GOOD MANAGEMENT PRACTICES FOR SHRIMP FARMING IN COSTA RICA

Instituto Costarricense de Pesca y Acuicultura

July 5, 2006

Lic. Álvaro Otárola Fallas
Departamento de Acuicultura
Instituto Costarricense de Pesca y Acuicultura
San Jose, Costa Rica

Dear Sr. Otárola:

Enclosed is our report entitled Good Management Practices for Shrimp Farming in Costa Rica. It was written at the Instituto Costarricense de Pesca y Acuicultura during the period from May 13, 2006 through July 5, 2006. Preliminary work was completed in Worcester, Massachusetts, prior to our arrival to Costa Rica. Copies of this report are simultaneously being submitted to Professor Guillermo Salazar, Professor Natalie Mello, and Professor David DiBiasio for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We sincerely appreciate the time that you and Tec. Carlos Luis Barrantes devoted to us.

Sincerely,

Daniel L. Bryand

Andrea L. Kadilak

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Report Submitted to:

Prof. Guillermo F. Salazar
Prof. Natalie A. Mello
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This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of the Instituto Costarricense de Pesca y Acuicultura or Worcester Polytechnic Institute.

This report is the product of an education program, and is intended to serve as partial documentation for evaluation of academic achievement. The report should not be construed as a working document by the reader.

Abstract

Shrimp farming in Costa Rica is a small industry, and INCOPESCA wishes to encourage its expansion, decrease detrimental environmental effects, and increase exportation. In order to achieve these goals, this project identifies and compares current Costa Rican shrimp farming practices with best management practices recommended for Latin American nations. Information concerning current practices was obtained through farmer interviews. The main deliverable of this project is a manual of recommended good management practices constructed specifically for shrimp farming in Costa Rica.

Authorship Page

All writing and research done for the completion of this report was done in equal measures by Daniel L. Bryand, Andrea L. Kadilak, and Sandro R. Pani. All of the team members were responsible for the writing of all the sections in the repot.

Acknowledgements

As we complete our work for our Interactive Qualifying Project, we realize that there are various people that we would like to thank, and without their contributions we would not have been able to complete this report.

We would like to start by thanking our liaison Lic. Álvaro Otárola Fallas, who not only helped guide us throughout the project, but also escorted us on our trip to conduct our various interviews.

We would like to extend our sincerest gratitude to our project advisors Professor Guillermo Salazar, Professor Natalie Mello, and Professor David DiBiasio for their guidance as well as their continuous comments and revisions through our preliminary work until the completion of the project.

We would also like to give thanks to two other individuals from INCOPESCA, Dr. Rolando Ramirez Villalobos for contributing with valuable information, and Tec. Carlos Luis Barrantes for escorting us to conduct interviews.

While we were in the United States we conducted a phone interview with Dr. Brian Crawford of the University of Rhode Island Coastal Resources Center. We would like to thank him for his time as well as the very valuable information and resources he gave to us.

Finally, we would like to thank the shrimp farmers and the biologists from the Gulf of Nicoya region for their time and valuable information. The information we gained through our interviews made it possible for us to complete this project.

Table of Contents:

List of Figures

List of Tables

Executive Summary

Aquaculture, the cultivation of marine organisms, is a rapidly growing worldwide industry, accounting for nearly 30% of global fish supplies in 2003 (FAO, 2005). Currently, Asia accounts for 90% of global aquaculture production, with China supplying 70% of all aquaculture goods (FAO, 2005). Nevertheless, aquaculture is very promising industry in Latin America, where nations such as Honduras, Nicaragua, Mexico, Brazil, and Panama are becoming growing competitors in global commerce. Although Costa Rica has only recently become involved in the global aquaculture market and is not yet a major producer, aquaculture is already an important sector in the national economy, accounting for .32% of the Gross Domestic Product (GDP) in 2002. In comparison, in China, aquaculture production makes up 10% of the nation's GDP (http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/004/Y2876E/y2876e06.htm). As these figures illustrate, even though Costa Rica does not produce or export a large volume of aquaculture products, it is a very important industry to the national economy.

Of all cultivated species, including fish such as tilapia, salmon, trout, and certain crustaceans, shrimp have some of the highest market prices as a luxury commodity. As a result of this, shrimp farming has the potential to become a very lucrative business. The value of this industry has been recognized in Costa Rica, where shrimp comprises 14% of national aquaculture production, second behind tilapia (Quirós, 2002). However, the growth of the industry has recently been impeded by environmental regulations imposed by the Ministerio de Ambiental y Energia (MINAE), which is concerned about the detrimental effects shrimp farms have on the surrounding environment and communities. The consequences of these regulations are that no new farms are allowed to be built. In response, the Instituto Costarricense de Pesca y Acuicultura (INCOPESCA) is working to improve the practices performed on farms. INCOPESCA currently has information on shrimp farming, but there is no specific information or manual of shrimp farming practices specifically applicable to Costa Rica.

The primary goals of this project were to assist INCOPESCA in addressing the issues stated above by improving management practices used on Costa Rican shrimp farms, and reducing the detrimental environmental impact of shrimp farming in the nation. Finally, the long term goal of this project was to increase production and export levels of Costa Rican shrimp farms.

To accomplish these goals, the project accomplished the following objectives:

- Identified and evaluated Best Management Practices (BMPs) used on shrimp farms in other Latin American nations
- Identified and evaluated current shrimp farming practices used in Costa Rica
- Compared BMPs with current practices and made recommendations appropriately

- Identified and discussed socio-economic and environmental effects of shrimp farming in Costa Rica
- Identified effective training methods for farmers
- Designed and created a manual of Good Management Practices (GMPs) applicable to Costa Rican shrimp farms

To achieve these objectives, we first conducted archival research. We investigated the current status of the shrimp farming market and industry globally, in Latin America, and most specifically in Costa Rica. We compiled information concerning BMPs recommended for practice in Latin American nations such as Honduras, Nicaragua, and Mexico and examined laws and regulations pertaining to shrimp farm production. We also researched diseases and other problems that commonly affect shrimp farms. In order to create an effective manual, we studied document design and manual layout. Additionally, we investigated the environmental effects and social implications of shrimp farming in Latin America, focusing on Costa Rica.

Throughout the process, we conducted an interview with Brian Crawford of the University of Rhode Island Coastal Resource Center (CRC), asking him about recommended BMPs and new developments in the industry that could be applied to Costa Rican farms. Additionally, we interviewed Rolando Ramirez Villalobos, the marketing director of INCOPESCA about the marketing potential of farmed shrimp in the national economy. Most importantly, we interviewed 17 shrimp farmers and 2 biologists in Guanacaste and Puntarenas in the Gulf of Nicoya region. We asked about their current practices, any training they had received, production information, and inquired as to any particular problems they had encountered and information they required.

We next analyzed the information obtained from the research and interviews. A wealth of valuable data was obtained from farmer interviews, and made up the bulk of the results and information that was analyzed. We tabulated and graphed production levels and identified and categorized the different practices used on the shrimp farms we visited. We then compared and contrasted these practices with the recommended BMPs to determine the GMP plan most applicable for Costa Rican shrimp farmers. We also identified and addressed common problems or recommendations voiced during the farmer interviews.

Throughout the interview process, we found that most farms were operating proficiently at the basic level. Most farms employ a biologist who helps them monitor water conditions, develop a feed plan, acclimate postlarvae (PL), measure growth and survival rates, and assist in any other general practice issues. Additionally, most farms keep rigorous records of water quality conditions and growth rates, so the potential for further organization and improvement is most definitely present.

