
2. Purpose: The purpose of the proposed action should be given.
3. Alternatives including the proposed action: The environmental impacts of the proposed action and the alternatives should be compared. Reasonable alternatives should be discussed in detail and reference made to other alternatives that did not justify detailed study. Reference should be made to the alternative of no action and the Agency's preferred alternative or alternatives.
4. Affected Environment: The environment to be effected by the proposed action or alternatives should be clearly described. The details given should reflect the significance of the impact with less important material summarized, consolidated or referenced.
5. Environmental Consequences: The consequences of the proposed action and the alternatives should be discussed. The relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity should be discussed. Any irreversible or irretrievable commitments of resources which would be made should be discussed. This section should include direct and indirect effects of the proposed action and the alternatives as they relate to terrestrial, water quality, atmospheric, natural resources, economic, social, and cultural effects.

6. The Environmental Assessment shall list the names and professional qualifications of the individuals primarily responsible for preparing the Environmental Assessment.

7. Appendix: An appendix of relevant supporting information may be included.

There should be consultation with the host country government and AID staff both in the early stages of the preparations of the Environmental Assessment and when the Assessment is completed before the project is authorized. The host government will be encouraged by the AID mission to make the Environmental Assessment available to the general public of the recipient country. If Environmental Assessments are prepared on activities which are not country specific, the assessment will be circulated by the Agency Environmental Coordinator to AID's Overseas Missions and interested governments for information, guidance and comment and will be made available in the US to interested parties.

An Environmental Impact Statement shall be prepared when agency actions significantly affect: (1) the global environment or areas outside the jurisdiction of any nation; (2) the environment of the United States; or (3) other aspects of the environment at the discretion of the Administrator. The following format is recommended.

1. Cover sheet
2. Summary
3. Table of contents
4. Purpose and need for action
5. Alternatives including proposed action
6. Affected environment
7. Environmental consequences
8. List of preparers

9. List of agencies, organizations and persons to whom copies of the statement are sent

10. Index

11. Appendicies (if any)

The project should be described in detail clearly stating the purpose and goals of the project and the methods to be used in obtaining them. All proposed modifications should be identified. The time frame and life expectancy of the project should be stated.

The Environmental Impact Statement should give full consideration to alternative actions. These actions would include the alternative of making no changes, actions which are not related to the proposed actions but are feasible alternatives, and modifications of the initially proposed action. The environmental consequences of these alternatives should be detailed.

In describing the present status of the environment, the following areas should be addressed:

Terrestrial example: soil type, geology, hydrology, extent of errosion, land use pattern, etc.

Water Quality example: physical, chemical, and biological aspects.

Natural Resources example: plant and animal resources, aquatic and terrestrial habitats threatened or endangered species, etc.

Atmospheric example: physical and chemical quality, climatology, etc.

Social example: health, demographic and population characteristics, community attitudes, etc.

Economics example: economic base of the area, employment patterns, etc.

Cultural example: historical and archeological significance, esthetics, etc.

The environmental consequences of the project should address: any adverse environmental effects which cannot be avoided should the project be implemented; alternatives to the proposed action; the relationship between local short-term uses of the environment and the maintenance and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

In considering the effects of the proposed action, the following factors should be addressed where appropriate: air quality; noise quality; solid waste disposal; hazardous substances; vegetation and wildlife effects; energy supply and natural resources effects; natural hazards and geological effects; land management effects; socioeconomic and cultural effects.

The draft of the Environmental Impact Statement will be circulated for information and comment by AID to affected foreign governments and will be made available for comment to Federal agencies with jurisdiction by law or special expertise with respect to any environmental impact involved.

The draft Environmental Impact Statement will be made available to public and private organizations and individuals for not less than forty-five days. Notice of availability of the draft Environmental Impact Statements will be published in the Federal Register.

Circulation of this draft will preceed the approval of a Project Paper and comments from such circulation will be considered before final project authorization.

All comments will be attached to the final Environmental Impact Statement and those relevant comments not adequately discussed in the draft Environmental Impact Statement will be dealt with in the final Environmental Impact Statement.

