Constructing a Model for Small Scale Fish Farmers

by

Robert A. Longoni, Jr.

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Technology

Approved April 2011 by the
Graduate Supervisory Committee:

Mary Jane Parmentier, Chair
Gary Grossman
Narciso Macia

ARIZONA STATE UNIVERSITY

May 2011

ABSTRACT

Fish farming is a fast growing industry, which, although necessary to feed an ever growing worldwide population, has its share of negative environmental consequences, including the release of drugs and other waste into the ocean, the use of fish caught from the ocean to feed farm raised fish, and the escape of farm raised fish into natural bodies of water. However, the raising of certain types of fish, such as tilapia, seems to be an environmentally better proposition than raising other types of fish, such as salmon. This paper will explore the problems associated with fish farming, as well as offer a model, based on the literature, and interviews with fish farmers, to make small-scale fish farming both more environmentally, and more economically, sustainable. This paper culminates with a model for small-scale, specifically semi-subsistence, fish farmers. This model emphasizes education of the fish farmers, as well as educators learning from the fish farmers they interact with. The goal of this model is to help these fish farmers become both more environmentally and economically sustainable.

TABLE OF CONTENTS

Page

LIST OF TABELS

Table Page

LIST OF FIGURES

Chapter 1

IDENTIFICATION OF PROBLEM AND OBJECTIVES

Identification of Problem

Fish farming is currently practiced on a scale ranging from simple subsistence operations to highly sophisticated operations run by well established companies. The purpose of this paper is to work toward an economically and environmentally sustainable model for fish farmers who are presently engaged in semi-subsistence farming, which the literature shows to be an operation that provides a product for the fish farmer's household use, but which creates a regular surplus for sale to others. The literature also defines semi-subsistence farms as generally being between one in five hectares in size (Challenge for Europe, 2009).

This model should work best in arid climates. This is because farms in arid areas are less likely to be near natural bodies of water. As the literature shows, proximity to a natural body of water is an issue. It is an issue for three reasons. First of all it is an issue because of the release of waste from the fish farm into the natural body of water. Secondly it is an issue due to fish escaping from the fish farm into natural bodies of water. Finally, it is an issue due to the concern of diseases being transferred from the farmed fish to wild fish. Since a large percentage of the world's population lives in arid climates, but still may see fish as a healthy way to obtain protein, this model could be very beneficial to the population living in arid regions.

Dr. Modalugu Gupta helped to set up very basic fish farms, using ditches that had been abandoned, as well as fields that are flooded part of the year (Weise, 1990). However, some fish farm operations are much more expensive both to set up and maintain, as in the case of the modern salmon farming industry. Another example of fish farm operations that are expensive to set up is what Simon R. Bush, of the Environmental Policy Group, at Wageningen University, in Holland, wrote about. He studied fish farming in three regions, in the country of Laos. As a result of this study he came to the conclusion that building fish farms is an expensive undertaking that few of these Laotian farmers can afford. Banks were generally unwilling to lend money to these farmers to build fish farms. Some of the farmers Mr. Bush studied dug fish ponds by hand, but this meant that it could take years to build one fish pond. Some of the farmers studied were lucky enough to have ponds that were inadvertently created when roads were built. However, in the opinion of Mr. Bush, in general, in these regions, fish farms have become places created by well off individuals, to become focal points for business meetings (Bush, n.d.).

Like so many other types of agricultural activity around the world, fish farming is often done in ways that are both detrimental to the environment and the communities that the fish farms are located in, especially large scale commercial farming. As an example, Colin Nash, who is cited later in this paper, discusses some of the negative effects of net-pen salmon farming in the State of Washington (Nash, 2001). As another example, Rogers, the Environmental Defense Fund, and a fish farming consulting company, AquaSol, all deal with the negative environmental effects of shrimp farming (Sustainable Aquaculture, 2003; Environmental Defense Fund, n.d.; & Rogers, 2006). However, the literature will show that smaller operations, especially, subsistence operations, generally pose much less of a threat to the environment than larger, more sophisticated operations, that generally use more outside inputs, and create more waste.

There are multiple reasons for developing a sustainable semi-subsistence model, for fish farming. First of all, subsistence fish farms may have less negative impact on the natural environment than semi-subsistence operations, due to their small scale, and lack of pressure to produce enough fish to sell to the public. Therefore, there is less of a need to create a model for them, in order to protect the environment. Also, others, like Gupta, have already focused their efforts to helping out subsistence fish farmers. There is nothing in the literature to indicate that similar efforts have been made on behalf of semi-subsistence fish farmers who are feeling the pressure to not only feed their family but raise a significant quantity of fish that can be sold to others. At the other end of the spectrum from subsistence fish farms, full scale commercial fish farm operations, with their sole emphasis on the bottom line may be less likely to want to follow a model that puts too many restrictions on them, as possibly evidenced by the interview of one of the fish farmers done for this paper. However, it is the goal of this author to come up with a model of fish farming that will lead to increased incomes for these smaller scale fish farmers, while protecting the natural environment. Consequently, the model will help fish farmers to reduce their costs, as well as get them to do things that make their farm more environmentally sustainable. Some of these measures to protect the environment should help fish farmers to save money in the long run. This would also help out the fish farmer's bottom line.

In order for this model to apply to all of the arid parts of the planet where fish farming already exists, as well as may very well exist in the near future; as well as to at least some degree the rest of the planet, the model will allow the growing of different species of fish in different places, with an emphasis on growing fish native to the area. The alternative allowed would be to grow fish that are well-adapted to the climate they are being grown in.

In a totally artificial environment, at least theoretically, all of the various requirements for each type of fish could be controlled, and it wouldn't matter what kind of fish is grown where. As an example, warm water fish could be grown in a greenhouse at the North Pole, and coldwater fish would even be able to be grown in a greenhouse at the equator. However, this is the kind of operation that large corporations would have the resources to set up, not semi-subsistence farmers. Consequently, this type of thinking would not be incorporated into the model, since one of the main goals of the model is to be able to improve the standard of living for small scale fish farmers who have few financial resources.

Objectives

There are three objectives to this paper. The first objective is to derive a model for sustainable semi-subsistence fish farming. The second objective is to discuss this model with fish farmers in Arizona. The final objective is to create a new model based on input from the fish farmers that the first model was discussed with.

Chapter 2

LITERATURE REVIEW

Subsistence v. Semi-Subsistence Agriculture

The *Merriam-Webster Online Dictionary,* at mw 1.merriam Webster.com, merriamwebster.com, gives two definitions for subsistence farming. The first one is “farming or a system of farming that provides all or almost all of the goods required by the farm family usually without any significant surplus for sale.” The second definition given by this source is “farming or a system of farming that produces a minimum and often inadequate return to the farmer.” This is also referred to as *subsistence agriculture* (Subsistence Farming, n.d.).

The organization Challenge for Europe, in an article they recently posted on-line, characterizes a subsistence farm as an operation where the food produced is used mainly for the farm family’s own consumption. Very little, if any, of these farms’ production would be available for the purpose of selling or bartering. They also state that governments generally consider subsistence farms to be those that are under one hectare in size (Challenge for Europe, 2009). This same organization, in this same posting, describes a semi-subsistence farm as an operation where the surplus is great enough, after the families own needs are met, that it can be sold on a regular basis. According to them, it is farms between one and five hectares in size that governments generally define to be semi-subsistence (Challenge for Europe, 2009). Other literature also provides some examples and characteristics of what might be considered semi-subsistence agriculture. What could be considered an example of this type of agriculture, is given by (Galmiche-

Tejada, n.d.), although he never uses the term "semi-subsistence." For this article Galmiche-Tejada studied fish farmers in the Mexican state of Tabasco. He determined that, in general, these farmers raised fish for subsistence purposes, with cattle being the primary source of income for these farmers. However, one could argue that these farm operations are really still subsistence operations based on what Galmiche-Tejeda wrote elsewhere in this article. There he gave four common characteristics of these farms: 1) The bulk of the food produced on the farm is also used on the farm; 2) The farm uses very few goods not produced on the farm; 3) there is very little cash available to the farm; 4) and the farm doesn't very often purchase what it needs from urban markets.

In an on-line article authored by several university researchers, there are several characteristics given for semi-subsistence farming that tend to distinguish it from agricultural operations that are more commercial in nature. First of all, semi-subsistence agriculture is characterized by very little specialization. On the other hand, there is a great amount of diversification. Another common characteristic of these operations is that crops and livestock are grown in the same operation. It is also a common practice for these farms to grow a wide variety of both crops that are live for just a single year, and crops that go dormant, but come back year after year (Antle, et. al, n.d.).

A second characteristic that sets apart these semi-subsistence operations is intercropping. Intercropping is defined in Antle's 2005 article as the "planting [of] two or more species within any individual parcel of land." A third characteristic mentioned in this article, which distinguishes semi-subsistence farming from agricultural operations that are more commercial in nature, is "high rates of crop failure." A fourth characteristic of these operations, according to Antle, et al., is that the fields are "extremely small," and the fields sub parcels are reconfigured seasonally. Antle, et al's fifth characteristic for these semi-subsistence operations is that they don't use very many purchased inputs, which are more likely to be applied to the crops that are going to be marketed than to the crops that will be consumed by the farm household. The sixth characteristic of these semi-subsistence farm operations, given by this article, is "high … transaction costs," including the cost of transportation. These transaction costs are high for both the things that need to be bought and the production that is sold. These high transaction costs are combined with these farmers not having formal markets available to them for both purchasing some of their inputs, and selling some of their outputs. Finally, Antle et al.'s last characteristic for these semi-subsistence operations, which distinguishes them from operations that are more commercial in nature, is that the credit available to these farmers, for production purposes, is not available through formal sources. If they are not able to obtain credit through informal sources they will not be able to get credit at all.

Definition of Aquaculture

In order to have an intelligent discussion about fish farming or aquaculature, one needs to not only have some basic information about farming in general, but what exactly aquaculture is, and therefore, what sets it apart from other type of agriculture. The website for Northern Aqua Farms gives both a long and a short definition of aquaculture. The long definition is that it "is an industry that encompasses the cultivation of aquatic plants and animals in controlled systems for commercial, recreation or resource management purposes." The short definition is that it "is the cultivation of any aquatic (freshwater and marine) species of plant or animal" (Freeman, n.d.).

General History of Fish Farming

Freeman (n.d.) states that according to the historical record, fish farming started in China, possibly as long as 4500 years ago. These Chinese fish farms contained fish, mainly carp, which were captured after a river flooded. These fish were then held in either lakes or ponds created by humans. The nymphs and Although the connection is not clear, Freeman sees the nymphs and byproducsts of silkworm farming that were fed to the fish as being part of a polyculture operation. According to (Bocek, 2008), (at least in terms of aquaculture) polyculture is a practice whereby multiple species of organisms are grown in the same pond.

According to Freeman (n.d.) the Chinese practiced this farming in a way that was uncomplicated, yet done in a very creative way, as well as being done sustainably. It was set up so as to both increase the amount of food it provided and lessen the impact on the environment that another farm activity would otherwise cause.

Freeman states that historically, the Romans, the Egyptians, and the Hawaiian's, also practiced aquaculture. References in the bible as well as Hieroglyphics, indicate that "Egyptians of the Middle Kingdom," a civilization that was around between 2052 and 1786 B.C., built ornamental fish ponds.

Freeman states that this same civilization also tried to engage in what Freeman calls “intensive fish culturing.” Freeman characterizes the Romans, as being very good when it came to fish farming. Freeman also states that the Hawaiians used fish ponds, which they constructed, as part of their practice of aquaculture. An example of this is a pond located at Alekoko, which is at least 1000 years old.

However, it is only in recent decades that aquaculture has become a major industry. An article in the *Encyclopedia of Food & Culture*, which was originally published in 2003, but posted online in 2006, characterizes modern aquaculture as being made up of a multitude of large industries. This modern incarnation of aquaculture is only decades old (Cengage, 2003).

Significance of Fish Farming

According to an article appearing on the AquaSol website in 2003, “Sustainable Aquaculture,” of this planet’s “major marine fisheries,” almost three quarters are presently being fished to capacity or are being overfished at this time. The expectation is that they will not be more productive anytime soon. According to Safina (1995), catches are declining in every area of three of the world’s oceans, the Atlantic and Pacific Oceans, as well as the Mediterranean Sea. Some of these areas have seen their catches decline by over half since their peak, which was as long ago as the as the early 1970’s. Aquasol sees aquaculture or fish farming as at least part of the solution to the problem of declining catches, since it can add to the world’s food supply.

Freeman, writing on the web site for Northern Aqua Farms, is also concerned about overfishing. He sees fish farming as a means to keep the planet's wild fish stocks from being overfished. This is because fish farming can be used to bridge the gap between what wild fish stocks provide and the amount of fish that humans consume.

The Food and Agriculture Organization of the United Nations (2002), sees fish farming as being important in helping to meet the expected increased demand for fish. It says this in light of its prediction for the future supply of fish caught in marine environments. Its prediction is that the supply of fish from these environments, "in most countries," will either stay the same or decrease.