However, many farms exhibited problems concerning sanitary procedures and disease control. Nearly all farms out of the 35 we obtained information from experienced some form of disease outbreak, the most common being the bacterial infection vibriosis and White Spot Syndrome Virus (WSSV). We concluded that the frequency of illness in cultivated shrimp on the farms was the result of inadequate sanitary precautions and disease control methods. Therefore, the majority of our recommendations centered on how to maintain sanitary and biosecure conditions on a shrimp farm. We mainly addressed the following sanitary precautions:

- Wild and domestic animal control around the ponds;
- Proper feed and chemical storage;
- Water quality maintenance;
- Proper disinfectant use, and;
- Employee hygiene.

On the farm visits, we observed a number of common practices that were harming the surrounding ecosystem. The farmers, INCOPESCA, and Costa Ricans in general are all very concerned about the preservation of the environment. However, shrimp farmers lacked the required information about environmental precautions. Therefore, we recommended that farmers make sure to maintain equipment so that it does not leak oil into the water supply or leach chemicals into the soil, exchange water less frequently, monitor chemical and suspended solid levels in effluent water, and try to minimize destruction of mangroves.

,We learned of common problems affecting nearly all shrimp farmers in the area. Many of these farmers show the desire and capacity to improve their practices, however lack both the proper information and financial resources. Therefore, we developed a few scenarios, where we analyzed costs, risks and benefits, as well as gave recommendations that the farmers, INCOPESCA, and the Costa Rican government could use for the further development and financing of the industry. Our scenarios are very simple and basic but they give a socio-economic view of our recommendations.

Finally, we constructed a manual using all the information gathered from the interviews and archival research. The manual was specifically dedicated to good management practices for Costa Rican farmers, focusing on areas where we believed the farmers could use the most help. The manual was designed using the research previously conducted on document layout and manual writing as a reference. In this manner, we created a manual that was aesthetically pleasing, informative, practical, and easy for the farmers to understand and use. The manual was our main deliverable and the most important part of our project, since it was going directly to the farmers.

We recommended that this manual be thoroughly reviewed, by INCOPESCA employees, biologists, and farmers before it is fully implemented. We recommended that this manual be consistently and regularly updated as developments are made in the shrimp farming industry. Furthermore, we suggested that additional training methods, such as workshops conducted by INCOPESCA technicians, accompany the recommendations made in the manual.

Chapter 1: Introduction

Aquaculture is an extremely important method of food production in contemporary society. Even though aquaculture has existed since the 5^{th} century B.C., it is only during the last century that it has developed into an industry of global significance (http://www.peopleandplanet.net/doc.php?id=429&section=6). In 2003, the total world production of aquaculture accounted for 30% of global fish supplies (FAO, 2005). Currently, Asia is the center of the world's aquaculture industry, and produces 90% of aquaculture products, with China alone accounting for 70% of global aquaculture production. Even though Asian nations dominate much of aquaculture industry at present, Latin American nations such as Ecuador, Brazil, Costa Rica, and Honduras are growing powers in the global markets for aquaculture. While Costa Rica is still only a small producer, even in the Latin American context, it has a rapidly developing aquaculture sector that already contributes substantially to the Costa Rican economy and could be of considerable value in the future. For example, the fishery and aquaculture industry accounted for .32% of the Costa Rican GDP in 2002, compared with 10% of the Chinese GDP (http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/004/Y2876E/y2876e06.htm). As can be seen by these percentages, although China produces an extremely large amount of aquaculture products, it is a relatively small portion of the nation's significantly larger GDP. In Costa Rica, aquaculture production is obviously less than China's production levels, but it is an extremely important industry to the national economy. Furthermore, the importance of aquaculture in Costa Rica is expected to grow, especially since it is becoming a major supplier of fresh aquaculture products to the United States and Europe. However, for Costa Rica to fully profit from the growing demand for aquaculture, the most efficient practices applicable to the nation must be identified and promoted.

Costa Rica has successfully expanded aquaculture in recent years, one particular example being the development of tilapia farming throughout the nation. In 1997 the total tilapia production was 4817 metric tons while in 2001 it went up to 8500 metric tons. (Otárola, 2002). Tilapia farming is now well-established in the country and is the most exported aquaculture product. Therefore, Costa Rica is looking to increase the number of exports and production of shrimp farming, which is not yet a major industry in the nation. Although shrimp is the second most exported aquaculture product in Costa Rica and makes up 14% of total aquaculture production, there is room to expand the industry (Quirós, 2002).

Instituto Costarricense de Pesca y Acuicultura (INCOPESCA) is the government organization in charge of regulating and supporting fishing and aquaculture in Costa Rica. The organization is currently pursuing strategies to increase shrimp farm production levels. In order to achieve this goal, it is necessary for INCOPESCA to provide training and education for shrimp farmers. Additionally, INCOPESCA needs to appropriate resources and funding to help expand the industry.

Costa Rica is a very environmentally concerned country, with 25% of its land consisting of national biological reserves. Consequently, the government and organizations such as INCOPESCA are unwilling to support the development of industrial-level shrimp farms that could harm local farmers, markets, and ecosystems. Additionally, INCOPESCA doesn't wish to promote commercial, intensive farms, because these are very expensive and require substantial resources and funding that are not readily available to the majority of citizens in a developing country. INCOPESCA is also opposed to the development of intensive farming because of the adverse environmental impacts associated with such techniques. Instead, INCOPESCA intends to focus on the development and improvement of small, independently-run farms currently found in Costa Rica. These farms rely mostly on natural resources to raise shrimp and do not depend much on the use of technology. As a result, these smaller farms pose less of a threat to the environment and also provide a valuable source of income for Costa Rican farmers. Nonetheless, these small farms can still cause damage to the surrounding environment or local communities, through release of polluted effluent and destruction of mangrove forests. This project surveyed the current practices and addressed environmental and socio-economic concerns of shrimp farming.

As stated previously, INCOPESCA is currently researching methods to increase Costa Rican production levels in shrimp farming. However, the most appropriate management practices for shrimp farming in Costa Rica have not yet been fully identified. In order to understand current practices on the Costa Rican and international levels, we conducted interviews of experts, INCOPESCA employees, and local shrimp farmers. The farmer interviews provided especially valuable information concerning methods used on Costa Rican farms and common problems encountered by farmers. Once current management practices and problems were identified and analyzed, best management practices (BMPs) used in other Latin American nations were compared and applied to Costa Rican shrimp farming. In this manner, our project identified and evaluated the most efficient methods applicable to Costa Rican shrimp farmers.

Currently, many managers of small Costa Rican shrimp farms don't have the resources or necessary education to drastically increase production on their farms. Thus, it is necessary that the best management practices are communicated to farmers through training programs and farmers receive additional support in the necessary areas in order to increase production. INCOPESCA's involvement in tilapia production and education programs used by various organizations in the United States can be used as models for identifying successful training techniques and problems. Once these successful training techniques were identified, we made recommendations to INCOPESCA concerning education programs for shrimp farmers throughout the nation. Finally, as the main deliverable of this project and another method of training, we composed a manual recommending good management practices (GMPs) for INCOPESCA to distribute to shrimp farmers to help them improve their practices.

This report was prepared by members of Worcester Polytechnic Institute Costa Rica Project Center. The relationship of the Center to the Instituto Costarricense de Pesca y Acuicultura and the relevance of the topic to the Instituto Costarricense de Pesca y Acuicultura are presented in Appendix A.

Chapter 2: Literature Review

Our project involves a great deal of research and understanding of shrimp farming as an industry and its actual practices. To become acquainted with the topic, we researched the following areas:

- Aquaculture in the world and Costa Rica
- Shrimp farming in the world and Costa Rica, including its pros and cons, as well as environmental issues and socio-economic issues.
- General practices, with topics ranging from the types of farms to the equipment used.
- Government involvement which includes not only laws but also certifications or permits for shrimp farming.