For further details on environmental procedures as related to AID one should refer to AID Regulation 16 Environmental Procedures CFR, Vol 22, part

216, the Bureau Environmental Officer, a Regional Environmental Officer or a Regional Legal Advisor. For more information on procedures related to the National Environmental Policy Act one should refer to FR, Vol 43 55978-56007 and CFR Vol 40 parts 1500-1508.

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APPENDIX A

CHECKLIST OF ENVIRONMENTAL EFFECTS

The following is a checklist which can serve as a guide in determining the environmental effects of aquaculture. Emphasis is given to understanding the aquaculture system to be developed and the conditions under which it will be developed. The checklist should be used to point out areas of possible ecological, economic or social conflict.

Name of Project

Type of Project

Prepared For

Investigator

I. Project Description

Purpose

Goals

Methods to be used

Scale of project

Agency or agencies to be involved

Existing environmental legislation

II. Aquaculture Procedures

A. Species used (native or exotic)

_____

_____

B. Source of Fingerlings

C. Culture Procedures

D. Fertilizers Used

1. Availability

2. Other uses

3. Costs

E. Feeds Used

1. Availability

2. Other uses

3. Costs

F. Chemicals Used

1. Purpose

2. Frequency

3. Concentration

G. Harvest Methods

1. Partial harvest

2. Seining

3. Draining

4. Other

H. Marketing Methods

1. Sold at pond bank to

a. consumer

b. middlemen

2. Preservation used

a. sold live

b. sold fresh no ice

c. sold fresh on ice

d. frozen

e. salted

f. smoked

g. other

III. Terrestrial Effects

A. Nature of land to be developed

1. Agricultural

a. type of crop

b. value of crop/ha

2. Forest

a. managed

b. unmanaged

c. value as forest

3. Pasture

a. improved

b. unimproved

c. value as pasture

4. Other

a. current use

b. value of current use

5. Comparisons of land to be developed to adjacent land

6. Percent of land with similar habitat not to be developed

7. Land ownership patterns

8. Alternative land uses

B. Construction Procedures

1. Amount of land to be cleared

2. Method of construction

3. Time needed to complete construction

C. Water supply

1. Runoff

a. size of watershed

b. vegetative cover

c. soil type

d. slope

e. amount of errosion

f. land use

g. rainfall pattern and intensity

2. Spring or seepage

a. flow rate

b. seasonal changes

c. other uses

d. availability

3. Wells

a. hand drawn

b. pumped

c. artesan

d. depth of well

e. seasonal variation

f. flow rate

g. nature of aquifer

h. restrictions on use of wells

i. amount of well development in area

4. Streams

a. size of stream

b. seasonal variation

c. percent of stream to be diverted

d. frequency and extent of flooding

e. upstream users

f. downstream users

g. nature of watershed

aa. agricultural

bb. woodland

D. Effect of pond discharge

1. Frequency of draining

2. Volume of discharge relative to the volume of receving stream

3. Nature of receiving stream (water quality, fishery)

4. Other water users downstream

IV. Natural Resources

A. Description of Conditions

1. Physical features

a. Geography _____

b. Geology and soils _____

c. Climate _____

d. Water _____

e. Other _____

2. Vegetation

a. Plant communities-dominant plants

_____

_____

_____

b. Unique vegetation features

3. Fauna

a. Animal populations-dominant animals

Mammals _____

Birds _____

Reptiles _____

Amphibians _____

Fish _____

Insects _____

Other invertebrates _____

b. Threatened or endangered species _____

B. Habitat Significance

1. Unique habitats for:

	Important Plant Species	Important Wildlife Productivity	Visual, historic, and/or aesthetic values