The Environmental Defense Fund (also known by the initials EDF) (1998), also shows support for increased fish farming, similar to the rationales given above. It states that during the last three decades the world's demand for seafood has greatly increased. It gives three reasons for this increase. First of all, there is the increase in the world's population. Secondly, there are rising standards of living. Finally, the third reason summarizes the effect of the first two reasons: greater numbers of people are eating greater amounts of fish. In this article, EDF acknowledges that restoration of wild fisheries has the potential to increase fish supplies. However, this article goes on to state that there is agreement among the experts that if the world is to greatly increase its seafood supply there is only one way to do it, and that is through aquaculture.

Cengage (2003), gives a health reason for aquaculture. It states that animals raised in aquaculture operations may be safer to eat than wild fish. The reasons given for this assertion by the author of this article, is essentially that the fish are being raised in an environment that can be controlled.

Finally, Aquasol (2003), in its “Sustainable Aquaculture” article, gives some economic areas that aquaculture or fish farming can help out with. These areas are growth and trade, as well as living standards. However, the article doesn’t elaborate on how aquaculture would do this, or has already done this. It also doesn’t comment, if aquaculture has already offered these benefits, or who they have gone to. Finally, it doesn’t comment on who these benefits will go to in the future.

Extensive v. Intensive Fish Farming

Guy Delince (1996), gives a lengthy explanation as to the difference between extensive and intensive fish farming. Delince gives the following characteristics of extensive fish-farming: 1) The fish are raised in either ponds or other types of bodies of water that range in size from medium to large; 2) the fish being raised are dependent on what is naturally available in the water they are inhabiting; 3) the water’s level of enhancement ranges from slight to moderate; 4) low levels of outside inputs; 5) low costs; 6) low levels of capital investment; 7) low level of production relative to size of operation; 8) low level of control of production factors; and 9) high return on labor.

Delince then writes about intensive fish farming. He states that in intensive fish farming there is a large amount of fish production relative to the amount of space that the fish are grown in. Delince goes on to mention three of the controlled production factors in an intensive fish farming operation. The first one is what is fed to the fish. The next one is the quality of the water that the fish are raised in. The last of the three factors he mentions is the quality of the fingerlings that the water is stocked with. The reasons that Delince gives for the control of these production factors are to make the culture more intense, as well as to have better conditions for production. Delince acknowledges that some use an intermediate category of semi-intensive, which he states has some similarities to both intensive and extensive fish farming. However, he characterizes this term as being “ill-defined.”

Edwards (1997) writes about all three categories of fish farming, extensive, intensive and semi-intensive. Based on what he writes, it is implied that just like with Delince, the term semi-intensive is an intermediate category, in terms of intensity, between extensive at the low end, and intensive at the high end. As an example, in Mr. Edward’s definition of extensive agriculture, no nutritional inputs are intentionally added. However, in a semi-intensive system fertilizer is allowed, and certain types of feed are allowed. The type of feed that is permitted to be fed to the fish includes vegetation, bran and oil cake.

A good example of extensive fish farming is all of the small farms set up in southern Asia as a result of the work of Indian Scientist Dr. Modadudu Gupta. For his work, in 2005, Dr. Gupta was named the winner of the World Food Prize (World Food Prize, n.d.); (Embassy of the United States, 2005.); and (Weise, 2005). According to (Weise, 2005), the fish farms set up as a result of Dr. Gupta’s work have small yields. The fish are raised in ditches and ponds that were abandoned by others, in fields that are flooded part of the year, or in ponds created as a result of other human activity such as road building. Also, in these operations, the fish are fed waste from other agricultural activities. Articles appearing at other websites also provide descriptions of Dr. Gupta's work (Embassy of the United States, 2005), (The World Food Prize Foundation, n.d.), and (Modadugu Gupta, 2011).

A good example of intensive fish farming is the fish farming that takes place on integrated fish farms in China, as described by Yingwu (1989). In this instance, the fish are mainly raised in small ponds constructed by people, where the water is between 1 and 2.5 meters deep. The fish raised in these ponds have a diet that consists of commercial food. They are also densely stocked. The reason given for this dense stocking is to create production that is both high and stable. The article goes on to say that Chinese aquaculturists, who have worked in intensive fish culture for a long time, have described eight characteristics of this intensive fish production. Some other highlights of these operations are that the fish are raised in deep water, the fish come from healthy stock, the fish population is dense, but renewable, the operation is elaborately managed, and there is a focus on keeping the fish healthy.

Overview of Today's Fish Farming

According Subasinghe (n.d.), between the years 1970 and 2006, the average per capita yearly growth rate, for the animal, as opposed to plant producing sector of aquaculture, was 6.9 percent between 1970 and 2006. According to Paul Rogers, writing for the March/April, 2006 issue of *Stanford Magazine,* the fish farming industry contributes $54 to the world's economy. However, it is unclear as to whether subsistence fish farming is included in that figure, or if that only includes commercial operations.

According to Allison et al (2007), developing countries account for 98% of the world's total aquaculture production, up from the 90% figure given by the Food and Agriculture Organization of the United Nations (2002). The same 2002 article seems to indicate that a disproportionate percentage of this production takes place in Asia.

The phenomenal growth, in recent decades, in aquaculture, is reflected in the increasing percentage of fish consumed by humans that come from fish farms. According to both the World Watch Institute (2003), and AquaSol's 2003 article, "Sustainable Aquaculture," between the years 1970 and 2000, the share of the world's fish and seafood coming from fish farming, by weight, jumped from 3.9% to 27.3%. However, the percentage of fish consumed by humans, coming from fish farms, has increased almost as much since 2000 as it did in the previous thirty years. According to Allison et al. (2007), the percentage of human consumed fish coming from fish farms has increased, since 2000, to approximately fifty percent. Rogers (2006), seems to back up this assessment. According to his article, 2006's total world demand for fish was 110.4 million tonnes. Almost half of that total demand was being met by fish farms, which provided 51.7 million tonnes of fish that year (Matangi, 2008). (Rogers, 2006), cites United Nations estimates, in claiming that within the next two decades, wild fish stocks will no longer provide even half of the fish consumed by humans.

However, in spite of the fact that fish farming has, in recent decades, accounted for an ever larger percentage of the fish consumed by humans, the reality is, that over time, the rate of growth, for aquaculture, has decreased significantly. The annual growth rate for this sector was just under 12% for the time period that covered 1985 to 1995. However, for the next ten years, the average rate dropped to 7.1 percent. This annual growth rate was down even further, at 6.1 percent, in the middle of the first decade of the 21st century (Matangi, 2008).

Regardless of whether one sees the continued growth in fish farming as good or bad, Rogers (2006), explains why this growth has taken place. He states that while over the last five decades the human population has increased, the population of blue fin tuna, cod, sea bass, and rockfish, has gone down. He goes on to write that this decline in wild fisheries is the result of "decades of overfishing." Bures (2007) throws out this startling statistic: "96 percent of all wild fish considered edible are endangered." This has meant that the fish catch from the world's oceans is not going up much, at the same time that aquaculture production increases (p. 70).

Rogers states that this planet's present population, of over 6 billion people, is estimated to reach the 9 billion mark by 2050, with developing countries accounting for almost the whole population increase. This is accompanied by the reality that presently over 1 billion of the people occupying this planet have fish as their main source of protein.

Commonly farmed fish

According to Bures, in 2004, by weight, "Carp and other Cyprinids" made up the biggest category of fish or sea based animals raised in aquaculture operations, accounting for 18.3 million metric tons being farmed that year (Bures,

p. 70). The habitat of the Cyprinidae, a family that contains 2100 freshwater and brackish water species. It's natural habitat covers all of North America, as well as Africa and parts of Europe and Asia. There is great variation in length between species in this family. A large number of these species are under 5cm in length. (Family Cyprinidae-Minnows or Carps, n.d.). According to a web page for Cornell University, most of the species that are native to North America are rarely longer than four inches (Minnow Family: Cyprinidae, n.d.) However, the longest species most likely can get up to 3 meters in length (Family Cyprinidae-Minnows or Carps, n.d.). According to this same Cornell University web page, the Cyprinidae family's common name is minnow. No other family of fish in North America is as large as the Cyprinidae family. Later on this article gives three possible reasons why this family of fish is so abundant. First of all, the members of this family are capable of occupying many different habitats. Secondly, most species are ready to breed at a relatively young age. Finally, due to the minnows' small size, it is possible to get many of these fish in a small space, with the fish still being able to find enough food, as well as adequate shelter (Minnow Family: Cyprinidae, n.d.).

The next highest category of fish or sea based animals that were farmed in 2004, were oysters. They accounted for 4.6 million metric tons of production that year (Bures, p. 70).

However, the fish that are most commonly sold are not necessarily the ones that create the most income. According to Rogers, salmon is the fish that really brings in the money. Farm raised Salmon are one of the highest priced fish sold. Rogers states that salmon are raised in countries that have both “coldwater” and “protected coastlines.”

Another high value marine product is shrimp. According to the editors of *E/The Environmental Magazine* (2000), shrimp farming’s value at that time was $5.6 billion (White Gold, 2000).

According to Kraft, et al. (n.d.), in the United States, channel catfish are raised on farms more than any other fish. The other general characteristics of catfish that this author gives are that they are found in warm water habitats; they have a greater tolerance for low levels of oxygen and light than a large number of other types of fish; According to this same web posting, catfish are up and about during the night, or if they choose to eat during the day, the water they feed in is turbid. When looking for food in these darkened waters they go after insects and crustacea, as well as other fish.

Another commonly farmed fish is tilapia. According Pompa and Masser (1999), the name tilapia is a general name given to a group of fish that are only native to the African continent. Tilapia account for over 800,000 metric tons of production per year. According to Aakre and Sell (1993), tilapia have been farmed in their native Israel for approximately two and a half centuries. According to Pompa and Masser it was during the previous five decades that tilapia started being widely farmed in both tropical and semi-tropical regions of the world. According to Pompa and Masser, tilapia are the second most farmed fish in the world. Pompa and Masser state, with the exception of the continent of Africa, Nile tilapia account for over nine out of ten tilpia raised commercially.

According to Aquasol’s 2003 posting “Tialpia Farming,” tilapia are raised in a wide variety of different environments. AquaSol also states, in this same online posting, that ponds are used in three levels of intensity of tilapia production, extensive, semi-intensive, and intensive. This article, states that ponds have an advantage over tanks and raceways, in that they have lower construction costs. According to this same article, the relatively low construction cost for these ponds is one of the reasons that in Latin America, ponds are used more than any other habitat, to raise tilapia in. These ponds also make it easier for the operators of these farms “to stimulate natural productivity.” What the AquaSol article describes “as the major drawback” of raising tilapia in ponds is the increased risk of tilapia reproduction getting out of control. However, there are measures that can be taken to minimize this possibility. This issue of uncontrolled reproduction is one that will be written about further, later on in this paper. It is also written in the AquaSol online article, that hapas are an addition or modification to the pond environment. This article defines hapas as being “fine net mesh enclosures.” The approximate size of these enclosures is 40 square meters. These hapas have the advantage of creating “more easily managed units” within the pond. Finally, the AquaSol article states that operations engaged in intensive or superintensive farming are where you will usually find tanks and raceways. Even though they cost more to construct than ponds and hapas, their advantage is that they create a more controlled environment. The article gives another advantage of tanks over other environments that tilapia can be raised in, in that in that they can more efficiently gather together and raise the fry. According to the article, hapas are the next most efficient method, with ponds being the least efficient of these three types of structures.

Pompa and Masser list some environmental factors that tilapia have a greater tolerance to “than most commonly farmed freshwater fish.” These factors are high levels of salt and ammonia in the water, water with low dissolved oxygen levels, and high water temperatures. According to Pompa and Masser, another characteristic of tilapia that makes them good for aquaculture is that their diet consists of many different types of natural food, as well as organisms, including “decomposing organic matter.” Pompa and Masser go on to write that in cases where the tilapia are given large amounts of feed, “natural food organisms” usually are still responsible for between 30 percent and half of tilapia growth. This is in sharp contrast to channel catfish. In the case of these catfish, the total percentage of their growth coming from these natural organisms is significantly less, and at 5 to 10 percent. Pompa and Masser also contend that tilapia digest plant protein more efficiently than catfish. However, their efficiency rate when it comes to digesting animal protein found in their feed is roughly equivalent to channel catfish. Pompa and Masser state that tilapias’ efficient use of “natural food” allows them, when supplemental feed is not used, to be raised at densities in excess of “2,700 pounds of fish per acre ” if the ponds are “well fertilized.” Similarly, Aakre and Sell state that tilapia are capable of surviving on lots of different kinds of food. However, wild tilapia probably eat more algae than any other kind of food.

In the article, "Local Feed Production for Tilapia," (2002), it is stated that feed accounts for the largest expense on a tilapia farm. This expense is responsible for limiting the growth of tilapia farming. This article is about an experiment done in the Northern Mariana Islands, sponsored by a grant of $4,500.00 from SARE. According to this article, "the primary objective of this…experiment is to explore whether alternative and locally available feeds can be cost-effectively used to raise tilapia." The results of this experiment were that the average weight of the fish raised on the commercial feed was eight ounces, but none of the fish whose diet consisted of the local feed got to be heavier than 3 ounces. Therefore, no measurable cost benefit could be seen as coming from using local feed. According to the author of this article, the project coordinator wanted to run the experiment again. However, he was looking to have better monitoring the second time around. He also wanted a different technical adviser for the second go around.