2.1 Fisheries and Aquaculture

Aquaculture has its roots dating back to China and Egypt around the 5th century B.C., but it wasn't until the 20th century that declining fish populations became a global issue. As the fishing industry grew and new technologies became available, it was easier to fish larger amounts, which has ultimately caused a decline in many of the world's commercial fish stocks. This decline has encouraged the development of today's aquaculture industry (Hinrichsen, 2004).

Almost every country has some form of aquaculture, but the major producers are found in Asia, the most important one being China. China, India and Japan make up for 80% of aquaculture production in Asia, while Korea, Philippines, Indonesia and Thailand are other major producers on the continent. The types of aquaculture pursued differ by country and culture. For example, trout and salmon are farmed mainly in North America and Northern Europe, and seaweeds in Japan. Although more recently, commodity products such as salmon, freshwater prawns, and marine shrimp have become very important in aquaculture in Latin America and Australia, and are at the top of the list in the world in terms of production value.

(http://www.thecanadianencyclopedia.com/index.cfm?PgNm=TCE&Params=A1SEC816103).

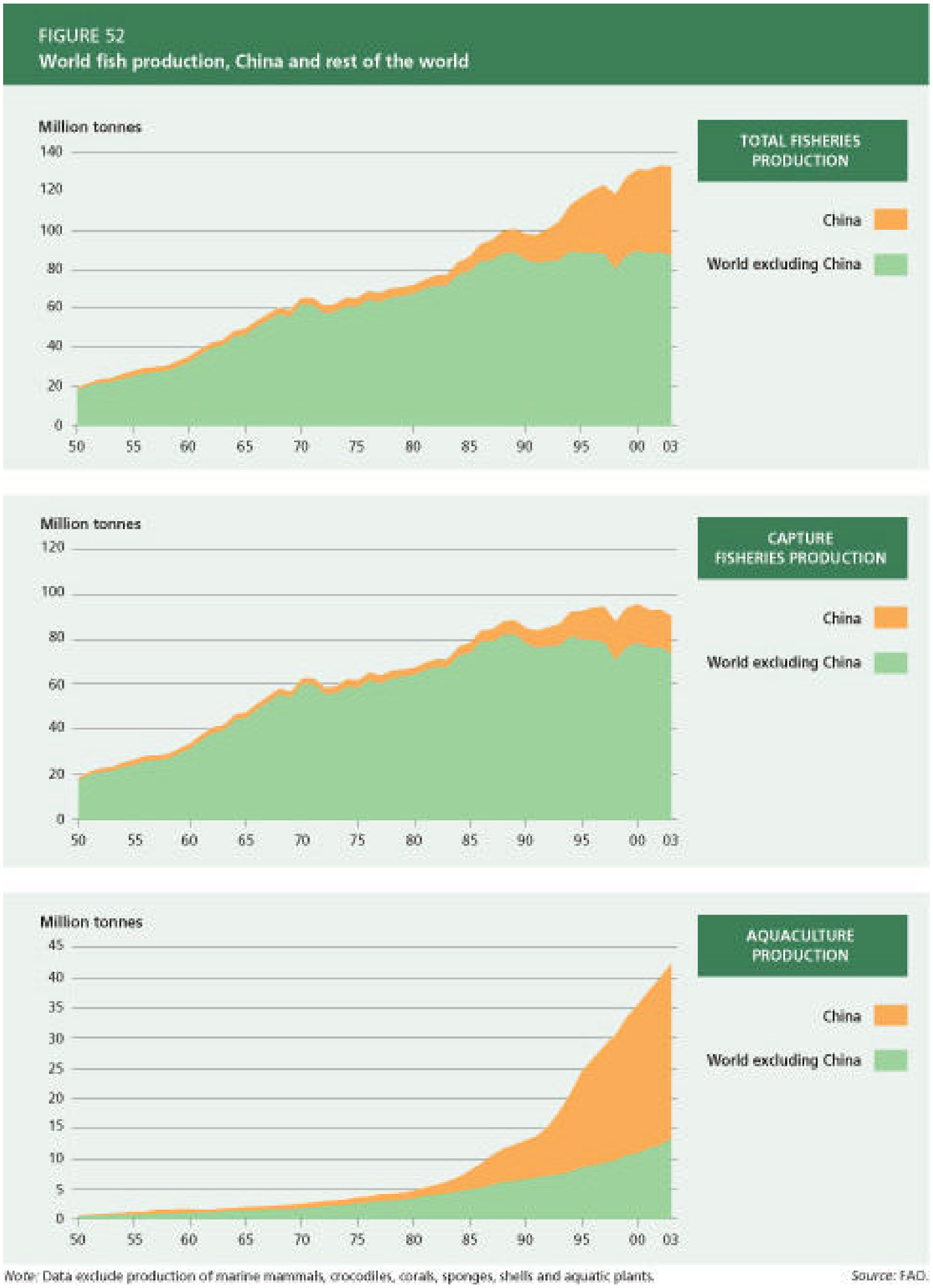


Figure 2-1 World Fish Production (FAO, 2005). Food and Agriculture Organization of the United Nations [FAO], 2005).

Fisheries and fish farms are a very important part of the world economy, providing more than 38 million fishermen and farmers with their livelihood. The total world production in 2003, for both fisheries and aquaculture, was 132.5 million metric tons. China alone produced 16.8 million metric tons. Aquaculture contributed to the global supply of fish with approximately 42 million metric tons, in 2003, which is about 32% of total fish production, which can be observed in **Figure 2-1** (Food and Agriculture Organization of the United Nations [FAO], 2005). **Figure 2-2** shows that production has increased greatly in the last 50 years on the American continent and the rate of growth is very similar to that of Asia even though the total production in Asia is much greater.

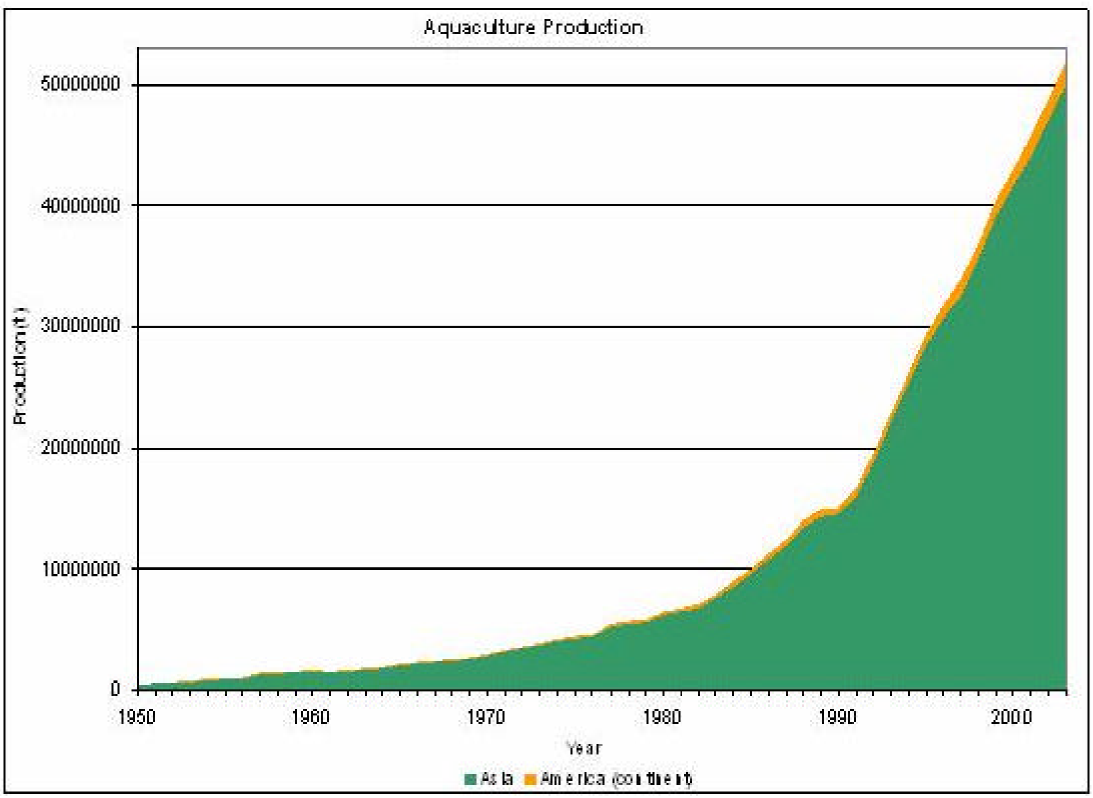


Figure 2-2 Aquaculture Production in Asia and America from 1950 – 2003 (Fisheries Global Information System, 2006)