2. Conditions of unique habitats:

	Disturbed to pristine	Fragile to durable	Recovery potential and speed

3. Special relationships

1. Vegetation to substrate _____

2. Animal to Substrate _____

3. Plant to animal _____

4. Animal to plant _____

5. Animal to animal _____

6. Other _____

4. Aquatic habitat

1. Present condition _____

2. Visual, historic and/or aesthetic features _____

3. Sport, commercial, recreational, or educational values _____

4. Threatened or endangered species _____

V. Economic and Social Effects

A. Group to which the project is directed

1. Precent of total population

2. Median income

B. Investment requirements of program to farmer

1. Land

2. Labor

3. Capital

4. Alternatives

C. Economic infrastructure required

1. Credit programs

2. Availability and costs of materials and supplies

3. Transportation

D. Diet

1. Normal diet of target group

2. Amount of animal protein in diet

a. types of animal protein

b. percent of each type in diet

c. cost of each type

E. Health Considerations

1. Major diseases in area

2. Percent population infected

3. Sources of infection

4. Purity of water supply

a. type of contamination

b. source of contamination

5. Normal water use and contact patterns

6. Public awareness of health problems

F. Traditional views

1. Toward fish consumption

2. Toward agricultural management

a. are crops managed with fertilizers or pesticides

b. what type of animal husbandry exist

c. what are the divisions of labor (male and female)

3. Toward development and self-betterment

4. Toward land ownership

5. Toward water rights and supplies

6. Toward private ownership of natural resour

7. Toward esthetics of the environment

8. Toward conservation of natural resources

APPENDIX B

SPECIAL CONSIDERATION FOR BRACHISHWATER AQUACULTURE

A variety of marine organisms live part of their lives in brackishwater conditions. Brackishwater is a mixture of freshwater and sea water which has a salinity of 10-32 parts per thousand with seawater being greater than 32 ppt. Several types of shrimp and fish are found in brackishwater that can be used for aquaculture. They are reared in ponds or cages, or in the case of shellfish or algae on the bottom or attached to objects in the water.

Site selection is difficult for brackishwater pond culture. Ideally the site should be protected tidal land of a clay soil with a water supply of the correct salinity range and adequate tidal change. In tropical areas this is often mangrove marshes or salt grass marshes near the mouth of a river or inside a bay. The soil needs to be of a clay nature without too much sand or organic matter. Sandy soil is a problem nearer the open beach. Organic deposits can be a particular problem in swampy areas. The organic material in the soil used for building the dike will decompose weakening the dike and often leaving mineral deposits such as sulfates which can acidify the pondwater. It is important that a soil profile be made to several meters in depth. Coastal areas have changed often in their geological history and it is common to find sand or coral deposits just under the surface. Salt marshes may have deep accumulations of peat.

Ideally the water supply for the site is a tidal stream which has enough variation between high and low tide so that the ponds can be filled at high tide and drained at low tide. A tidal variation between 0.5 and 1.5 meters is acceptable. One of the points to look for in selecting a site is that the site be naturally flooded 10-20 cm at high tide. It should be remembered that the maximum and minimum tides vary within the month and the year. So there will be times when the high tide will be greater than normal and there could be flooding if the dikes of the ponds are not high enough. The danger of storm surges needs

to be considered. Sea storms often push a wave of water ahead of them as they approach shore and compounded with a high tide can cause extensive flooding.

In addition to the water supply having adequate tidal variation it needs to be in the proper salinity range of 10 to 30 ppt. Some aquaculture species require the lower salinities and others higher. Yearly variations in salinity should be noted. In estuaries of major river systems there may be distinct variations in salinity during the year. In the rainy season the floodwaters coming down the river may make the estuary almost freshwater with salinities less than 5 ppt for a month or more. But during the dry season the river flow is reduced and the salinity in the estuary may increase to 30 ppt or greater.

Evaporation from the pond during the dry season can be considerable and the salinity in the ponds can increase to undesirable levels. In such cases a source of low saline water is needed so that the pond water can be diluted to reduce the salinity. The frequency and intensity of rainfall is important. Areas of high rainfall are not suitable because an intense rainfall can rapidly dilute pondwater creating undesirable salinities.

Construction is often difficult due to the nature of the site. In mangrove areas there are often dense stands of trees with intertwining root systems. Such stands make the initial surveying difficult, the clearing of the site time consuming and the root fragments left in the soil are difficult to remove. Salt marshes may be easier to survey but deep organic deposits often interfere with construction. Because the sites are typically subject to daily flooding it is often difficult to use heavy equipment in the construction and most of the construction is done by hand.