Aakre and Sell also write about the feed given to tilapia, stating that when tilapia are raised on farms their diet consists of pelleted feed with high levels of protein in it. AquaSol, Inc. in its 2003 post, "Tilapia Farming," gives more specific information on this feed. It states that the diets of farm raised tilapia contain "high protein" pellets, which are given to them at a rate as low as 1.0% of their body weight per day, and as high as 30% of their body weight per day, in order to get the tilapia to grow fast. According to this article, exactly how much of this "pelleted" feed is given to the tilapia is dependent on how big they are and what species of tilapia they are. Aakre and Sell also write that the usual frequency for giving these pellets to the fish is two times each day. Soltan, Hanafy, and Wafa (2008), contend that as much as one-quarter of the fish meal in the diets of tilapia and catfish can be replaced by Fish By-product silage (FFS), without making much difference in how fast the fish grow. (p. 80-81). Aakare and Sell (1993) state that where the environment is controlled, the growth rate of tilapia can be as high as "3 percent of body weight per day." However, as one can see, this is about 1.5 times higher than what Aakre and Sell characterize as the "more likely average" of 2 percent. These authors also state that the tilapia raised in these controlled environments have an expected weight gain to food consumed ratio of 1:1.5.

Everything that Pompa and Masser (1999) write about tolerance of water temperatures indicate that tilapia definitely prefer warm water over cold water. They recommend that tilapia be raised in water is whose temperature range is between 76 and 84 degrees farenheit. However, they also state that a little higher temperature rang of the mid to high 80's is what is ideal for growth. Pompa and Masser also indicate that you don't want to let the water temperature fall below 75 degrees farenheit, if you want to maintain high levels of reproduction. They will not reproduce if the water temperature gets below 68 dgrees. If the water gets below 65 degrees, it is much harder to sample or harvest the tilapia without increasing the likelihood that they will die from disease. Pompa and Masser state that the water temperature below which Tilapia "generally stop feeding" is 63 degrees F. Pompa and Masser also write that temperatures below the 50-52 degree Fahrenheit range are lethal to "most species" of tilapia, after a few days.

According to Pompa and Masser, tilapia will survive dissolved oxygen (DO) concentrations at dawn, that are much lower than what “most other” fish that are farm raised can survive on. However, according to Pompa and Masser, tilapia grow faster, and are generally healthier, if these morning readings are kept higher, or at least are not allowed to fall too low for too long a period of time.

Pompa and Masser state that every species of tilapia tolerate salt water. However, according to them, not all species of tilapia have the same level of tolerance. They also state that of all of the “commercially important species” of Tilapia, The Nile tilapia, which is the most popular with fish farmers, has the hardest time tolerating saline water.

Another issue with tilapia, which can be both an advantage and a disadvantage, is the young age at which they sometimes reach sexual maturity. According to Fitzsimmons (n.d.), sometimes tilapia reach sexual maturity before they reach six months of age. However, Fitzsimmons also states that, at six months of age, Tilapia are not anywhere near being adult size. Aakre and Sell state that tilapia are taken to market when they are six months old, and weigh between 1.5 and 1.75 pounds. Pompa and Masser state that different species reach sexual maturity at different ages and sizes. Also, what age they reach sexual maturity at is dependent on what type of environment they are raised in. According to Pompa and Masser, tilapia who grow up in large lakes reach sexual maturity at an older age. These lake raised tilapia also reach sexual maturity when they are larger than their small farm pond counterparts. According to Pompa and Masser, if their growth is slowed, their sexual maturity will be pushed back one or two months. However, for “stunted” members of this species of tilapia it is possible that they will spawn when they still weigh “less than 1 ounce.”

Pompa and Masser explain the life cycle of tilapia raised on a farm. They state that 1 gram are put into “nursery ponds,” to facilitate growth . They stay there until they reach a weight of somewhere between 1 and 2 ounces (20-40 grams). According to Pompa and Masser, this takes place somewhere between 5 and 8 weeks after they are put in the nursery pond. At this point in time, they are put into “growout ponds” until they are harvested. If these grow-out ponds are aerated “static water ponds” they are generally stocked at a density that is between 6,000 to 8,000 males per acre. If, however, according to Pompa and Masser, where it makes economic sense, the ponds can achieve a high enough “daily water exchange” rate, these tilapia males can be stocked at a density that is at least 2.5 times higher than the 8,000 figure.

Fitzsimmons (n.d.), sees the early sexual maturity of some tilapia as being advantageous if you are doing “selective breeding.” This is because this early sexual maturity allows “many generations to be produced in the time it takes other fish to reach maturity.” However, Fitzsimmons sees two ways in which the tilapia’s “high potential for reproduction” can be a problem. First of all, tilapia raised in areas that they are not native too, may affect native fish populations due to their ability to reproduce so fast. Secondly, if tilapia are being raised in ponds that lack predators, they may overpopulate these ponds. According to Fitzsimmons, the result of this latter issue is that the fish farmer has a large number of stunted fish on his hands.

Pompa and Masser offer ways to keep the tilapia from being overcrowded, or becoming stunted. The first strategy is "cage farming." The second strategy is to engage in polyculture. The other species of fish raised would be "a predator fish." Finally, the last strategy offered is to have ponds that only have males in them. These male only ponds also are a good thing since the male growth rate is about twice that of the female.

Finally, before we end our discussion of tilapia here is something to think about. While it is too soon to tell, a recent health report may cause public pressure to be put on tilapia farmers, to change the content of the feed they give to the tilapia. Dr. Phillip S. Chua writes about a study done by at an American university's school of medicine, which showed that the farm raised tilapia they examined "contained a very low level of Omega-3 fatty acids (the good fat)." Conversely, the level of Omega-6 fatty acids, considered to be "bad fats," found in these fish, were "very high." Chua goes on to write that if what this study seems to show about the levels of Omega-3 and Omega-6 fatty acids in farm raised tilapia, then a person who eats tilapia less than every other day or possibly less than every third day may still be harming his/her health. This would be especially true for individuals with a variety of diseases ranging from arthritis to coronary artery disease. This result comes about since Omega-6 fatty acids may "cause an exaggerated inflammatory response" as well as "cause … damage to the arteries of vital organs of the body." However, according to this article, "local experts" may have come up with a solution to this problem. This possible solution, according to Chua, means that the tilapia are fed rice bran and soybean. This is because these two ingredients have fewer Omega-6 fatty acids.

Problems Caused by Fish Farming

The literature points out many problems with modern day fish farming, as it affects the activities of other people, as well as the natural environment. The first problem is with the feeds that “top-level” carnivorous fish use. According to Matangi (2008), these carnivorous fish include salmon and shrimp, which Matangi states are often raised in developing countries and exported to wealthy consumer markets. Different sources give different accounts of how much fish meal and/or fish oil it takes to grow carnivorous fish. According to Rogers (2006), the ratio of pounds of salmon produced to fish oil and fish meal used is 1:3. He states that this fish oil and fish meal consists of the following fish: herring, anchovies and sardines, all of which come from the ocean. Bures (P.27), fortunately, states that herring and sardine are plentiful. The World Wildlife Fund (2003) gives a higher average amount of wild fish needed to feed these farmed salmon. They state that usually the ratio of wild fish to farmed salmon is four to one. Bures gives a ratio that is over fifty percent higher than the World Wildlife Fund’s ratio, at 6.5 to one. However, according to Bures, most of the wild fish fed to these farmed fish are species that are plentiful, such as herring and sardine (Bures, p. 27). Nonetheless, according to Matangi, the amount of fish oil and fish meal used in formulated aquaculture feeds went up by a factor of three in a ten year period ending in 2006. This meant that by 2006 the aquaculture industry was responsible for consuming over half of the fish meal produced, and nearly 90% of the fish oil produced. Matangi also states that Salmon farms were responsible for the largest share of this sector's consumption, being responsible for using more than half of this sector's share of these two fish products.

A second problem with fish farming is the transfer of disease from farmed fish to wild fish. Rogers is concerned that when many fish are confined together, conditions are ripe for the spread of diseases. These diseases include sea lice. These sea lice are capable of going from the farmed fish to their wild counterparts.

A third, and related problem, is the negative environmental impact caused by the use of compounds to control the sea lice. Nash (2001), lumps the pharmaceuticals and pesticides used to control sea lice on salmon farms into one category, which he refers to as therapeutic compounds. Nash states that these compounds are used by European salmon farmers, to control sea lice. These compounds are used for two reasons. First of all, they are used to protect the fish from the unhealthy effects of the sea lice. Secondly, they are used to decrease the chances that the farmed fish will spread the sea lice (page XII).

There are two problems, which are similar to each other, with the use of these therapeutic compounds. First of all, there is the concern that that the more commonly used compounds affect all crustaceans, not just sea lice. Secondly, "several" of these "commonly used compounds," which Nash refers to as broad-spectrum biocides, may have the adverse impacts on many different kinds of organisms, not just crustaceans (Nash, p. XI). Later on in Nash's article it states that every hatchery, as well as every facility that rears fish, uses drugs. This is an issue, because “overuse of drugs” causes bacteria to become more resistant to these drugs. The article goes on to state that because of this development of drug resistant bacteria, there is the potential that antibiotic resistant bacteria will start showing up in either net-pen salmon farms for Atlantic salmon smolt hatcheries. As a result of this, these antibiotic resistant bacteria have the potential, over time, to affect the native salmonid population (p. XVI-XVII). Nash cites government regulation of the use of these compounds for reducing how much risk is associated with the use of these compounds. This regulation took place after “extensive research” as to these compounds “effects on marine organisms.” This research took place both in a laboratory setting and on-site (p. XI).

A fourth issue is that of the discharge of bio-deposits from salmon net-pens. This issue also is dealt with by Nash (2001). He states that bio-deposits, which they define as fish feces and uneaten food, make their way onto sediments that are in the vicinity of the net-pens. According to Nash (2001), these bio-deposits have the potential to affect these sediments chemical and biological makeup (p.X).

Nash gives four chemical changes that would be expected to take place in relation to the sediments that are very close by the net-pens that are presently being in use. One of these changes is the increased biological oxygen demand of the sediments found in the vicinity of the net-pens.

However, Nash sees this issue of biological oxygen demand as being a problem for the farmed salmon, rather than for the wild organisms that inhabit areas near the salmon farms, at least in the Puget Sound area, which is the area studied for this article. This is because of salmon's high oxygen demand and great sensitivity to low levels oxygen levels relative to other species. However, Nash sees the salmon farms, themselves, as creating a situation where the salmon's oxygen demand would not affect other organisms, since their oxygen demand would not be high enough to interfere with these other organisms (p. XII).

According to Nash, the effects of these bio-deposits, from the salmon net-pens, in regards to life at the bottom of the ocean, can be either positive or negative (p. X). Nash states that in some cases the buildup of bio-deposits have the potential to enrich those organisms living at the bottom of the ocean. However, if there is poor circulation at the site of the net pens, the accumulations of these bio-deposits can be greater than the ability of the sediments to aerobically assimilate them (p. X).

According to Nash, this accumulation of bio-deposits above the level at which the sediments can aerobically assimilate them, can cause certain effects on the surrounding environment. One of these effects is that "under extreme conditions," these sediments may lack any oxygen. However, Nash downplays all of the negative effects, seeing the effects a being "ephemeral," since "conditions … returned to normal" anywhere from weeks to years later, whenever there was a fallow period (p. X). However, it could be argued that taking years for conditions to return to normal hardly makes the situation ephemeral.

According to Nash, the effects of net-pen salmon farming on the organisms living at or near the bottom of the ocean can be either negative or positive, depending on how well flushed the sites are, the production levels of the sites, and other activities that take place on site, such as the cleaning of the nets on site. If the level of production on these net-pen farms is high enough, and certain activities, such as the cleaning of nets, take place on site, at a poorly flushed site, then there is there will be changes to both the amount of the infauna and the variety of the infauna, in the vicinity of the net-pens. These changes have the potential to go out nearly a third of a kilometer (p. X). If these sites have lower "production levels," and the nets are not cleaned on-site, the impacted area may extend out fewer than 15 meters.

The World Wildlife Fund and the Environmental Defense Fund are also concerned about discharges from fish farms into the surrounding environment. The World Wildlife fund is concerned when fish farms are located in environmentally sensitive areas, since these farms can negatively impact the surrounding environment. This is because these farms discharge into the surrounding environment nutrients, pathogens and chemicals. The World Wildlife Fund (2003) also gives an example of damage to the environment with its claim that waste coming out of fish farms is to blame for major damage in parts of northern Europe. The Environmental Defense Fund's concern is that waste from net-pen salmon farms pollutes nearby waters. The Environmental Defense Fund also blames shrimp farms located in coastal nations, such as Thailand and Ecuador, for polluting the surrounding water (Environmental Defense Fund, 1998). Rogers (1996), puts this whole issue in perspective. He states that waste from fish farms can produce smothered 'dead zones' in bays and inlets. He then states just how much fecal matter is created by Salmon farms, by citing Roz Naylor, a PhD economist who he states has studied fish farming on four different continents. Rogers states that according to Naylor, 200,000 farmed salmon create roughly the same amount of fecal matter as the amount of untreated sewage coming from 65,000 people. Consequently, you can imagine what might be happening in the countries of Norway, Canada, and Chile. This is because Rogers claims that many of the farms in those three countries have on hand four to five times more salmon than the 200,000 example given above.