Costa Rica has a population of only 4.3 million, yet its fisheries produced approximately 45,253 metric tons of fish (value for the year 2001) from both fishing and aquaculture (http://www.fao.org/fi/fcp/en/CRI/profile.htm). The fishery and aquaculture industry made up 0.32% of the Costa Rican GDP in 2002. This may seem as a small number but it is still very significant if compared to countries such as Mexico where aquaculture is further developed it still only makes up .4% of their GDP. These are just a few facts on fish production in the world, but they give a scope on where Costa Rica stands and helps to better understand the impact of Costa Rican aquaculture.

2.2 Shrimp Farming

Aquaculture is the fastest-growing form of food production in the world. Even though other products such as mollusks and carp are produced in greater numbers, shrimp dominates the aquaculture production by value. Also shrimp farming is one of the fastest growing aquaculture products in the world. Between 1982 and 1992 its production increased nine fold while its price remained consistent (Clay, 2004). This is encouraging for new shrimp farmers since prices don't go down even though there is more competition. Unfortunately, with this increase in production, there are growing concerns about the environmental impacts, especially the destruction of mangrove swamps, pollution from antibiotics and pesticides used in intensive shrimp farming, and damage to the wild shrimp species. Since shrimp farms have been constructed using environmentally unsound practices, current methods may have to be re-evaluated.

From 2000 to 2003 the amount of cultivated shrimp in the world rose from about 1,150,000 to 1,800,000 tons. Currently, about 85% of the shrimp production is based in Asia, 10% in South America, and 5% in North America. China leads the world in shrimp farming, but the United States is the largest importer, with almost 500,000 tons of shrimp imported every year. At about $5,000 (U.S.) per ton, America spends about $2.5 billon per year on shrimp. Collectively, the Asian countries are the largest shrimp producers, but they export little and consume most of the shrimp they produce themselves. China only exports about 100,000 tons of shrimp per year, which is only about a fifth of their total production. Shrimp aquaculture accounts for almost half of all internationally traded shrimp, and it is the most valuable traded fish product in the world. In the United States it accounts for almost half of all seafood imports, by value. The United States, the European Union and Japan make up 90% of the final markets for aquaculture shrimp.

Costa Rica is not one of the major aquaculture producers in the world, but is still a major exporter of shrimp and tilapia to the United States. Throughout the last 50 years, its total production in fish products has increased exponentially Costa Rica produced 4582 metric tons of shrimp in 2003, compared to only 272 metric tons from 1990 (**Figure 2-3**) (Fisheries Global Information System (FGIS), 2006). Costa Rica exported 1980 metric tons of shrimp during the first 11 months of the year 2001 (for more detailed, monthly production numbers, see **Table B-2** in **Appendix B**). The United States, Spain and France were the main markets for Costa Rican shrimp. The U.S. imported 46.82% of all the exportable Costa Rican shrimp, while Spain received 43.18% and France 9.75% of exported shrimp (**Figure 2-4**)(Quirós, 2002). (See **Table B-1** in the **Appendix B** for more detail of U.S. shrimp imports). It is important to note that most of the shrimp exported to Europe is farmed; this accounts for more than 50 percent of total Costa Rican shrimp exports.

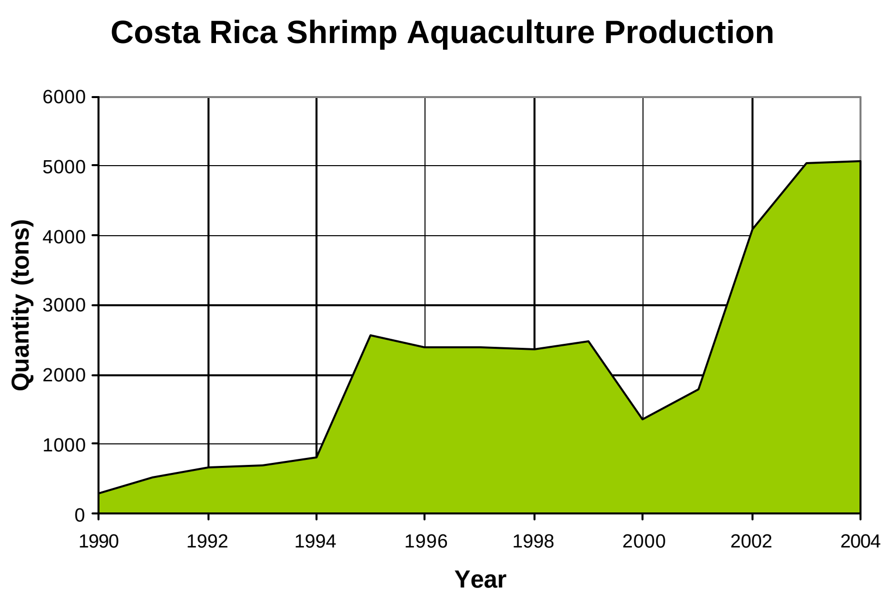


Figure 2-3 Costa Rican Total Shrimp Aquaculture Production 1990 -2004. (FGIS, 2006)

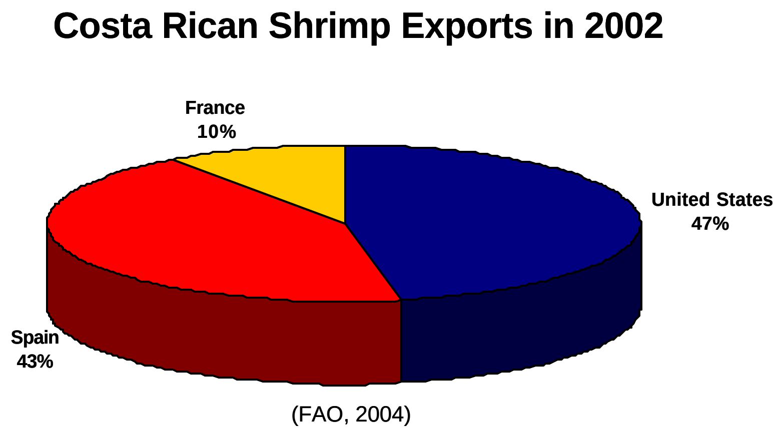


Figure 2-4 Costa Rican Shrimp Exports in 2002 (FAO, 2002).

In North America, the leading producer of cultured shrimp is Mexico with about 46,000 tons per year. Costa Rica's production may not be comparable to that of Mexico, but it is still a very important industry in Costa Rica, which exports 40% of its shrimp farming production. At $5,000 (US) per ton, the Costa Rican income from cultured shrimp is about $10 million (FAO, 2005). Therefore, it's a very important industry to the nation.