The size of the site is often several hectares and may be divided into several ponds. A perimeter dam is constructed to protect the site from flooding

during clearing and construction. The site is then subdivided into smaller ponds. The construction of the dikes is similar to that of a freshwater pond with special care given to the compaction of the soil and the removal of roots and other organic matter from it. The ponds are typically drained and filled via canals. A common canal connected to the tidal stream may serve several ponds. The water level and exchange in a pond is regulated by a concrete or wooden gate in the dike containing removable wooden boards. One or more gates may be located in a pond depending on the pattern of water flow desired. The common canal may have a gate to control its flow.

The stocks of organisms used for culture typically come from the wild. In extensive cultures the ponds are stocked with whatever organisms that enter with the water when the pond is filled. This may include an abundant amount of the desired species but a variety of undesirable species may also enter. In other systems the pond water is filtered and or posioned to eliminate any organism which might have entered in the water supply then is stocked with fish fingerlings or shrimp larva that had been caught from the wild. Some intensive shrimp culture farms use larva that have been obtained through artificial reproduction.

The culture methods vary depending on the species used and the region of the world. There are many traditional systems where no fertilizers or feeds are used or only fertilizers are used. There are more intensive shrimp culture methods where feeding is used.

There are many ecological considerations that need to be given to brackish-water aquauculture. One of the most important is the land that is going to be developed. The estuarine areas are a vital part of many marine fisheries. They serve as a nursery area for many of the commercial species. These species spawn offshore then the larva move into the estuarine areas where they complete their

juvenile life stages. When estuarine areas are altered and put into ponds this will affect the fishery but how significant this is depends on the scale. In regions with extensive estuarine areas the development of 100 hectares in ponds could have little effect but in other regions the loss of 100 hectares to ponds could have a significant effect. This is partically true for some smaller island countries where often the surrounding territorial waters do not support a very productive fishery and any loss of estuarine areas could have an impact on the fishery.

The location of brackishwater ponds can have varying effects. If poorly located the ponds may block or alter drainage patterns of other estuarine areas reducing their productivity. Where there is extensive pond development along tidal streams the dikes serve to channelize the stream. This in turn affects the stream flow, on a high tide the saltwater wedge may extend farther upstream than before. By confining the stream the depth of the stream may be increased permitting further navigation upstream and during flood periods freshwater may reach further out into the estuary. The first two effects are often of little consequence but freshwater extending farther out into the estuary can affect sessile organisms such as oysters or clams.

Particular care needs to be given in mangrove areas. Not only are the mangrove swamps important nursery areas for commercial fisheries but the mangroves also serve to protect inland areas by breaking up the winds and waves as they come in from the sea, thus preventing coastal erosion and stabilizing the shore line. Often the mangrove areas are already being used as a source of firewood, a habitat for oysters or a fishing grounds but are not heavily exploited. But as mangrove areas are cleared for ponds it will increase the degree of exploitation of the remaining mangrove areas. Few alternative uses remain for mangrove

swamps or salt marshes other than leaving them as they are, developing them into ponds, or putting them into pasture.

In areas where there are extensive developments of fishponds this can not only reduce the area of natural nursery grounds but also affect the fish stocks. There may be local reductions of seed stocks in an area as shrimp larva or fish are intensively collected for use in aquaculture. These effects are hard to document because often little data is available on the status of the catch fishery before aquacultural development began.

There are several socio-economic factors that should be considered. Among these are what are the laws and traditions affecting development in the coastal zones. Many countries have existing regulations as to what percent of an estuary can be developed or in mangrove areas what type of buffer zone is required. The coastal zone in many countries is legally considered property of the state and there may be complicated procedures to follow before it can be put into private development. This often favors the development of this land by the well to do individuals with the right political connections. In other countries the coastal swamps and marshes are traditionally considered to be common property where anyone in the community can fish, collect firewood or use it in other manners. The tidal streams and canals may be established passageways through a marsh between villages or fishing grounds and the diversion or alteration of these channels for aquaculture may be a source of social conflict. In some locations fish seed may gather in abundance at certain times of the year and would appear to be a readily available source of seed for stocking into ponds for aquaculture. But such abundances of fish seed may be considered to be the common property of a nearby village and any exploitation by outsiders would be opposed.