Nash also specifically identified the issue of the discharge of heavy metals into the environment, from net-pen salmon farms. The two metals he deals with are copper and zinc (p. XI). According to Nash, copper is found in anti-fouling paints used on the farm. It is also found in some commercial compounds that are used on the nets of the net-pens. As a result of both of these uses, elevated levels of copper can be found in the vicinity of "some net-pen farms." According to Nash, salmon need trace amounts of zinc for nutritional purposes. He states that this metal is an additive found in their feed. He also states that as a general rule, zinc levels are elevated in the vicinity of salmon farms. In Nash's article it is stated that at a few British Columbia farms the zinc concentrations have been above the standard that the State of Washington has set for sediment quality. Nash states that both copper and zinc can harm marine organisms.

Nash gives three factors that affect how much of a risk that these two metals are to the surrounding environment (p. XI). The first factor is "the concentration of sulfide in the sediment." The second factor is what the feed is made up of, since many farms are now using feeds that make it easier for the fish to actually use the zinc found in the feed, rather than having it build up as waste. Finally, where the net pens are washed affects the degree of risk. If the net-pens are washed upland from the farms, and the copper washed off of the net-pens is deposited properly, there is the potential to reduce how much copper accumulates in ocean sediments.

Two gases identified by Nash as being potentially toxic to the environment surrounding salmon net-pen farms are hydrogen sulfide and ammonia. However, Nash asserts that the release of these gases “into the water column” is an infrequent event. Also, according to Nash, the chance that the hydrogen sulfide will create harmful toxic conditions is not likely, except in the case of “extremely large emissions” where the water and sediment interface.

Another problem with fish farming is the escape of fish from fish farms out into the wild. According to Rogers, Some of the fish that have escaped from fish farms have survived. This is particularly true for Atlantic salmon. The result of these escapes is that the escaped fish became the wild fish’s competitors for food, and they also “interbred with” these wild fish. The problem is that this new generation of fish isn’t as capable of surviving in the wild as the preceding generation of wild fish. Nash states that according to records, approximately 600,000 salmon managed to get away from their farms during the four year period of 1996 through 1999. Nash gives the number of these escaped fish that “were subsequently accounted for” as 2,500, less than 5% of the total (p. XV).

Pens and cages are used in aquaculture, in other parts of the world, as well. As an example, in the Philippines they are used to raise milkfish. In one bay in the Philippines, according to Guerrero (2008), there are so many milkfish cages and pens, that they have caused the speed of the water current to fall between forty and sixty percent. Waste from these operations has caused high organic loading to take place. These two things combined to create dissolved oxygen levels that were so low during neap tide that massive fish kills took place.

Another issue, which the Environmental Defense fund brings up, is that, in coastal nations, such as Thailand and Ecuador, mangrove forests were removed to make way for shrimp farms. However, the eventual fate of many of these shrimp farms was either closure or relocation. Consequently, in the end, the people of these areas were left without either the shrimp farms or the mangrove forests" (Environmental Defense Fund, 1998). An article on the website of AquaSol Farms, from 2003, "Sustainable Aquaculture," acknowledges that shrimp farming has been responsible for the destruction of mangrove forests, but states that this destruction by shrimp farmers now happens less frequently than before.

Roz Naylor made observations similar to that of the Environmental Defense Fund, about the shrimp farming industry in Ecuador, when she visited that country, in the early 1990's. Rogers states what Naylor had learned during that trip that "aquaculture companies from the big city [went] to rural villages." There they replaced mangroves trees with shrimp farms. These shrimp ponds were profitable. However, "they destroyed the nurseries for young wild shrimp." Diseases eventually killed the shrimp, and the company management left. These mangrove forests, in the words of Naylor, "were the critical habitats for wild shrimp. I thought, 'here is something so unsustainable. The bigger the production the more the harm.' Sure enough, the whole industry there ended up crashing." Rogers concludes this episode this way: "The already-poor locals ended up with no farmed shrimp, no wild shrimp and no economy."

At least one disease epidemic also led to the closing of shrimp farms, last decade. I talked to an employee of a shrimp farm, in early 2005, who said that many shrimp farms had been wiped out by this disease. The farm she worked at was lucky enough to be able to start up again, but others still had not reopened.

The Environmental Defense Fund points out how these mangrove forests are important to the local ecology. First of all, they "provide critical habitat for commercially important fish and shrimp." Secondly, these forests act as a water filter. Finally, these forests "buffer the coastline against storm waves" (Environmental Defense Fund, 1998).

There is also a possible economic downside to fish farming, as explained in a New Orleans, LA newspaper. Groups involved in commercial fishing, reacting to plans to increase fish farming in the Gulf of Mexico, are concerned that this plan will put out of business commercial fishermen, who are already being negatively affected by imports (Kirkham, 2008).

Ways to Improve Fish Farming

The World Wildlife Fund advocates that fish farmers follow a Code of Conduct for Aquaculture, as well as "an approved set of best environmental practices." It also states that consumers of salmon can do their part by looking for certain labels on store bought salmon that indicate that the salmon were raised in an eco-friendly way, as well as by urging the stores they shop at to agree to sell only salmon grown on “well managed fish farms” (World Wildlife Fund, 2003). According to the Food and Agriculture Organization of the United Nations (2008), certification of products is also being advocated. This article states that this certification is being used for both fish caught by fishers and those being raised on farms. However, they see two problems with this scheme. First of all, as the number of these programs increases, seafood producers are having a hard time meeting the multiple standards that are coming out. The sources of these standards include countries, companies, and certifying organizations. The second problem is that too many schemes make it more likely that less than reliable certification labels are used, not just the “credible ones” (Food and Agriculture Organization of the United Nations, 2008).

The Food and Agriculture Organization of the United Nations (2008) is dealing with the above mentioned problems with the current certification regime. Besides working with one group, it has been meeting with a variety of groups. These groups represent certification bodies, producers, processors, and consumers. The purpose of all of this has been to come up with guidelines that can be applied universally. These guidelines would offer instructions on both the establishment of aquaculture certification schemes. As of the time this article was published, “a set of draft guidelines [had] been finalized,” however the final guidelines had not yet come out.

According to Rogers, Roz Naylor, the economist who was previously mentioned in this paper, offers a series of steps that Salmon farmers can follow to help out the environment. First of all, these salmon should only be given organic feed. Secondly, they should not be given any antibiotics. Thirdly, the net-pens that the salmon are in should have a low-density of fish. Another recommendation of Naylor is that the salmon's net-pens be "fallowed and rotated." Next, the quality of the water should be tested regularly. Also, no marine mammals should be killed as part of the operation of these farms. Finally, what is fed to the salmon should only have a small percentage of fish meal in it (Rogers, 2006).

Another measure that The World Wildlife Fund (2003) advocates is the identification of "vulnerable species and habitats," and adequate protection of these same species and habitats, before any new aquaculture operations are started. It would also like to see Environmental Impact Assessments (EIA) done for both large fish farms and regions that do not necessarily have any large scale operations, but have several smaller ones that are nearby to each other. It thinks that fish farms should not be located in "areas that need environmental protection". Along the same lines, the Environmental Defense Fund (1998), also advocates that fish farms be located a long distance away from places where certain animals engage in certain activities. The locations to be avoided are where marine mammals make their home, the hunting grounds for these same animals, as well as where groups of birds can be found.

In order to control parasites, at least in Norway, the World Wildlife Fund (2003) advocates, at least for fish farms in Norway, that more wrasse fish, a small fish found in that country, be used in the fish farms. Their function would be to remove sea lice from the salmon. The Environmental Defense Fund (1998) gives fish vaccinations as a strategy for controlling parasites in fish farming operations.

One of the suggestions that The Environmental Defense Fund (1998) offers to lessen the pollution that makes its way from fish farms into natural bodies of water is that fish farmers “use closed recalculating systems.” The reason they give for using such systems, is that they see them as a means to improve the control of wastewater, as well as a better way to treat this wastewater.

AquaSol, in its online article, “Sustainable Aquaculture,” (2003), argues for the use of settling ponds, possibly in conjunction with “a pond- based water recycling system.” It states the settling pond, by itself, can effectively reduce what it refers to as “source pollution.” According to this same Aquasol article, these same settling ponds may also have the advantage of being able to “increase productivity in a pond based water recycling system.”

The Environmental Defense Fund (1998) also advocates what one could define as polyculture, since they advocate the growing of organisms that can remove unwanted microorganisms and nutrients. These organisms include seaweeds and filter-feeders. The example of a filter feeder given is mussels. The removal of unwanted microorganisms and nutrients will improve the farm’s water quality.

The Environmental Defense Fund (1998) also advocates against the growing of predatory fish. Instead it states that better alternatives are filter feeders. These filter feeders include mussels and clams. They also advocate the growing of vegetarian or semi-vegetarian fish. The two examples they give are tilapia and catfish. Rogers gives three examples of environmentally friendly freshwater farmed fish. They are catfish from the United States, tilapia from

China, and trout from Europe. However, under Rogers' scenario, all of three of these types of fish would have to be raised inland, in either tanks or channels, to be considered environmentally friendly. Rogers specifically singles out tilapia as being environmentally friendly, since it thrives on an all grain diet.

For fish farmers who still want to raise predatory fish the Environmental Defense Fund (1998) states that these fish should be fed "a semi-vegetarian diet." In addition, the Environmental Defense Fund wants fish farmers to feed their fish byproducts that come from fish which are prepared for human consumption. However, if Daniel Purly, who is the director of Fisheries at the University of Columbia, is correct, the taste of the fish can change if you change the content of its diet. Mr. Purly states this problem rather bluntly: "If you use soy meal the fish tastes like soy" (Nobel, 2008). Rogers backs up this assessment. He states that if salmon are fed grain, as opposed to fish oil and fish meal, "they [won't] taste like salmon." He also points out that as a result of this grain diet, one would find a smaller number of Omega-3 fatty oils in these fish. According to Rogers, these beneficial oils are what has driven the popularity of salmon.

The World Wildlife Fund similarly argues for the use of fish feed that has reduced amounts of wild fish in it. Instead, more vegetable products are put in it. This has been the practice at a fish farm in Norway that the WWF points out as taking steps to be more sustainable. According to the WWF, another positive thing that this farm does is use a feeder with a sensor at the bottom of it. As a result of this sensor, the feeder will not release any additional food until the food that was already there has been eaten up by the fish. (World Wildlife Fund, 2003).

In order to reduce the number of fish that escape from fish farms into wild fish habitat, as well as the damage they do, when they do escape, the Environmental Defense Fund (1998) advocates the following: First of all, it wants fish farmers to raise native species. This will reduce the harm that could be done if a new species is introduced to the area. Secondly, they advocate that fish farmers "use closed systems like tanks," as opposed to what they characterize as "'leaky' netpens or cages." Finally, in order to identify which farms are responsible for the fish escaping, the Environmental Defense Fund advocates that fish from fish farms be marked, and that fish escapes be reported to the public.

Obstacles to Small Scale Fish Farming

The literature points out many obstacles to small scale fish farming. This section of the paper will discuss obstacles facing fish farmers in one south Asian country, Bangladesh, as well as Latin America.

Bangladesh

Sarker et al. (2006), discusses several of these barriers in their article "Entrepreneurship Barriers of Pond Fish Culture in Bangladesh-A Case Study from Myemensingh District." The authors, used a "focus group discussion," as part of their methodology. This focus group was made up of fish farmers and a fisheries officer from Bangladesh, as well as extension officers. The responses to a questionnaire, which was put together after this focus group, were the basis for determining the rank of each of these barriers.

“Lack of knowledge [of] pond management” came out as the number one barrier that these fish farmers face. The next biggest barrier was “unavailability of credit.” This is due to the obstacles they face in getting credit from commercial banks, as well as the “very high” interest rates that non-governmental agencies charge these farmers.

“Poor extension service and lack of information” came out as the third biggest barrier to fish farming. The next biggest obstacle facing these fish farmers is “lack of quality fish fry and fingerlings.”

The fifth biggest obstacle identified in this study was the “unavailability of balanced feed material. There is not enough fish feed, and what is available is too expensive for poorer farmers. The sixth highest barrier identified was the “prevalence of fish diseases.”

The next biggest obstacle is the low prices that fish farmers get in local markets. The consumers at these local markets have little buying power. However, fish farmers are relegated to selling their fish in these markets, when the fish are most plentiful, and therefore, the price is the lowest, Because of Bangladesh’s inadequate transportation system, as well as farmer’s lacking refrigerated storage for their fish.

The obstacle to Fish Farming that ranks as the eighth most important is what the authors of this article refer to as “poor market facilities.” The ninth biggest obstacle to fish farmers in Bangladesh is not enough people to work on the fish farms when they are needed . The tenth greatest obstacle to fish farming in Bangladesh, is what the authors of this article characterize as the “effect of terrorism." The authors of this article see terrorism as compromising the safety of Bangladeshi entrepreneurs across the country.

The eleventh greatest obstacle to fish farming in Bangladesh, according to the authors of this paper, is the behavior of neighbors toward fish farmers, where conflicts between families may one farmer to harm a neighboring farmer's operation. Finally, the smallest barrier of the twelve, to fish farming in Bangladesh, is the "lack of government initiative" in maintaining a "favorable" climate for entrepreneurs.

Latin America and the Caribbean

Lovshin (1999) has identified several obstacles facing subsistence fish farmers in this part of the world. These obstacles can be put into one of six different categories: economic, educational, environmental, physical, political, and social.