2.3 Pros and Cons of Shrimp Farming

The shrimp farming business has benefited many countries and has a great potential in Costa Rica. As with many other industries, aquaculture has its positive and negative sides. For example, the farming of shrimp can augment the wild harvest, which can fluctuate due to wild population and weather, yet it can be devastating to mangrove forests, a preferred location for these farms. Aquaculture has many more aspects that can affect a country's well-being and financial prosperity.

2.3.1 Shrimp Farming Vs. Traditional Shrimp Trawling

The high demand for shrimp is pushing the traditional harvesting to its limit. Some of the shrimp trawling techniques are becoming harmful to the surrounding environment, and with more nets in the seas than ever, these effects are becoming very noticeable (http://www.seaturtle.org/mtn/archives/mtn100/mtn100p22.shtml). Another side effect in the diminishing wild shrimp populations is that shrimp trawlers are starting to find it difficult to harvest all the shrimp needed for world consumption. This is pushing shrimp farming to become a large and successful industry world wide.

One example of the damaging effects of shrimp trawling is the inadvertent capture of sea turtles in the nets and their subsequent death due to drowning. The U.S. stopped the importation of wild shrimp from Costa Rica between July 2003 and January 2004, until the Costa Rican fishermen included TEDs (Turtle Excluder Devices) on their shrimping nets. TEDs are 97% effective in preventing turtle catches. The U.S. recertified Costa Rica in February of 2004, although there is evidence that not all the shrimp boats followed the new regulations (AM Costa Rica, 2004). Even without the TEDs, shrimp farming can help relieve the stress on the sea turtle population by reducing the number of nets in the wild. (http://www.amcostarica.com/020404.htm)

The actual number of shrimp in the wild is unknown, but boats are having more trouble finding large enough schools to keep up with production. Decreases in the shrimp populations can cause the fishable supply to plunge below the increasing demand. Aquaculture can help by producing enough shrimp to subsidize the supply gap. Although farming has some problems like disease and chemical leakage, these can be improved through regulations and new technology. Aquaculture is still new and these solutions haven't been fully implemented yet. If the shrimp farming industry can improve, the wild shrimp population can balance itself out and the growing production of the farms can produce enough to keep the supply with demand (http://www.sustainabilityinstitute.org/pubs/ShrimpRpt_7.2000.pdf).

2.3.2 Environmental Issues

Aquaculture is still a relatively young industry, having only been popular for about 25 years. Because of this infancy, there are many problems which have not been overcome yet. However, studies have shown that the construction of fish and shrimp farms may adversely affect the ecology. Acres of mangrove forests may be removed because these present some of the best locations for shrimp farming. The mangrove forests, however, are important as wild breeding grounds for many species of fish and shrimp and they also serve as barriers to coastal erosion. As a result of the deforestation of mangroves, shrimp no longer have their natural habitat to mature into adults. Additionally, farmers occasionally supply their farms with wild postlarvae captured from mangrove forests. This depletes the wild shrimp population and in the long term, also depletes the supplies for the farms.

Shrimp farming is an intensive activity, and the spread of diseases amongst the shrimp within the farms is a constant threat. These diseases may also spread to wild shrimp. Other problems include: the lowering of local water tables from refilling the large ponds with local underground water, the release of chemicals (including nitrates, phosphates, and antibiotics) and micro-organisms into to the ocean and ground, and sediment from the shrimp ponds being dredged and disposed of improperly. The sediment from the effluents of shrimp farms can be washed out into the ocean where it can destroy coral or placed in piles where it will decay and pollute the soil. (http://www.unrisd.org/UNRISD/website/document.nsf/d2a23ad2d50cb2a280256eb300385855/a90a3147dd72acc480256b67005b6935/$FILE/dp74.pdf)

2.3.3 Socio-Economic Issues

Shrimp farms affect more than just the shrimp industry; they affect the surrounding communities also. Shrimp can earn a great deal of money for a country. In fact, "In monetary terms, shrimp farming is the most profitable enterprise in Asian aquaculture" (http://www.unrisd.org/UNRISD/website/document.nsf/d2a23ad2d50cb2a280256eb300385855/a90a3147dd72acc480256b67005b6935/$FILE/dp74.pdf). This can be advantageous or detrimental to a society.

Because shrimp aquaculture is such a lucrative business, farms are springing up in many communities. Aquaculture requires many resources to be successful. One requirement is large plots of land in locations where the farm has easy access to fresh water, roads, and labor. This land is highly desirable for many people, including fishers and agricultural farmers, and the displacement of these groups can cause tension between the farms and the communities.

Shrimp farming may also damage the natural resources on which communities depend. Some ponds near a local fishing area or canals may draw too much water away from the community. Also, the over fishing for post-larval shrimp is causing wild populations to decrease, putting pressure on shrimp harvesters.

2.4 General Practices

Shrimp farming, as with any other aquaculture industry, has a variety of practices that can be developed. Farms are divided into extensive, semi-intensive, and intensive levels, each of which has been classified according to the actual practices used for the farm. Extensive farms are more traditional and less productive, while intensive farms use the most technology and have the highest production. No matter what the farm production or level of technology used, farmers must address the shrimp species cultivated, feed, equipment, location of the farm, and disease outbreak management.

2.4.1 Types of Shrimp Farms

In the following section, the differences and similarities of the three degrees of shrimp farms: extensive, semi-intensive, and intensive; will be discussed.

2.4.1.1 Extensive Farms

According to Kumar (1999), extensive farms are the most rural, traditional form of aquaculture operations. The stock is usually farmed and harvested from natural bodies of water such as ponds (Kumar, 1999), as shown in **Figure 2-5**. Extensive farms raise fewer than five shrimp for each cubic meter of pond water (Clay, 2004). As Kumar emphasizes, the only extraneous material added in this form of farm is the original stock of shrimp, usually in the postlarvae stage, often acquired directly from their natural source and transplanted into the body of water. The shrimp can also be brought into the pond by tides (Clay, 2004). Similarly, the input and output of water and nutrients occurs by natural processes, such as tidal exchange (Kumar, 1999). As further shown in **Figure 2-5**, examples of extensive farming exist in Vietnam, Indonesia, and Ecuador (Rosenberry, 2004). Individuals or families are usually the ones who set up these farms, with few inputs or technology. They build large ponds usually with a size of up to 100 hectares on costal areas where land is cheap. The ponds are usually built by making simple dams in the natural watercourses. The shrimp is harvested by draining the pond and catching the shrimp at the opening made in the dam. It is also important to note that diseases are rare due to the low density of shrimp in the pond. This type of farming does not create many effluents since density is low, farmers rarely use any chemicals or medicines if ever, and feed is not administered to the shrimp. Production on extensive farms is usually less than 1000 kilograms per hectare per year, and commonly only a few hundred kilograms per hectare (Clay, 2004).

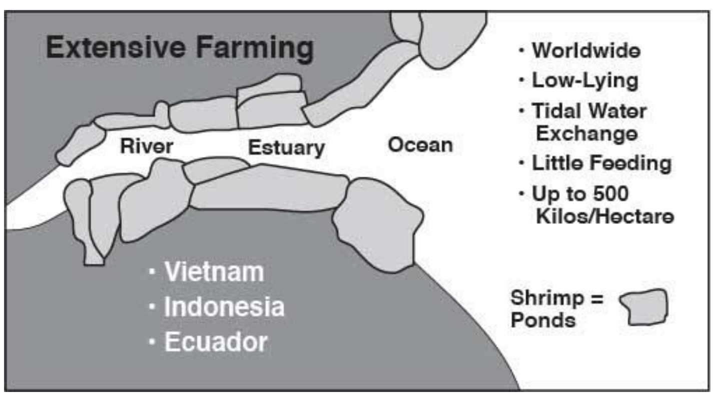


Figure 2-5 Extensive Farming (Rosenberry, 2004).