Another consideration is who is receiving the benefits from an estuarine area in its present form or if it were put into aquaculture. Although an estuary is an important nursery area, the fish produced may move offshore to be captured by the commercial fishing fleet of another country and no one living near the estuary would receive much benefit. If part of an estuary were put into aquaculture then the benefits would be more locally felt. Individuals in the area would be managing the ponds, others working as laborers and other involved in collecting the seed and selling and transportation of the production. But estuarine areas also have traditional artisanal fisheries that would be affected if large areas would be put into aquaculture.

The public health problems are generally less in brackishwater aquaculture than in freshwater. Because the water is brackish it is used less for domestic purposes thus, if the water were contaminated the chance of exposure is reduced. The dieoff rate of bacteria in brackishwater is similar to that in freshwater. A majority of the human parasites which complete part of their life cycle in freshwater can not do so in brackishwater. The incidence of mosquitos in a salt marsh area may or may not be reduced as marsh land is put into ponds.

APPENDIX C

OTHER FORMS OF AQUACULTURE

Cage Culture

One of the keys to aquaculture is to have the organisms located so they can be managed and harvested as desired. In pond culture the organisms are confined within the pond and can be managed and harvested there, but a large lake or river can not be managed as easily. One alternative is to use cages or pens in these types of waters.

A cage or pen is a mesh enclosure made of wire, netting or wood with openings small enough to prevent fish from escaping, and large enough to allow movement of water in and out of the cage. The cages may be free floating or connected to the bottom. The size used may be less than $0.5m^3$ to more than $5m^3$. They are suitable for use in waters whose primary use is not aquaculture. This can include unmanaged farmponds, lakes and reservoirs, rivers and bays. When used as a production unit the typical procedure would be to stock a high number of organisms per unit area and feed them a quality feed until a marketable size organism is produced. This might be done by one farmer having one cage of fish for home use, or a commercial operation with many large cages. Among the species of fish that have been used in cage culture include catfish, tilapia, carp and trout.

As in pond culture the environmental effects are related to scale. How many cages or pens are involved, in how concentrated of an area. In some Thai fishing villages it is common for the family to have a cage of fish in the river by the house. The effects of this are minimal when the small sizes and numbers of cages involved are considered relative to the size and flow of the river. But in one bay in the Philippines the use of pens has had an adverse effect on the environment. Over a period of years the concentration of pens has increased to where navigation is restricted, water circulation altered and water quality lowered.

Cages and pens are generally used in existing bodies of water so there is little competition for land but there is a competitive use for the water. The cages can become so concentrated in an area as to restrict navigation or water circulation or remove an area from the catch fishery. When at a high enough concentration cages or pens can effect the water quality. The aquatic environment has a point where it cannot assimilate additional waste from aquaculture without the water quality deteriorating. This can be deceptive in cage culture where it might appear there are only a few cages relative to the surface area of water available. What must be remembered is the high concentration of fish per cage. A few cages per hectare might equal the normal stocking rate if the fish were free in the pond and additional cages could exceed the water's capacity to absorb the waste. This is not a problem in a river where the flow can dilute and wash the waste away or in a large lake or reservoir where the number of cages per area is relatively few. But it is more a problem in smaller bodies of water where the number of cages per surface area is greater.

There are also social and economic effects that should be considered when cages or pens are used in public waters. Will public access be restricted in waters where the cages are located? Restricted access to areas that had been traditionally open may be a source of social conflict between the cage owners and other villagers. This may be particularly true in regard to fishing rights. The area may have been a traditional fishing area and the cages may have attracted more fish to the area. Cages in public waters may be subject to thievery, testing community values in regard to what is private property.

Cages in public waters have an advantage in that the cage owner does not have to be a land owner to be a fish farmer but the intensity of management required is greater than some pond culture systems. The materials to make a

cage may be locally available at little cost but the costs of the feed may be restrictive to some potential fish farmers.

Any public health problems unique to cage culture are not documented but similar problems could be expected as with pond culture when in contaminated waters.

Another form of aquaculture practiced on an extensive basis in esturine areas is oyster culture. Oysters are sessile filter feeding organisms which rely on the surrounding water to provide natural food organisms.

The basic aquaculture system consists of providing substrate on which the larva can attach themselves, then harvesting the oysters as they reach a marketable size. A variety of substrates have be used. One of the simpliest forms is to scatter shell along the bottom of the estuary. Another method is to suspend various materials such as branches, shell or plastic on cords from rafts or pilings.