The economic obstacles he identified include the following: 1) The cost of feed, fertilizer and livestock, 2) no "reliable source of small fish (fingerlings)" that the fish farmers need to stock their ponds with, 3) the lack of credit available in the private market, 4) the lack of effective long term technical assistance from either government or aid agencies, and 5) the lack of a stable financial climate.

The Political factors that Lovshin identified in his article included the following: 1) governments and aid agencies being unwilling to make long term financial and technical commitments to fish farmers. This is due to the short time frame of aid projects, as well as the turnover of governments. Also, 2) People providing support to fish farmers are unwilling to work in rural areas where there is civil strife.

There are five social obstacles to fish farming discussed in Lovshin's article. The first of these obstacles is that the communities that aid agencies and governments are introducing fish farming into are not given enough time to integrate fish farming into their social fabric before the government agencies, and aid agencies, withdraw their financial and technical support. A second obstacle is that older farmers lose their incentive to farm, when their children leave home, since the older adults no longer have young children depending on them for food. Instead, often these grown children are supporting their parents. A third social obstacle that Lovshin identified was "conflict among participants of communally managed projects." This was an issue for a fish farming project, in Panama, in the 1980's. A fourth social obstacle was "theft of fish from fish ponds not located close to the household."

There are two educational obstacles to fish farming that are identified in Lovshin's article, and they both concern subsistence fish farmers. First of all, subsistence fish farmers lack access to adequate, long term, technical assistance from governments or non-governmental organizations. Secondly, these farmers also lack the education and/or training to be able to fill out credit applications.

The only physical obstacle to fish farming that was identified in this article was lack of physical strength among older farmers.

The environmental factor that was mentioned in Lovshin's article is fish farms being abandoned in Panama and Guatemala because the sources of water for the ponds dried up all or part of the year.

Small Scale Fish Farming Successes

Mozambique.

As a result of cooperative efforts between Mozambique's Ministry of Agriculture and the U.S. Agency for International Development, in 2002, agricultural cooperative in different districts of a Mozambique province were introduced to fish farming. Under this program, small scale farmers have learned what is involved in farming. The protein in tilapia has improved their diet. Also, this fish is a new source of income for them. Under this program, "once a group of farmers has established a successful operation," it is their turn to provide young tilapia to other farmers who want to raise tilapia (United States Agency for International Development, n.d.).

Southern Asia.

According to Weise (2005), Modadugu Gupta, who Weise states is an Indian scientist, spent the previous three decades "creating a cheap and ecologically sustainable system of small-scale fish farming." These fish farms made use of "abandoned ditches" as well as fields that are flooded part of the year. They also made use of water holes that Weise characterizes as being "smaller than the average swimming pool." The holes for the ponds that the fish are raised in were not dug for the purpose of creating a fish pond. Instead they were created when roads were built, or farmers "in wet, low-lying countries such as Bangladesh and Laos," removed soil, in order to elevate their houses (Weise, 2005). According to the United States' Embassy (2005), Dr. Gupta helped "landless farmers" as well as women with little financial means, turn "a million abandoned pools, roadside ditches, seasonally flooded fields and other bodies of water into mini-factories." This multitude of farms provide both food and income for the farmers.

According to The World Food Prize Foundation, (n. d.) Dr. Gupta's "novel techniques" were responsible for increasing India's "average annual fish production" since the early 1970's, by a factor of at least four. Other parts of southern Asia have had similar increases in production, including India's neighbor, Bangladesh. In Bangladesh, according to the World Food Prize Foundation, fish production, on a per hectare basis, "in less than a year," went up over eight-fold, starting at 304 kilograms per hectare, but eventually reaching a production level of more than 2500 kilograms per hectare.

According to Weise (2005), most of the farmers who have participated in Mr. Gupta's program have been "poor women and landless farmers." The typical farmer raises "as few as 200 fish." The carp and tilapia raised on these farms have a diet that consists of "farm waste." Although this so-called waste can include rice and wheat bran. The fish raised on these farms provide the farm families with "high protein food" as well as fish that they sell.

Mr. Gupta answered his critics, who objected to the environmental and health hazards created by fish farming, by conceding that there are farmers who have used too much fish feed and fertilizer. However, Dr. Gupta pointed out that the way to fix this problem was to teach the farmers the correct ways of practicing aquaculture (“Modadugu Gupta,” 2011).

Malawi.

A third example of successful small scale semi-subsistence fish farming is a fish farming program in the African country of Malawi, which, according to an article put out by the World Fish Center. It points out that Malawi is one of “the world’s least developed countries.” According to this same article, nearly one in five residents of Malawi, who are between the ages of 15 and 49, have either HIV or AIDS. According to this article, the death toll in Malawi, each year, from this disease, is in the tens of thousands. This article documents a program in Malawi where fish farms are started for those who have AIDS, and their families. This program has fish farms started for those who have AIDS, and their families. Under this program, ponds whose that cover the area of approximately 20 meters by 10 meters are dug out on the property “of the families participating in the program.” The water from these ponds comes from rainwater. In these ponds, the families raise tilapia and other “commonly cultivated fish species.” The diet of these fish consists of waste from both the farm and the kitchen. According to this article, the work required to run these farms is easy enough that both the “children and the elderly” are able to help out (World Fish Center, 2007).

Dr. Daniel Jamui, the Regional Director for Worldfish in Eastern and Southern Africa gives the rationale for the program this way.

> The purpose of the project is to develop technologies
> and practices in fish production that are specifically

> suited for orphan and widow-related households. As a result, we've seen that fish farming, while not a cure-all for their problems, can dramatically improve conditions among Malawis's rural families dealing with HIV/AIDS.

According to Stephen Hall, Director General of WorldFish, the participants in this program benefit in four ways from their fish farming operations. First of all they have income from the sale of the fish. Secondly the fish, in the words of Mr. Hall, are "a vital source of food that is critical to survival for people with HIV/AIDS." Thirdly, Mr. Hall states that the water from the ponds can be used on crops when there isn't enough rain. Finally Mr. Hall points out that sediment from the ponds creates an "excellent fertilizer" (World Fish Center, 2007).

Zambia.

Chongo (2007) recently wrote about the success of a program backed by the Zambian government, the World Bank and development agencies out of the United Kingdom and Sweden. This program trains individuals living in rural areas how fish ponds can become a source of income. As part of this program, these residents are instructed on choosing the right fish, where the fish can be obtained, taking care of the fingerlings, and construction of the ponds. According to Zambia's Department of Fisheries, more than 10,000 people should benefit from this program.

Summary of Literature Review

Fish farming is a centuries old endeavor. However, it is only in the latter part of the twentieth century that it became much more than a way of raising fish, or marine life, for the needs of local communities that the fish farms are located in. Thanks to the phenomenal growth of fish farming (a term loosely used to include the raising of any aquatic animals), in recent decades, it is now a worldwide multibillion dollar industry, as indicated by Rogers (2006), who doesn't make it clear if this even includes the contribution of subsistence farming to local economies.

While many argue that this growth is necessary to meet the worldwide, ever growing, demand for fish, some of these proponents, as well as others who are not so supportive of fish farming, are very concerned about the damage that fish farming is doing to the natural environment, in the areas where fish farm operations are sited. The damage they are concerned about includes both the damage done to the environment in the immediate vicinity of the fish farms, and the damage done because of these farms dependence on the natural environment. They are especially concerned about the damage done to the environment caused by obtaining feed for omnivorous and carnivorous fish from the world's oceans. The stakeholders in the future of this industry: scientists, environmentalists, aquaculture operators, development agencies, and the communities that these aquaculture operations exists in, are not in total agreement as to how much destruction these aquaculture operations are doing to the environment, and whether the damage is worth the benefits that this industry brings. These same stakeholders are also not in total agreement as to whether the proposed solutions will really work, and whether they are worth the cost.

Some of these stakeholders, such as Dr. Gupta of India, have done much work to promote this industry as a way of improving the lives of people around the world. The academic community has done its own research, to see what does and doesn't work in terms of creating a sustainable aquaculture industry. However, it seems to this author that more still needs to be done to determine just how financially successful subsistence and semi-subsistence farmers can be in improving their livelihoods, while still protecting the natural environment as well as the communities that the fish farms inhabit.

The literature indicates that there are five things that the model for sustainable fish farming should deal with, if this model is truly to make semi-subsistence fish farming sustainable for individuals, the communities the farms operate in, and the natural environment. They are cultural preservation, economic improvement of the individual that is engaged in fish farming, economic improvement of the community that the fish farms are in, the health benefits of the fish being raised, and environmental issues.

Cultural preservation is an issue because, as an example, the traditional activity of fishing has been destroyed by shrimp farming in Ecuador, where it has taken out the mangrove forests that natural fisheries are dependent on. This destruction of the natural environment in Ecuador is also an example of why this model needs to deal with environmental issues. Another environmental issue that the literature clearly points out that needs to be dealt with is the taking of fish from the ocean, to feed farmed fish, defeating part of the rationale for fish farming.

The issue of how different feed ingredients affect the nutritional benefits of farmed fish is clearly an issue that needs to be dealt with. This is because it is not really clear where to come down if, as seems to be the case, when the following conflict takes place. This conflict is, at least in the case of salmon, that the ideal feed for maximizing nutritional benefits is not the ideal feed for protecting the environment. This conflict may also play itself out, in the near future, for both tilapia and catfish.

The model needs to deal with the economic viability of fish farming for small scale farmers. No one wants to see these small scale farmers be put out of business by demands put on them to make their operation more environmentally sustainable. However, some things that help out the natural environment, such as fish farmers being more dependent on plant based feed, or feed created from ingredients on their farm may actually save them money. This, in turn may improve their bottom line.

Finally, economic improvement of the community ties in with cultural preservation. If fish farming destroys other well established businesses or industries in an area, then there might not be an economic gain for the community. Also, part of that community's cultural identity may have been destroyed in the process.

Chapter 3

METHODS

Fish Farming Model Based on Literature Review

This model (Table 1) deals with five areas of concern that the literature deals with, as described at the end of the last chapter, environmental protection, cultural preservation, economic improvement of both the farmer and the surrounding community, and the nutritional benefits of the fish. Under each area it gives things that can be done, mostly by fish farmers, to deal with these concerns. Education is made explicit in some of the suggestions offered, and implied in others. However, education is not the focal point of the model, as it is in the final model. There may also be a role for other institutions to play with some of the recommendations of this model. An example would be, if the community has some say in the future of fish farming in the community, what mechanism would be employed to do that. The original version of this model, which was read to Farmer#1, during my interview of him, can be found in Appendix A.

Table 1: Model 1, General ideas about Subsistence and Semi-Subsistence Fish Farming

Ideas	Who Served	Expansion	Choices for Fish Farming	Economic	Intergration with Existing Agriculture	Culturally Sensitive	Education	Technical Assistance
Cultural Presevation	Community	Decision made by local community	Grow what has always been grown	Preservation of community cusiness	Polyculture	Compatible with community work patterns	--	--
Economic Improvement of Individual	Individual	--	Feed, fertilizer, location & pest control method	Minimize capital Investments	--	--	Yes	Yes
Economic Improvement of Community	Community	--	Fertilizer	Preservation of Community Business	--	--	--	--
Health	--	--	--	Focus on health not economics	--	--	Yes	--
Environmental Issues	--	--	location, feed, intensity, energy usage,	--	Polyculture	--	--	--

Explanation

Ten potential interview subjects were initially found online, from a list of fish farms licensed by the Arizona Department of Agriculture. Due to a low response rate from these ten operations, letters were sent to three additional operations that were later identified from other sources.

In the end, requests for interviews were mailed to twelve different farm operations, and e-mailed to a thirteenth owner, after other contacts with this owner. Follow up phone calls were made to all ten of the first operations contacted. It was due to a low response rate from the initial ten that a search for other fish farm operations was done, with interview requests being sent to three additional operations. A short phone call took place with the manager or owner of one fish farm, out the first ten that interview requests were sent to. However, it was determined that his operation was not a full fledged fish farm, but a holding facility.

Of the thirteen operations that were contacted, one of which was determined, later, was most likely the same operation as another one on the list, but using a different name, only the owner or manager of three of these operations was ever interviewed. One of the interviews was less than a complete interview, since, as mentioned earlier, it was determined that his operation was not a complete fish farm, but a holding operation. For the rest of this paper, the farms for which complete interviews were obtained will be referred to as Farm#1 and Farm#2, with the corresponding interview subjects being referred to as Farmer#1 and Farmer#2.

The interviews of these two farmers were done over the phone. However, a tour of Farm#2 was done at an earlier date. This negated the need to do the interview at the site of the operation. The reason Farmer#1 was interviewed over the phone is he was not agreeable to a visit. Once a revision of the model was done, a copy of it was sent to him by e-mail. His response to this revised model is in Chapter 4. While Farmer#1 was given the details of model#1 over the phone, during the interview, prior to Farmer#2 being interviewed, he was e-mailed a copy of the revised model. The first model was never sent to him or discussed with him.

An issue that could have accounted for why there was such a low response rate, is that many fish farms in Arizona may have gone out of business. At least two of the letters mailed to fish farmers came back stating that the address was not good. Also, more than one of the phone numbers called for these fish operations was no longer in service, or were now assigned to another business. Finally, Farmer#1, stated that his fish farm may be the only commercially viable operation left in Arizona, and Kevin Fitzsimmons, a fish farming expert, with the University of Arizona, indicated that many fish farms are struggling just to hang on.