2.4.1.2 Semi-intensive Farms

Semi-intensive farms (**Figure 2-6)** are often held in or near natural bodies of water (Kumar, 1999).and involve stocking shrimp beyond the level that the natural resources could sustain without additional input (Clay, 2004). However, as Kumar (1999) explains they are employed primarily for the harvesting of shrimp, because ponds are built with regular shapes and depth and use dikes and levees, which make harvesting a lot easier

(Clay, 2004). Additionally, these lakes or ponds have built in eco-systems, and rely on mainly natural processes to clean and circulate water. As Kumar (1999) states, these farms add supplementary fertilizer and food sources that are often naturally obtained and have a low-cost. As a result of this, the density of fish in a given holding tank or body of water can increase, which increases the production levels of the farm as compared to an extensive farm, but still provide a resource for the community on small, rural farms (Kumar, 1999). Most semi-intensive farms stock the shrimp to a density from 2.5 to 20 shrimp per cubic meter (Clay, 2004). Disease is more likely to occur in these farms compared to the extensive farms because of the density. Also, there is less conservation of the environment and effluents rise because of the use of nutrients and chemicals to increase production. Production in semi-intensive farms can range between 1000 to 2000 kilograms per hectare per year (Clay, 2004). Examples of semi-intensive farms exist in Honduras, Mexico, Colombia, Ecuador, and China (Rosenberry, 2004). Semi-intensive farms represent the majority of Costa Rican aquaculture farms, followed by extensive farms, so our project will primarily look at methods corresponding to these levels of farming.

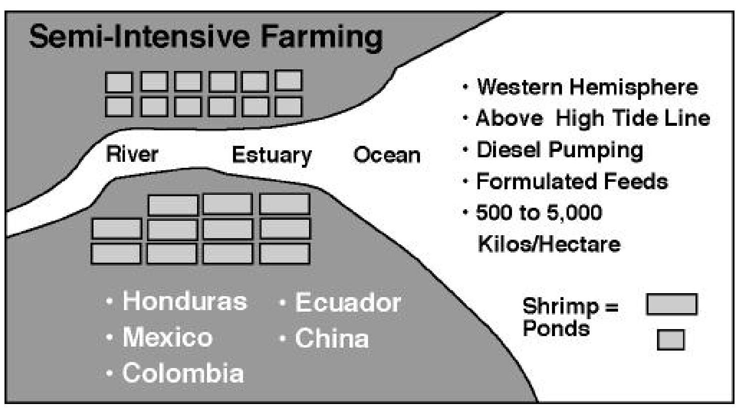


Figure 2-6 Semi-Intensive Farming (Rosenberry, 2004)

2.4.1.3 Intensive Farms

Intensive farms, as explained by Kumar and illustrated in **Figure 2-7**, are the large-scale, industrial farms that require investments in equipment and feed and fertilizer supplements that are not often reasonable for small farms. These farms are stocked with a density over

20 shrimp per cubic meter and can reach up to 150 shrimp per cubic meter (Clay, 2004). Intensive farms are also usually smaller in area (0.01 hectares to 5 hectares), but require many more inputs in terms of capital, labor, and materials. These facilities require artificial holding tanks, aeration systems, commercial feed and fertilizer, and water circulation systems, and thus experienced management (Kumar, 1999). Shrimp in intensive farms must be fed the entire time they are in the ponds, and because there are so many nutrients in the water it has to be aerated to keep the oxygen levels high so the shrimp survive. Production in the most intensive farms can exceed 22,000 kilograms per hectare per crop, and can have an average of 2.4 crops per year (Clay, 2004). It is very important to notice the cost of operating an intensive farm. The cost of pond construction can range between $10,000 dollars to $50,000 or more per hectare (Clay, 2004). As illustrated by Rosenberry (2004), intensive farming is often found in nations such as Thailand, Indonesia, and Taiwan.

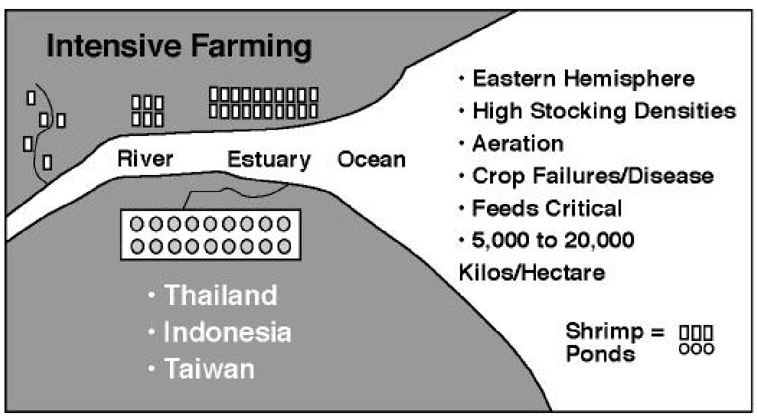


Figure 2-7 Intensive Farming (Rosenberry, 2004)

2.4.2 Shrimp Farming Species

Generally, most shrimp farms raise Penaeid shrimp, shrimp of the genus Penaeus or Litopenaeus. Below, **Figure 2-8** illustrates the general life cycle of a Penaeid shrimp.

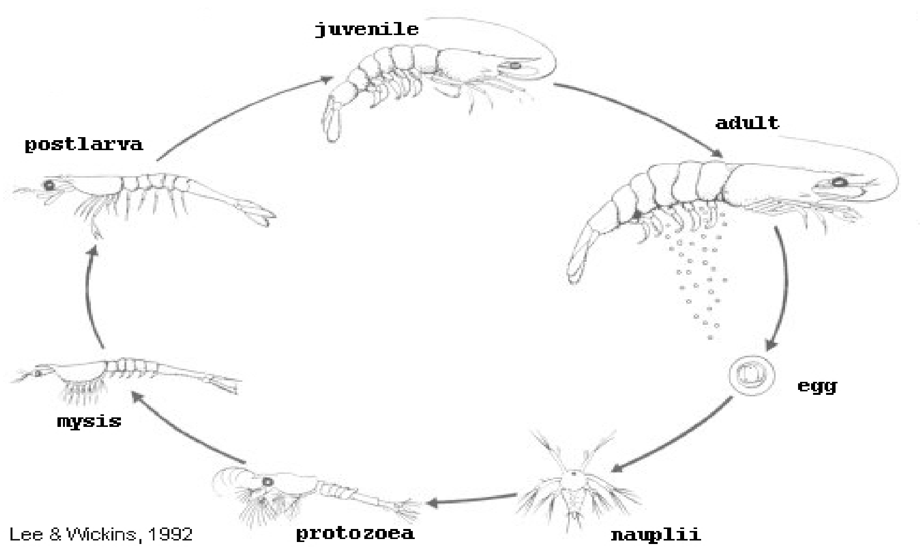


Figure 2-8 Life cycle of a Penaeid shrimp
(http://www.dec.ctu.edu.vn/sardi/cd_shrimp2/bio/lc1.htm).

Many Penaied species, particularly Litopenaeus vannamei, which is the primary species farmed in Costa Rica and other Latin American nations, are very sensitive and cannot be successfully bred in captivity without very specific laboratory conditions (Doré, 1993). As Doré (1993) explains, these shrimp are often harvested from the wild as nauplii or postlarvae and then raised to maturity to be harvested. Also, techniques have been used that consist of capturing the fertile, egg-laden female shrimp from the wild just after a specified mating period, and have them lay the eggs in captivity and then raise the offspring in tanks or ponds (Doré, 1993). However many new advancements are being made, and methods for completely raising the shrimp in captivity are currently being researched so shrimp farms can be more self-sufficient and curb depletion of wild shrimp supplies (Doré, 1993).