Many of the environmental effects are related to using public waters for private use. The rafts or pilings can offer navigational hazards. Extensive areas of rafts may affect water circulation patterns. Social questions may arise regarding fishing rights in these managed areas. Another hazard in oyster culture is oysters are effective in filtering out disease organisms and heavy metals. Thus the development of oyster culture in polluted areas would offer public health problems for the consumers.

APPENDIX D

GLOSSARY

Alkalinity: the total concentration of bases in water expressed as mg/liter equivalent $CaCO_3$. Is a measure of the buffering capacity of water.

Aquaculture: controlled management of aquatic organisms for the benefit of man.

Aquifer: a water bearing strata of permable earth

Artesian well: free flowing well made into an aquifer where there is sufficient pressure on the aquifer to force water through the well to the surface.

Bloom (phytoplankton): a concentration of phytoplankton sufficient to give water a colored appearance. The intensity of the color is a reflection of the phytoplankton concentration.

BOD: Biochemical oxygen demand, the amount of oxygen consumed by biological processes such as decomposition or respiration for a given temperature and period of time.

Brackishwater: water which is a mixture of fresh and saltwater with a salinity between 5 and 32 parts per thousand.

Cage: a man-made enclosure placed in water for fish culture.

Cercaria: the infectious larval stage of a digentic trematode which infects the final host.

COD: Chemical Oxygen Demand, the oxygen equivalent of the dichromate ion needed to oxidize a water sample, differs from BOD in that some portions of a water sample are not biologically oxidizable but are chemically.

Dam: that man-made portion of a pond above the natural ground level, constructed to retain water on one side.

Drainage system: (1) the mechanism through which a pond is drained, (2) the network of the various streams which merge to form the final river which enters the sea.

Effluent: the discharge of a pond.

Environmental Assessment: a detailed study of the reasonably foreseeable significant effects both beneficial and adverse, of a proposed action on the environment of a foreign country or countries.

Environmental Impact Statement: a detailed study of the reasonably foreseeable environmental impacts both positive and negative of a proposed AID action and its reasonable alternatives on the United States or the global environment outside the jurisdiction of any one nation.

Estuarine: area where fresh water and marine environments meet.

Exotic: an organism not native to the area in question.

Fauna: the animal life.

Feed conversion: the amount of feed needed to produce a unit of growth.

Feedstuff: the material which is fed to an organism.

Fertilizer: the nutrients added to a pond to increase plant production.

Flora: the plant life.

Green manure: undigested plant material such as grasses or leaves.

Habitat: a place where a plant or animal typically is found at some stage in its life.

Headwaters: the small streams which form the start of a larger one.

Initial Environmental Examination: a preliminary study of the reasonably forseeable effects of the proposed action on the human environment.

Intermediate host: organism which harbors larval or immature stage of a parasite.

Macrophytic plant: non-microscopic plants.

Mangrove marsh: a marsh area with the dominate vegetation being species of mangrove trees Rhizophora.

Miracida: the larval stage of a digentic trematode, hatched from an egg, which enters an intermediate host to form the next larval stages.

pH: an expression of acidity given as the negative log of the hydrogen ion concentration.

Phytoplankton: small algae normally found in a water column.

Plankton: small plants and animals normally found in a water column.

Primary consumers: animals which main food supply is primary producers (plants)

Primary producer: organisms which are able to take elemental materials and convert them into more complex forms.

Prophylactic: something given to prevent a disease from occurring.

Salt grass marsh: a marsh where the dominate vegetation is various types of salt grasses.

Salt water intrusion: the infiltration of salt water into an aquifer.

Secondary consumer: organisms which feed on primary or secondary consumers.

Settleable solids: the amount of solids that will settle out of a water sample in a one hour period.

Significant effect: an effect that will have measurable changes that are considered highly important when all aspects are considered.

Species: taxonomic level of organisms where the organisms are capable of freely interbreeding and producing offspring in its own image.

Stream bed: the natural channel of a stream when it is not in flood stage.

Watershed: area of land topographically located so that runoff water on that land will drain to a common point.

Watertable: upper limit of a portion of earth where the ground is saturated with water.