There are some questions that were asked of all of the fish farmers that were interviewed, which can be found in Appendix A. Follow-up questions were also asked as needed. It is because of the need for follow up questions that interviews were done, instead of mailing out surveys or questionnaires to fish farmers. The purpose of these interviews was to uncover what fish farmers are doing that has been successful, as well as what has not been so successful. The information from these surveys and interviews made it possible to come up with a better model for small scale fish farming. This model can be used by small scale fish farmers to improve their economic well being, as well as help out their communities, and minimize harm to the natural environment.

Chapter 4

RESULTS

Interview: Farmer #1

Farmer#1, who is the manager of the fish section of the farm, stated that fish are not the only thing being raised on his operation. Other things are grown on the farm include olives, pomegranates, Bermuda grass, alfalfa, barley, wheat, rye grass, Sudan grass, goats, and possibly, this year, oats. The total farm is 1,200-1,300 acres. Of that total, no more than 25-30 acres is taken up by the fish farm. The total fish harvest in 2009 was 730,000 pounds.

Previously, when the current owner's father ran the farm, it was a shrimp farm. However, it was changed to tilapia five or six years ago, after the son took over. Nile tilapia is the variety this farm raises the most of. Other varieties raised there are Mozambique, and a Florida Red- albino crossbreed.

At the time of the interview, the manager that was spoken to, stated that the farm, or at least the fish part of it, might make money for the first time in several years, in 2010, due to a combination of an estimated harvest of 1 million pounds of tilapia for the year, and better management of the operation. In 2009 either just the fish farm, or the whole operation, grossed 1.5 million dollars. However, there was no profit. The manager could not tell me what the total costs were in 2009, for just the fish farm operation, or the operation as a whole, since they only started doing comprehensive record keeping very recently. At a later date, this manger stated that a profit was made for 2010 for the whole farm operation, just like the loss he stated for 2009, in the earlier interview, was for the whole operation. According to him, they don't break down profits and losses by farms sections. Due to the large area that both the whole operation and the fish part of it take up, the amount of money the whole operation brings in, and the sheer number of fish produced, one would have to consider the fish operation to be a part of a full-fledged commercial operation.

The fish are fed pelleted feed. The feed was the biggest cost in 2009, although it is unclear if that is for the whole farm, just the fish part of the operation, or both. According to the manager, the top three ingredients in the feed are probably soybean, corn, and wheat. Other ingredients in the feed are vitamins, bone meal, and binders.

The manager that was spoken to didn't think that the farm followed my model very closely. He thought that it only followed the model in two ways. First of all, all of the water used on the farm goes through the fish operation first, and then is used by the rest of the farm operation. Secondly, the goats eat some of the plants grown on the farm.

According to the manager interviewed, in order to follow my model completely, his farm would have to spend a large sum of money to change the operation, possibly bankrupting the operation. According to him, the only way these changes would be feasible is if the economics of fish farming changes, with the public being willing to spend more money on food. At this time, completely following my model would either increase the losses, or decrease the profitability, of the farm. The manager also stated that the model would only benefit the larger community if the public valued what the model was trying to do. The manager also stated that the model has the potential to, but wouldn't necessarily, increase the quality of the fish raised on his farm. According to the manager, the model should be less encompassing, and have fewer variables.

The manager is not sure if having other fish farms in the area would help or hurt his operation. However, he is concerned that more fish farms in the area might introduce fish diseases to the area. They have not had to deal with any fish diseases on this operation since it started raising tilapia instead of shrimp. In response to my question about whether he knew of others who might be interested in taking up fish farming, the manager stated that if fish farming were profitable others would be involved in it. He doesn't know of anyone who is serious enough about fish farming, nor has the skill set to do it profitably.

The manager was not impressed with the revised model. He said that it was a list of goals. This is his e-mail response:

> Anyone can write down anything they want, call it whatever they want. The ONLY way any of it makes any sense is if you try it … actually put it into practice. And to do that you need to get specific. I don't see how I can evaluate your 'model.' It has no specifics to it. It is as broad as can be.

In terms of following the final model, farmer#1 doesn't do much better than he does for following the first model. His operation grows tilapia, which are not native to the southwestern U.S. but are well suited to the area in southwestern Arizona that this farm is located in. This farm operation uses pelleted feed. The owner didn't list fish oil or fish meal as being in the feed. However, he did state that vitamins, bone meal, and binders are in the feed, but he didn't state if any fish products are in any of these three ingredients. The farm operation could do better, environmentally, if the fish were fed plants grown on the farm. It was not determined what type of fertilizer is used in the fish operation, nor what type of pest control method is being used. Due to the part of the state that the farm is located in, it is probably not near any major natural body of water that regularly has water in it. No indication was given by the manager of the fish farm that solar energy, or any other alternative form of energy, is used in the operation. Since outside feed is used on the farm, the level of inputs is higher than it needs to be. However, the operation has to be given credit for running the water on the farm through the fish operation first, rather than using separate streams of water for the fish farm and the rest of the farm.

Interview: Farmer #2

Farm #2 is in the owner's backyard, and is significantly less than an acre in size. During the interview of this owner, it was found out that he started this farm in October, 2009, soon after he and his wife had bought the property. He had never been involved in fish farming before. According to the owner, the farm is significantly less than one acre in size. The fish he raises are Nile tilapia. Everything he feeds the fish is grown on his property: Water Hyacinth, Water Lettuce, algae, and duckweed. Other plants grown on the property include, but are not necessarily limited to, a wide variety of lettuce, tomatoes, zucchini, and Bok Choy. Chickens are also raised in this operation.

The owner of this operation estimates that hundreds of fish have been harvested in the past year, both for his family's use, and for sale as frys. He estimates that his total cost of running the operation, last year, was a couple hundred dollars. His biggest cost last year was operating the swamp cooler in the greenhouse. This operation grossed hundreds of dollars last year. Because of the small size of this operation, as well as the amount of money it brings in, this operation should definitely be considered either a subsistence or semi-subsistence operation.

Revised Model: Model 2

The revised model, below, was devised based on the input of fish Farmer #1, who thought that that first model was too involved. Just like with the first model, the original version of it, which was e-mailed to both Farmer#1 and Farmer #2, is in Appendix A. The education component was made more explicit in this model than it was in the first model.

Table 2: Revised Model, General Ideas about Subsistence and Semi-Subsistence Fish Farming

Ideas	Choices for Fish Farming	Economic	Intergration with Existing Agriculture	Culturally Sensitive	Education	Technical Assistance
Environmental Issues	Type of Fish, location, feed, intensity, energy usage, health, closed loop	Sustainable in a short period of time	Polyculture	Affects on surrounding community	--	--
Education	Health risks and benefits	--	--	Support tradition	extention agents learn from established farmers	Yes

Interview: Farmer #2 (Continued)

The owner of Farm#2 doesn't think that any aspect of this operation more closely follows the revised model than any other aspect of the operation. However, in the opinion of this author, the highlights of how this farm follows the model is that the water is re-circulated through the whole operation, the chickens fertilize the grow-out pond for the fish, and all that the fish are fed is grown on the farm. The thing that sticks out for the owner as not following the model is that the tilapia he raises are not native to the area. Therefore, if he were to completely follow the model, he would have to determine what fish are native to the area, and raise them instead of the tilapia. The owner of this operation didn't think that my model would affect his operation's profitability, since he already follows the model pretty closely. He does think that if other fish farmers followed this model it would help out the community, since he thinks that it would improve these farmers' return on investment, as well as being better for the environment. The owner of this operation said that one way to improve or change the model would be to allow the growing of hybrid fish, which one might consider to not be native to any given area, even if the hybrid fish were a mix of two native fishes.

The owner of this operation also stated that having more fish farmers in the area wouldn't hurt either his operation or the surrounding area. He would like to see fish farming become more mainstream. Finally, there is only one individual he knows of, who isn't already involved in fish farming, who he thought might be interested in getting involved in fish farming. This individual lives in Mexico. The next time he is in contact with this individual, he might talk to him about fish farming, and my work.

According to Farmer #2's web site, the operation uses the sun's energy to heat up the water used in the operation, as well as uses concrete to work against temperature fluctuations. Secondly, the operation recycles its waste water. Thirdly, the operation uses what the website terms "biofiltration." The website defines biofiltration as a "natural water filtration method using biochemistry and duckweed."

Finally, according to the web-site, the operation makes use of a large pool. The website states that this pool had no water in it at the time the present owners took over the property, and the pool was not in very good shape.

During the visit to the property it was found out that the owners are working professionals, who consequently have outside sources of income.

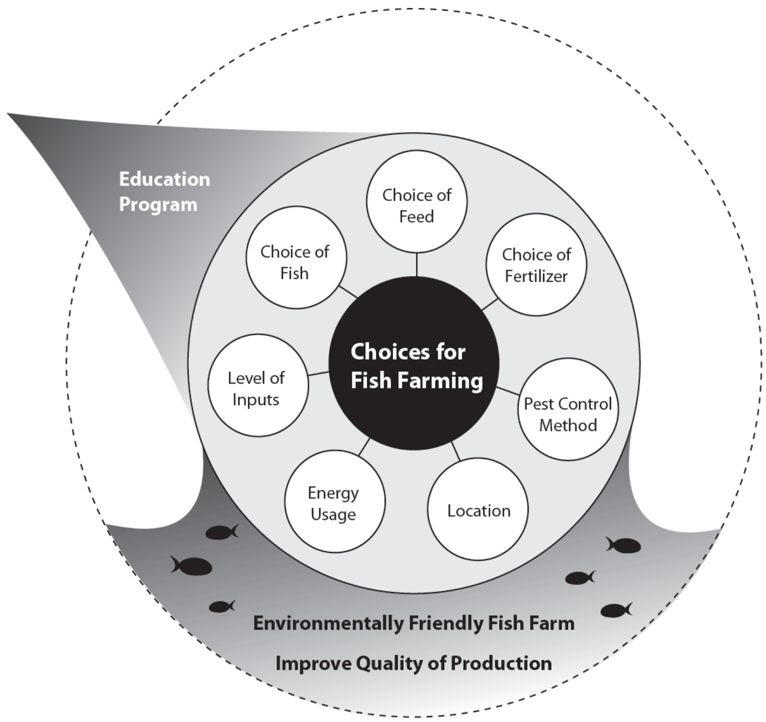
In terms of following the final model, which is discussed below, with a graphic representation, right after the discussion, as with the revised model, Farmer #2 follows it quite closely. He has definitely taken it upon himself to get himself educated about doing fish farming in an environmentally sustainable way. Consequently, he has made very good choices as to how to run his operation, so as to protect the environment, and consequently, not harm, or possibly help out, the surrounding community. His choice of fish to raise, tilapia, though not native to the area, is well adapted to the climate of the Phoenix metro area. Farmer #2 doesn’t use formula feed that contains animal products in it. Instead he feeds the fish plant matter grown in the same operation. The fish pond is fertilized by chicken manure, from chickens on the property. It was not determined what pest control method or methods were used. However, nothing that farmer#2 said in the interview, or that appears on his web site, indicates that any herbicides or pesticides are used in this operation. This operation is not located near any natural body of water. The operation is set up, with the use of solar, cement, and a green house, to minimize fossil fuel usage. Finally, based on the knowledge gained about this operation, there is every indication that the use of outside inputs isn’t all that great, on a regular basis, possibly limited to a grow medium used in the barrels that the fish start out in, and the electricity used to run the evaporative cooler in the greenhouse. However, the initial inputs were greater, with the building of the greenhouse, the barrels that the fish start out in, the solar panels, and the evaporative cooler.

Final Model: Model 3

Figure 1 is a graphic representation of the final model for this paper, which is based on both the literature and the knowledge gained through interviewing two fish farmers in Arizona. What mainly distinguishes the final model from the first two models, is that it makes education the centerpiece of the model. That is why education is at the edge of the graphic. However, unlike the first model, this model doesn’t emphasize keeping capital costs down. Instead, it helps to provide assistance to small-scale fish farmers. This was done so that small scale fish farmers will be able to take advantage of technology, such as solar technology, in order to protect the environment.

In this model, educators help out the fish farmers. However, the educators also learn from the fish farmers, and take what they learn, to help out other fish farmers.

Figure 1: Final Fish Farming Model



Chapter 5

CONCLUSION

These two interviews show that the size and nature of the individual operation may have a bearing on the owner or manager's willingness to follow my model. They also show that the model may work, in large part, for some farms, but not others. Those who have already decided to follow the model, intentionally, or unintentionally, may find it easy to stick with the model, especially, if the farm is not their sole source of income. However, for those who have the farm as their sole source of income, and have established their business in a way that doesn't follow the model, may be very resistant to changing how they do business. This resistance would come from a fear that whatever changes they make, especially in terms of investment in capital, may not pay off in greater profitability. A further line of research may be to follow fish farmers who are willing to adapt the model, and see how financially well their operations are doing. However, this will take more than one time interviews. This will mean developing strong relationships with these farmers, so that they are willing to divulge information that they wouldn't otherwise be willing to divulge. Another line of inquiry would be to determine how much it would actually cost to implement the model, and then determine if there are enough consumers out there who are willing to pay the added cost, so as to make these changes pay off for the farmers who are willing to make them.