The anatomy of the shrimp is simple; the following diagram (**Figure 2-9**) shows main parts and names of the shrimp's anatomy.

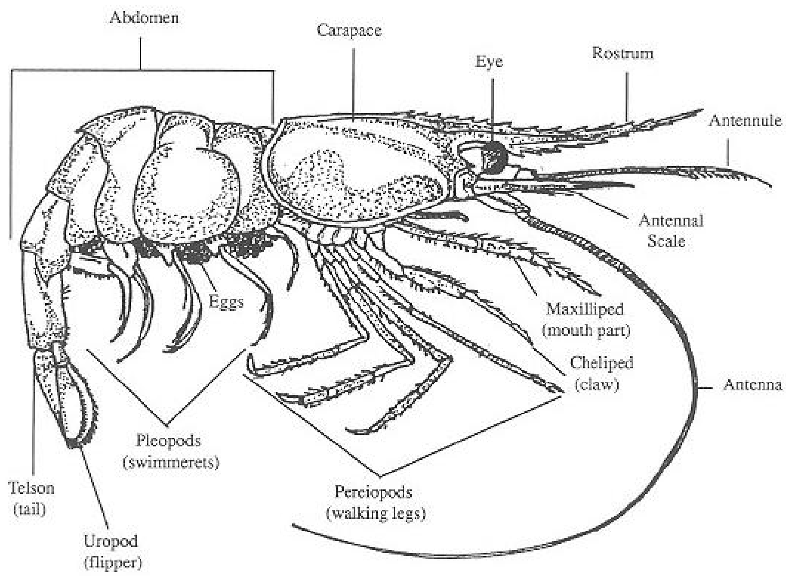


Figure 2-9 Shrimp Anatomy (http://mainegov-images.informe.org/dmr/rm/aquarium/teachers_guide/shrmip.jpg).

In Costa Rica, the primary shrimp species farmed is Litopenaeus vannamei, also referred to as Pacific white shrimp or whiteleg shrimp (see **Figure 2-10**).

Figure 2-10 Litopenaeus vannamei or Pacific white shrimp

L. vannamei is also the primary species of shrimp farmed in other Latin American nations, with Ecuador being the world's main producer of this particular species (Doré, 1993). The shrimp is found in the wild along the Gulf of California and along the Pacific coast of Central and South America and these wild populations are harvested for stocking shrimp farms, as stated previously by Doré (1993). The fact that this species is native to the area is a major advantage because, as said before, postlarvae are easily harvested from the wild, and also the environmental effects of introducing an alien species do not apply (Boyd et al., n.d.). As Doré (1993) further states, this species is so widely farmed because it is a relatively hardy species, able to endure a wide range of pH, salinity, temperature, and oxygen supply. Furthermore, L. vannamei is an omnivorous shrimp species, as opposed to P. monodon farmed in Asia which is carnivorous (Doré, 1993). Because of this, the diet for L. vannamei includes microscopic organisms, such as phytoplankton, algae, diatoms, and a number of others which can be maintained naturally in ponds. This particular species also does not require as high a protein content in its feed as do carnivorous species. Feeds with lower protein content are less expensive and maintaining a level of microorganisms is essentially free of cost for the farmers. Farming an omnivorous species such as L. vannamei is far more cost effective than farming a carnivorous species of shrimp (Doré, 1993). See **Appendix D** for more details concerning shrimp species L. vannamei.

However, L. vannamei are extremely vulnerable to a number of viruses which will be discussed later. As a result of these outbreaks, other Latin American nations, such as Mexico and Panama, have begun to farm Litopenaeus styrilostris, commonly called blue shrimp (see **Figure 2-11**).

Figure 2-11 Litopenaeus styrilostris or blue shrimp (http://bookshop.frdc.com.au/photos/SE01403.jpg)

This species is extremely similar to the Pacific white shrimp, except it is less vulnerable to certain diseases (Martinez and Leung, 2004). Since many of these diseases may also pose a threat to Costa Rican shrimp farms, this species must also be considered for culture. L. styrilostris is also found in the wild along the Pacific coastlines of many Latin American nations, and as a result is often harvested along with the L. vannamei and both are raised in the culture together (Doré, 1993). However, blue shrimp is also omnivorous, but is a more selective eater than the Pacific white shrimp, which, as stated previously, is very adaptable to different feeds (Doré, 1993).

For both species, the postlarvae, obtained from the wild, hatcheries, or both, must be in good health in order for culture to have a desirable survival rate. First, many farmers will have the postlarvae tested for various diseases, such as white spot syndrome virus (WSSV) or Taura syndrome virus (TSV), which often requires samples to be sent to laboratories far away from the farm (Boyd et al., n.d.). This can result in a major lapse in time between when the larvae are put in the production ponds and when laboratory results are received, so if possible, farms should be constructed near any of these laboratories or vice versa (Boyd et al., n.d.). Additionally, the postlarvae must be acclimated to the living conditions of the ponds, including stress levels induced by stocking density, temperature, pH, oxygen levels and salinity (Boyd et al., n.d.). Boyd et al. (n.d.) specify that the optimal stocking density for extensive to semi-intensive farms is between 5 and 15 shrimp per m^2, temperature should be approximately 29°C, the pH should be approximately neutral at 7, and dissolved oxygen should not fall below 2.5 mg/L. As a result, all of these levels must be consistently and carefully monitored in ponds or tanks throughout the entire life cycle, since shrimp survival rates depend upon them.

Shrimp have various degrees of classification on the market, but are usually only classified by size and/or processing and rarely is the species a factor for market sales (Clay, 2004). As a result, farmers in Costa Rica can choose to farm the species that best applies to their situation and not have to worry about putting sales of the product in jeopardy because of the chosen species.

2.4.3 Materials

Shrimp farms require many supplies to successfully harvest the large numbers of shrimp needed to make a profit. There are many choices of equipment and feed which can be used, but some are better for certain locations and practices. The key to a successful farm is to choose the best equipment which can maximize income while decreasing overhead.

2.4.3.1 Food and Fertilizer

As explained by Tacon (1986), there are essentially four different techniques for feeding a shrimp culture on a farm. The first and clearly least expensive method is to merely rely on the natural food sources already present in the environment, used frequently for extensive or small, subsistence farms (Tacon, 1986). Another technique is fertilizing the water. Fertilizers can be derived from manure, plant cuttings, or other agricultural by-products, depending on the farm and on the species being farmed (Tacon, 1986). As Tacon (1986) states, fertilizing is most often used on extensive or semi-intensive farms, where these agricultural supplies are often readily available. Thirdly, feeding supplements are often used on semi-intensive farms, supplying additional nutrients to the water so higher stocking densities can be achieved (Tacon, 1986). Finally, what Tacon (1986) refers to as complete diet feeding, supplying the entire dietary needs of the species in pellet form, occurs on most intensive farms. For our project, it will be very important to analyze which method or combination of methods is the most beneficial and cost effective for the small, semi-intensive or extensive shrimp farms of Costa Rica.

According to Naylor et al. (1998), shrimp feed currently used on most shrimp farms contains about 30% fish meal and 3% fish oil. As they state, this is often contradictory to the belief that aquaculture is less harmful than fishing the wild supplies because these ingredients are often procured from wild fish supplies. Thus, these wild species are being depleted in order to feed shrimp and other carnivorous farmed fish, such as salmon (Naylor et al., 1998). This method of feeding is also very inefficient in addition to being environmentally destructive. As Naylor et al. points out, the input of fish products is two times the volume of output from the shrimp. It is crucial for Costa Rican farmers, particularly subsistence and semi-intensive farmers, and INCOPESCA to evaluate which shrimp species to farm because carnivorous shrimp species, as opposed to herbivorous or omnivorous species, are far more expensive, unproductive, risky, and detrimental to the environment merely due to the feed they require.