Small scale fish farmers who are starting off, as well as those who want to make improvements that will benefit the surrounding community in addition to themselves, may need help locating financial resources, in order to make these improvements, such as low cost loans, grants, and tax credits. However, in the end, the desire to help out the environment sometimes comes in conflict with keeping costs down. Then, it has to be determined which goal is more important, and whether there is a feasible way to do both things.

More research should be done with farmers who are willing to cooperate, to hone in on the individual variables in the model. This would be for the purpose of getting a better idea of which things in the model are really doable under current market conditions, and which things are just too expensive to do at this time.

While the literature is full of horror stories about how fish farming, as in large scale commercial farming, has done much damage to the environment, both the literature and my own primary research point to ways that fish farming can help to improve the lives, including the incomes, of those of modest means. This can be done while minimizing the negative effects that these fish farm operations have on the surrounding environment. Also, some farmers may need to have income from outside of the farm, especially when they are getting started out. There are also practices, as shown in the literature, as well as my research, that small-scale farmers can follow to minimize their negative impact on the environment. However, these smaller-scale farmers may need help from outside experts, especially when getting started. Consumers can also help out these small scale farmers, and other farmers who are willing to run operations that are more environmentally sustainable, by making a conscious decision to buy fish that comes from operations that are run in more environmentally friendly ways.

Since interviews were only done of fish farmers in arid areas of Arizona, where proximity to natural bodies of water is generally not an issue, this model may not work for all fish farm operations, where they need to deal with issues of proximity to natural bodies of water, and keeping their operations from negatively impacting these bodies of water. However, it should work for most of the rest of the small-scale fish operations around the world. As this model is explained, it will be pointed out which aspects of this model may not work for which type of operation.

The first two models were helpful in offering guidance for the interviews of fish farmers, but those models weren't very well integrated. However, the final model has most of the individual components or expectations of the fish farmers that the first two models had, but is clearer as to how everything fits together.

In the final model, the educational process will encourage the fish farmers being educated, to do various things. First of all, the farmers will be encouraged to use native, non-carnivorous fish. However, they will also be encouraged to grow the type of fish that they have traditionally grown, unless that fish creates too much damage to the environment. Secondly, the educational process will also encourage the fish farmers to feed the fish what they would naturally eat, as well as kitchen and farm waste, where practical, and hopefully, to use feed that is not animal based. The reason for using kitchen and farm waste is to keep the farmers' feed costs down. The avoidance of using animal based feed is to keep fish farms from using fish from the ocean to feed farm raised fish. Using fish from the ocean to feed farm raised fish defeats one of the reasons for fish farming, which is to lessen overfishing of the oceans. The nutritional value of the fish raised should be taken into consideration, as well. Farmers should be encouraged to feed ingredients to fish that will make them more nutritionally beneficial to humans. In the case of tilapia, according to Chau, as stated earlier in this paper, this would mean feeding them rice bran and soybean, since they contain less of the Omega-6 fatty acids, than some of the other food that is often fed to them in fish farms. The question then is what happens to the omega-6 levels in tilapia if they are fed what they naturally eat in the wild. Is it the commercial feeds that are often fed to them that are the problem, or their natural diet as well? This is something that should be further studied, since in order to save farmers money, it would be ideal if they could grow tilapia and catfish on waste and what would naturally grow in their ponds, or in the alternative, other crops on the farm, rather than having to spend a lot of money to buy feed made of rice bran and soy.

In addition, even though tilapia are very well suited to warmer climates such as that found in the Southwestern U.S., rice is a very water intensive crop that would have to be imported from somewhere else. There is also a conflict, as well, in terms of what salmon should be fed, since what is good for the environment may not be the best practice in terms of the quality of the fish raised. The literature, as shown earlier in this paper, indicates that Salmon taste best when they have a carnivorous diet, and also may have the best ratio of Omega-3 to Omega-6, when they have a carnivorous diet.

The main argument that can be used with these farmers, to get them to adopt these feed guidelines, is the money they will save. If they are raising fish native to the area, then it shouldn't be too hard to grow the food that the fish would naturally eat, possibly even in the same pond that the fish are in. Also, supplementing the fish's diet with farm and household waste that would otherwise be thrown out, would save fish farmers money.

While some of the food for the fish can grow naturally in the same pond, it may require that at least some of the food for the fish be grown away from the pond that the fish are being raised in. If other animals are raised on the farm, then the fertilizer from the farm animals can potentially be used to fertilize the fish ponds or other places on the farm where the fish's food is grown, thus reducing, or eliminating, altogether, the need for commercial fertilizer to grow the fish's food.

The farmers should also be encouraged to use a closed-loop system for re-circulating the water from the fish farm. This type of system is ideal for a polyculture operation. However, this closed loop system obviously won't work in all fish farms, such as net-pen salmon farms that are in the ocean.

Fish farmers should be made aware of the need to keep their operation far enough away from natural bodies of water, in case their fish escape. This is another idea that will not work for fish raised in net-pens that are in the ocean, but should be feasible for just about all other fish farm operations. However, if the salmon raised are not hybrids, and are native to the area, then their escape from net pens shouldn't be a problem. However, in the case of operations that are very near to, or even in, a natural body of water, such as a net-pen salmon farm, measures should be taken to keep fish from escaping from the operation. This will help to both protect the surrounding environment and the bottom line of the fish farmers, since escaped fish are a financial loss to the farmers.

Fish Farmers should also be educated on the advantages of having an extensive, or semi-intensive, operation, instead of an intensive operation. This is because intensive operations, with their high density of fish, and dependence on commercial feed and fertilizer, tend to be worse for the natural environment than extensive or semi-intensive operations are.

Another way that fish farmers can help to protect the natural environment is to use renewable forms of energy, especially energy that can be generated on-site, such as solar power. Farmers should be encouraged to incorporate the use of solar energy, especially in places with lots of sunlight. In order to offset some of the cost of using solar energy, other alternative forms of energy, as well as some of the more expensive energy conservation measures they may choose to employ, fish farmers need to be educated as to loan and other programs that would be available to them, as stated previously.

Another issue that the model addresses is the control of organisms that may harm the fish. Fish farmers should be educated about natural forms of pest control, such as using beneficial organisms to feed on unwanted organisms. An example that was brought up earlier in this paper was the wrasse fish that were used to control parasites found on salmon.

Finally, besides making fish farming more environmentally benign, it should also be possible for small scale fish farmers to make a profit after being in business for only a short period of time, but also to be able to operate in a way that they can sustain this profitability over the long term. This would mean following practices that don't sacrifice the future for the present, such as not raising fish at such high densities that they are prone to diseases that will wipe out the fish. It also means not giving the fish antibiotics, which drive up the cost of the operation. Thirdly, it would mean following other practices mentioned above such as using the resources that are already available on the farm, like other crops and farm waste. Finally, at least in some cases, it will mean educating farmers about the availability of financial resources that will not saddle them with unbearable debt.

In the end, while it would be beneficial if all small-scale fish farmers were to completely follow the model above, not all of them are going to choose to do so. Some operations, by nature, such as net-pen salmon farms, out on the ocean, are never going to be able to completely follow this model. However, it is the hope of this author that by getting as many fish farms as possible to follow this model, the fish farming industry will eventually evolve into a more environmentally and economically sustained industry than it presently is, and that it will make it possible for small-scale fish farmers to continue to operate profitably.

REFERENCES

Aakre, D., & Sell R. (1993). Tilapia. Retrieved 03/12/11 from http://www.ag.ndsu.edu/pubs/alt-ag/tilapia.htm

Allison, E.H., Andrew, N.L., & Oliver, J. (2007). Enhancing the resilience of inland fisheries and aquaculture systems to climate change. Retrieved 03/27/11 from www.icrisat.org/Journal/SpecialProject/sp15.pdf

Antle, J. M., de Jager, A., Meijerink, G.W., Stoorvegel, J.J., &Vallejo, A.M. (2005). Econcometric-process models of semi-subsistence agricultural systems: An application of the nutrient monitoring data for Machakos, Kenya. Retrieved 4/19/08 from www.tradeoffs.montana.edu/pdf/EP-Models.pdf

AquaSol, Inc. (2003). Sustainable aquaculture. Retrieved 04/15/11 from www.fishfarming.com/sustainableaquaculture.html

AquaSol, Inc. (2003). Tilapia Farming. Retrieved 12/26/08 and 03/28/11 from www.fishfarming.com/tilapia.html

Area Conversion Calculator (n.d.). Retrieved 04/24/11 from *www.asknumbers.com/AreaConversion.aspx*.

Benthic. (n.d.). In *The Free Dictionary by Farlax*. Retrieved 2/7/09 from www.thefreedictionary.com/benthic.

Bocek, A. (Editor) (2008). Introduction to polyculture of fish. Retrieved 8/3/08 from www.ag.auburn.edu/fish/international/polycul.html.

Bures, F. (2007). Fewer fish to fry. *Wired*, 70.

Bush, Simon K. (n.d.). Comparing what matters with what is done: Questioning the role and importance of inland small-scale aquaculture. Retrieved 4/21/08 from web.uvic.ca~jpy/Crossroads/BushComparing_what_matters_with_what_is_done.pdf.

Cengage, Gale (2003). Aquaculture in S. H. Katz (Ed.), *Encyclopedia of Food & Culture*. Ed. Vol. 1. eNotes.com. 2006. Retrieved 03/03/2011 from http://www.enotes.com/food-encyclopedia/aquaculture

Challenge for Europe. (2009). Subsistence and semi-subsistence farming in Europe: a challenge to EU and national policies. Retrieved 8/22/09 from http://challengeforeurope.blogactiv.eu/2009/06/17subsistence-and-semi-subsistence-farming-in-europe-a-challenge-to-eu-and-national-policies/

Chau, P.S. (2009). Tilapia and Lapu-Lapu. Retrieved 4/15/11 from http://dutch-phorum.com/index.php?topic=7786.0

Chongo, S. K. (2009). Zambian farmers try their hand at fish farming. Retrieved 3/14/09 from http://origin.www.voanews.com/english/archive/2009-02/2009-02-02-voa23.cfm

Delince, G. (1996). Extensive or Intensive Fish Farming? Retrieved 02/06/11 from http:/dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/3072/art06.pdf?sequence=1

Editors of E-Magazine. (2000). White Gold: The social and ecological consequences of high intensity shrimp farming. Retrieved 03/12/11 from www.emagazine.com/archive/674.

Edwards, P. Sustainable Food Production Through Aquaculture. *Aquaculture Asia*, Vol. 2 (1): 4-7 (1997). Retrieved 04/13/08 from www.aquafind.com/articles/sust.php

Embassy of the United States-New Dehli. (2005). Indian scientist Modadugu Gupta named winner of the 2005 world food prize. Retrieved 4/14/08 from http://newdehli.usembassy.gov/pr090705.html

Environmental Defense Fund. (1998). The promise and perils of fish farming. Retrieved 04/14/11 from ww.edf.org/page.cfm?tagID=16150

Family Cyprinidae-Minnows or Carps. (1994) Retrieved 6/3/09 from http://filaman.ifm-geomar.de/Summary/FamilySummary.cfm?id=122

Fitzsimmons, K. (n. d.) Introduction to tilapia reproduction. Retrieved 03/27/11 from http://www.docstoc.com/docs/3539656/Introduction-to-Tilapia - Reproduction.

Food and Agriculture Organization of the United Nations. (2008). Is the aquaculture boom starting to fade. Retrieved 4/16/10 from http://www.fao.org/newsroom/en/news/2008/1000930/index.html.

Food and Agriculture Organization of the United Nations. (2002). Towards sustainable fish farming. Retrieved 2/16/08 from www.fao.org/english/newsroom/news/2002/4140-en.html.

Freeman, R. B. (n.d.). Aquaculture resources. Retrieved 2/16/08 from www.northernaquafarms.com/aquaculture

Galmiche-Tejeda, A. (n.d.). Subsistence fish farming: An alternative for sustainable development in rural Mexico. Retrieved 3/10/08 from http://pacrc.uhh.hawaii.edu/mexico/files/bmp_surveys/survey1_001.pdf

Guerrero III, R. (2008) Eco-Friendly Fish Farm Management and Production of Safe Aquaculture Foods in the Phillipines. Retrieved 11/21/09 from www.agnet.org/library/bc/55003/.

Infauna. (n.d.) In *Estuaries.gov*. Retrieved 3/31/11 from http://www.estuaries.gov/Resources/Default.aspx?ID=136.

Integrated Fish Farming in China.

Kirkham, C. (2008). Fish farm plans under scrutiny. Retrieved 4/27/08 from the 4/6/08 edition of *The Times-Picayune.* New Orleans, LA.

Kraft, C. E., Carlson, D. M., & Carlson, M. (2006). *Inland Fisheries of New York (Online),*Version 4.0. Department of Natural Resources, Cornell University, and the New York State Department of Environmental Conservation. Retrieved 04/15/11 from http://pond.dnr.cornell.edu/nyfish/fish.html

Labile. (n.d.). In *The Free Dictionary by Farlax*. Retreived 7/11/09 from www.thefreedictionary.com/labile.

Local Feed Production for Tilapia. (2002). Retrieved 5/23/09 from http://wsare.usu.edu/pro/pr2002/FW98-003.pdf

Lovshin, L. L. (1999). Requirements for the development of subsistence and middle income freshwater fish culture farms in Latin America and the Caribbean. *Red de Acuicultura Rural en Pequena Escala*, ARPE, FAO-UCT.

Mantangi: Tonga Online. (2008). The future of fish farming. Retrieved 5/19/09 from www.matangitonga.to/article/fao_131_0510_pf.shtml.

Minnow Family Cyprinidae. Retrieved 04/24/11 from http://dnr.cornell.edu/nyfish/Cyprinidae/cprinidae.html.

Modadugu Gupta. (2011). In *Encyclopædia Britannica*. Retrieved 3/30/2011 from http://www.britannica.com/EBchecked/topic/1243898/Modadugu-Gupta

Nash, C. (2001). The net-pen salmon farming industry in the Pacific Northwest. Retrieved 04/02/11 from http://www.nwfsc.noaa.gov/assets/25/4283_06162004_141612_tm49.pdf

Nobel, J. (2008). Greener fish to fry. *Environ Press.* Retrieved 4/2/2011 from http://www.mnn.com/green-tech/research-innovations/stories/greener-fish-to-fry

Oxygen Tension. (n.d.). In *Wrong Diagnosis: Dictionary*. Retrieved 8/21/08 from www.wrongdiagnosis.com/medical/oxygen_tension.htm

Pompa, T. & Masser, M. (1999). Tilapia Life History and Biology. Retrieved 05/23/09 from www.ca.uky.edu/wkrec/TilapiaBiologyHistory.pdf

Redox Potentials. (n.d.). Retrieved 7/11/09 from http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/R/RedoxPotentials.html

Rogers, P. (2006). Economy of Scales. *Stanford Magazine.* Retrieved 11/11/08, from www.stanfordalumni.org/news/magazine/2006/marapr/features/fishfarming.html.

Safina, C. (1995). World's imperiled fish (global fish declines). *Scientific American.* 46-53. Retrieved 03/22/11 from www.seaweb.org/resources/articles /writings/safina6.php

Salmonid. (n.d.). In *The Free Dictionary by Farlax*. Retrieved 7/11/09 from www.thefreedictionary.com/salmonid.

Sarker, M. A., Chowdhury, A. H., & Itohara, Y. (2006). Entrepreneurships barriers of pond fish culture in Bangladesh-A case study from Mymensingh District. *Journal of Social Sciences*, 2, 3, 68-73. Retrieved 5/19/09 from www.scipub.org/fulltext/jss/jss2368-73.pdf.

Sensorex Corporation. (n.d.). Dissolved oxygen technical education. Retrieved 7/11/09 from www.sensorex.com/support/education/DO_html.

Soltan, M. A., Hanafy, M. A., & Wafa, M. I. A. (2008). An evaluation of fermented silage made from fish by-products as a feed Ingredient for

African catfish (clarias gariepinus). *Global Veterinari,* 2, 2, 80-86. Retrieved 03/30/11 from http://www.idosi.org/gv/gv2(2)08/7.pdf

Subasinghe, R. (n.d.). State of world aquaculture. Retrieved 7/11/09 from www.fao.org/fishery/topic/13540/en

Subsistence Farming. (n.d.). Retrieved 11/8/08 from www.answers.com/topic/subsistence-farming.

Subsistence Farming. (n.d.). Retrieved 11/8/08 from mw 1.merriam-webster.com/dictionary/subsistence%20farming.

Sunlit Ocean (Euphotic) Zone. (n.d.). Retrieved 03/30/11 from http://www.enchantedlearning.com/biomes/ocean.sunlit/

The World Food Prize Foundation. (n.d.). Dr. Modadugu Gupta: 2005 World Food Prize Laureate. Retrieved 04/14/08, from http://www.worldfoodprize.org/laureates/Past/2005.htm

United States Agency for International Development. (n.d.). Local co-ops dive into fish farming. Retrieved 3/5/08 from www.usaid.gov/stories/mozambique/pc_mz_fishfarming.html.

Weise, E. (1990). Fish Farming Pioneer Wins 'Nobel of Food.' USA Today. Retrieved 4/12/08 from www.usatoday.com/news/health/2005-10-12-world-food-prize_x.htm

World Watch Institute. (2003). Matters of scale-factory fish farming. *World Watch Magazine*,16, 5. Retrieved 4/26/2011 from http://www.worldwatch.org/node/760.

World Fish Center. (2007). Malawi: Innovative fish farming project for HIV-affected families doubles incomes and boosts household nutrition. Retrieved 4/12/08 from http://allafrica.com/stories/200708160839.html

World Wildlife Fund. (2003). The rising tide of fish farming. Retrieved 06/21/09 from www.panda.org/news_facts/newsroom/features/index.cfm?uNewsID=8281.

Yingwu, F. (1989). Pond culture of food fish. In NACA (Ed.), *Integrated Fish Farming in China*. *NACA Technical Manual 7. A World Food Day Publication,* (pp. 294). Bangkok, Thailand: Network of Aquaculture Centres in Asia and the Pacific. Retrieved 4/24/08 from http://www.fao.org/docrep/field/003/AC264E/AC264E00.htm.

APPENDIX A

QUESTIONS FOR FISH FARMERS

1) How long have you been engaged in fish farming?
2) What type of fish do you raise?
3) What do you feed these fish?
4) Do you grow anything other than fish, as part of this operation? If you do, what other crops or livestock do you grow, and are the raising of these crops or livestock integrated with the fish farming?
5) Has this been the only location you have ever had your fish farm in?
6) How many acres is this operation?
7) How many fish did you harvest last year?
8) What were your total yearly costs last year?
9) What was your biggest cost?
10) How much money did you gross last year?
11) Was last year a typical year in terms of costs, harvest, and profit? If not, explain.
12) How close does your fish farm come to following the model that I have presented to you, today?
13) What aspects of your fish farm most closely follow the model?
14) What aspects of the fish farm are least like the model?
15) If you were to follow this model, what are the major things that you think you would have to do differently?
16) Do you think that following this model would improve the profitability of your operation, and why? If you think that it will not increase the profitability of your operation, do you think it would decrease the

profitability of your operation, and why?

17) Do you think that this model will help out the community that your operation is in, and why?

18) Do you think that this model will improve, maintain, or reduce the quality of fish that you harvest, and it what way?

19) Do you have any ideas as to how this model should be changed in order to help out yourself, other fish farmers, or the community that surrounds this operation?

20) Do you think that having more fish farmers in the area would help or hurt your operation, as well as the surrounding area.

21) Are there any individuals, especially individuals engaged in other types of farming, who might be interested in doing fish farming? If so, how would I contact them?

Model 1: Shared with Farmer #1:

1) Environmental issues:

A) Avoid raising carnivorous fish when other native non-carnivorous fish can be economically farmed.

B) Have extensive, or even semi-intensive, as opposed to intensive, fish farms.

C) Encourage polyculture, thus being able to use the same water to grow both fish and plants.

D) Grow native fish.

E) Keep fish farms away from natural bodies of water.

F) Feed the fish food that they would naturally eat in the wild. As an alternative, feed them farm waste, or feed that contains relatively inexpensive ingredients. Especially where native fish are being raised, use locally grown feed.

G) Minimize the use of animal based feed.

H) Make use of locally available forms of energy that are not damaging to the environment, to provide the energy needed in fish farming operations.

2) Cultural Preservation:

A) Encourage fish farmers to grow what they have traditionally grown, rather than trying to grow something that the experts think they should grow.

B) Don't allow fish farming to push out other, more traditional, forms of economic activity, especially other types of agriculture.

C) Get input from locals before trying to "improve," or expand fish farming in a given community. It is especially important to get input from those individuals who are either already engaged in fish farming, or who are likely to take up fish farming in the near future. (See 2A and 2D).

D) If fish farming is new to the community, use polyculture as a way to make it possible for fish farmers who are already engaged in other agricultural activities to continue to engage in those other agricultural activities.

E) Use methods for raising fish that are compatible with the way that work is already organized in the given community.

3) Economic Improvement:

A) Improve the economic well being of the individual farmer.

1. Minimize the cost of inputs

a) Raise fish that require little or no formulated feed, especially formulated feed that contains a large percentage of animal matter in it.

b) Educate farmers on the cost and benefits of various feeds.

c) Make use of natural predators to control the populations of organisms that are harmful to the fish.

d) Where it is cheaper for the farmer, use manure or compost that is from nearby sources, rather than commercial fertilizer, to fertilize fish ponds.

2. Encourage the fish farms to be set up to minimize the need for capital investments such as man made fish ponds or greenhouses. Where possible, instead, raise the fish in ponds or ditches that have already been created by other human activities, such as road building.

3. Technical assistance given to fish farmers should not just be for understanding the science of fish farming, but, also, to understand how to make their farms more profitable through better business practices, such as selling their fish directly to consumers.

B) Improve the economic well being of the community.

1. Fish farming should be done in each community in a way that adds to the overall income of the community, and doesn't push out other forms of economic activity that the community sees as being beneficial.

2. Fish farms in a community should become economically self-sufficient, in a short period of time, not dependent on financial assistance from government or aid agencies.

4. Use manure or compost that is from a nearby source, rather than commercial fertilizer, to fertilize fish ponds.

4) Health:

A) Fish farmers should raise the fish in ways that retain the well known health benefits of fish.

B) Educate farmers as to the health benefits and risks of the fish they are raising or thinking of raising.

C) Where feasible, use feeds that will be both good for the fish and the people who will be eating them, even if this means slightly lower production.

Revised Model: Model Shared with Farmer #1 and Farmer #2

Type of Fish
-Native, non-carnivorous
-What farmers have traditionally grown

Type of Feed
-Not animal based
-What fish would naturally eat
-Waste

Other Aspects of Operation
-Polyculture, closed loop
-Away from natural bodies of water
-Use locally non-environmentally damaging energy
-Extensive or semi-intensive
-Use Manure or compost that is locally available, as opposed to commercial fertilizers
-Use natural predators to control pests
-Avoid raising fish in ways that will reduce health benefits
-Operation economically sustainable in a short period of time
-Factor in how farm operation may affect the surrounding community

Education of Fish Farmers
-Educate fish farmers as to the health benefits and risks of the fish they want to raise
-Educate fish farmers as to how to raise their fish to maximize nutritional benefits
-Technical assistance that not only explains the science, but the economics
-Extension agents need to learn from other established fish farmers
-Don't push farmers too far away from what they have traditionally done.

APPENDIX B

FISH FARMS THAT WERE SENT INTERVIEW REQUESTS

1) Brown's Fish Farm and Supply

HC 01

Box 5100

Pima, AZ 85543

(928)485-9385

2) Cactus Lane Ranch

156 W. Olive Avenue

Wadell, AZ 85355

(602)935-3845

3) Desert Mirage Farm

31204 N. 169th Avenue

Sun City, AZ 85373

(602)584-4451

4) Desert Springs Tilapia

HCI Box 46A

50621 Agua Caliente Road

Dateland, AZ 85333

(928)454-2360

5) Garden Pool

1605 W 7th Place

Mesa AZ 85201

(480)980-3294

6) International Strategies, Inc.

11010 W. Laurelwood Lane

Avondale, AZ 85323

(928)454-2871

7) Maricopa-Stanfield Irrigation and Drainage District

P.O. Box 870

Stanfield, AZ 85272-0870

(928)253-8905

8) Quaker Unity Trust

P.O. Box 441

Gila Bend, AZ 85337

(520)683-2494

9) Rainbow Trout Farm

HC 30

Box 1025

Sedona, AZ 86336

10) Sanudo’s Catfish Farm

Rte. 1, Box 37-JA

Elfrida, AZ 85610

(928)642-3281

11) Williams’ Fish Farm

P.O. Box 183

Arivaca, AZ 85601

(520)398-3631

12) Wood Bros. Farms, Inc.

PO Box A1

Gila Bend, AZ 85337

APPENDIX C

GLOSSARY

Benthic: “Of or relating to or happening on the bottom under a body of water” (Benthic, n.d.)

Euphotic Zone: The top layer of the ocean. This layer “is bathed in sunlight during the daytime.” It varies in depth. However, what differentiates it from the other ocean zones is that the amount of light in this zone is great enough that photosynthesis can take place (Sunlit Ocean, n.d.).

Hectare: Equals approximately 2.4 acres (Area Conversion Calculator, n.d.)

Infauna: “organisms living between the grains of sand or mud” (Infauna, n.d.)

Labile: “Constantly undergoing or likely to undergo change, unstable” (Labile, n.d.).

Oxygen Tension: The “concentration of dissolved oxygen at which its partial pressure is in equilibrium with the solvent” (Oxygen Tension, n.d.).

Partial Pressure: “If different gases are mixed in a confined space of constant volume and a definite temperature, each gas exerts the same pressure as if it alone occupied the space. The pressure of the mixture as a whole is the total of the individual or partial pressures of the gases composing the mixture … The partial pressure of each gas is proportional to the number of molecules of that gas in the mixture” (Sensorex Corporation, n.d.).

Redox Potential: “A measure (in volts) of the affinity of a substance for electrons-its electronegativity-compared with hydrogen (which is set at 0). Substances more strongly electronegative than (i.e. capable of oxidizing) hydrogen have positive redox potentials. Substances less electronegative than (i.e. capable of reducing) hydrogen have negative redox potentials” (Redox Potentials, n.d.).

Salmonid: “Of, belonging to, or characteristic of the family Salmonidae, which includes the salmon, trout, and “Of, belonging to, or characteristic of the family Salmonidae, which includes the salmon, trout, and whitefish” (Salmonid, n.d).