As Tacon (1986) demonstrates, there are many commercial feed, dietary supplement, and fertilizer combinations that can be implemented on shrimp farms. He particularly addresses a number of different practical and relatively economical feed plans for three different shrimp species. See **Appendix C** for detailed feed plan examples.

However, since Tacon published these numbers in 1986, there have been many changes in the shrimp market and production costs for feed have greatly increased. Tacon (n.d.) states in a later study that using commercial feed has the potential to become extremely costly. As the fitness and health supplement industries continue to rapidly grow, the demand for fish oil and fish meal that are often used in supplements will greatly increase demand for these products (Tacon, n.d.). As a result, Tacon (n.d.) predicts the stock prices will most likely increase and it will be difficult for smaller farms to purchase these supplies used for feed, which is often the greatest contributor to a farm's operating cost. This further illustrates how important it is that an alternative food source be used on shrimp farms if possible, particularly when considering small farms in Costa Rica that might not have enough money to invest in large amounts of the increasingly expensive commercial feed.

Few detailed studies have been conducted to determine the particular nutritional requirements of crustaceans, such as marine shrimps, but it has been shown that a substantial part of their natural diet consists of phytoplankton, zooplankton and other microscopic organisms that are plentiful in natural bodies of water (Tacon, n.d.). Particularly, as Otoshi et al. (2003) found, L. vannamei prefer various diatoms, microscopic plant or algae-like protozoa, over other commonly used green algae blooms, as a natural food source. The use of these diatoms as a natural food source greatly increases shrimp growth as compared to simply using commercial feed. Additionally, the algae or diatoms are photosynthetic organisms, and through this process release oxygen and thus increase dissolved oxygen in the water so that ponds do not require as much aeration (Boyd et al., n.d.). This poses a major advantage to small farms using ponds as holding tanks, where the supply of these organisms is abundant. When plankton or other microorganisms are present in a considerable amount, it has been shown that not as much commercial feed is required for the shrimp (Tacon, n.d.). Tacon points out that China has utilized this fact by implementing a polyculture technique on many fish farms. As he further explains, a polyculture farm essentially reconstructs an artificial food chain and ecosystem in each holding tank or body of water. Farmers stock the holding tank or pond with plankton, herbivorous fish, cleaner fish, and carnivorous fish in particular proportions so they can harvest the greatest amount of carnivorous fish possible (Tacon, n.d.). This theory could be also be applied for shrimp farming, although it would not need to be quite so extensive an ecosystem. The farmers could stock holding tanks with phytoplankton, zooplankton and other natural food sources of the shrimp to decrease the addition of commercial feed or fertilizer.

As Boyd et al. (n.d.) state, factors such as amount or quality of feed, application of feed, and physical form of feed, can influence its effectiveness. Boyd et al. (n.d.) recommend that farmers carefully monitor the actual amount of food applied at a given time because too little food can obviously decrease the growth rate of the shrimp or result in mortality, but too much food can also cause problems. For example, if more feed is added to a pond than the shrimp can eat, the remainder that is not consumed will settle on the bottom where it will decompose, depleting oxygen levels (Boyd et al., n.d.). Ideally, the amount of feed added to a pond should vary as biomass and growth levels vary, both of which should be regularly measured and monitored (Boyd et al., n.d.). Another way to control how much feed is released in a given time is using food in pellet form that slowly dissolves and can not be consumed at once (Boyd et al., n.d.). Additionally, Boyd et al. (n.d.) emphasize that feed be kept in cool, dry areas where no mold, bacteria, or pests can infect it, which could contaminate the culture when added to the pond and possibly result in mortality. Controlling the application of feed is also vital to pond success. The feed should be applied uniformly over the whole pond, rather than heavily in small areas, and the entire daily amount required should be applied at regular intervals rather than all at once (Boyd et al., n.d.). Finally, Boyd et al. (n.d.) state that feed should not be given if dissolved oxygen rates are less than 2.5 mg/L because feeding is inhibited in stressful conditions, such as when the oxygen levels are too low. An easy solution to many of these problems is the application of food using a feeding tray, which assures that the feed does not settle along the bottom, that feed is applied uniformly over the surface of the pond, and allows farmers to monitor the amount consumed to see if there are any problems with the culture (Boyd et al., n.d.). This is an easy and practical application, especially for shrimp farmers in Costa Rica, and will be discussed in the next section.

2.4.3.2 Equipment

Since farming shrimp can occur in many separate stages, some farms may have more extensive facilities than others. The three different facilities that might be needed would be a hatchery, nursery, and growout ponds. Each one of these stages needs slightly different equipment to be successful and to obtain an optimal survival rate.

Hatcheries can range in size from small operations to large industrial scales. Farmers usually raise the postlarve shrimp in tanks ranging from less than 10 to about 30 tons. Only the larger hatcheries require water exchange because algal blooms and bacteria are used to feed the shrimp. The large tanks use a gas or electric pump to move the water in and out. Controlled lighting is also needed for optimum mating. A day and night cycle should be achieved with about 9 hours of darkness and 15 hours of light, with a 1 hour transition period between both (McVey, 1993). This causes the shrimp to mate during the 1 hour transition period, and allows you to collect the mated females during the dark hours, which can be now scheduled during the day if indoors. Some minor temperature control may also be used. In tropical regions, this may just be ventilation fans and windows in the hatchery.

Some farms will implement a nursery to help the shrimp grow larger and permit more crops since they are often indoor facilities. Nurseries will occasionally use large, long, rectangular tanks called raceways. These tanks can be made from anything that will prevent leakage of the water, like fiberglass, cement, or a lined trench. They can be covered or inside a greenhouse enclosure and are used to hold the postlarvae before moving them to the growout ponds. These tanks typically need water control systems to aerate and filter the tanks.

All farms have some form of growout pond. This is where the shrimp spend most of their lives. These ponds can be natural dirt ponds or tanks. They require aeration systems, like a paddle wheel or forced air system and some pumps to move fresh water in and waste water out. Some new farms also use feeding trays (Bob Rosenberry, 2004), which are simple screens across a PVC frame and are used to raise and lower the food. They help the feeding efficiency of the shrimp, allow farms to reduce wasted food and prevent the feed to be discharged with the waste water, which can cause adverse environmental effects from the overwhelming amount of nutrients.

In addition to conventional farming techniques, many new effluent-free systems are being developed. As Otoshi et al. (2003) state, one particularly innovative system is a recirculating aquaculture system, commonly referred to as RAS. These systems are completely self-contained, requiring no influent or effluent of water, but instead recirculate the water (Otoshi et al., 2003). Often the water is circulated into empty tanks to clean and oxygenate the water using aeration systems, or the tanks themselves have a complex agitation and aeration system (Otoshi et al., 2003). As Otoshi et al. (2003) emphasize, an RAS is less harmful to the environment surrounding shrimp farms than systems with effluent laden with wastes and diseases. However, since higher stocking densities are required, often growth rates are slower than in traditional extensive ponds such as those found throughout Costa Rica (Otoshi et al., 2003). However, this is an alternative that could be considered for the very environmentally-conscious nation of Costa Rica.

2.4.4 Outbreak Management

As expressed by the U.S. EPA (1999), viruses are rapidly sweeping through both wild shrimp populations and shrimp aquaculture. The outbreaks have spread quickly throughout Asia and Latin America, the major producers of farmed shrimp, posing a very real threat to Costa Rican farmers (U.S. EPA, 1999). In a time when the shrimp market is booming and demand is ever increasing, particularly in the United States, which is Costa Rica's main importer (U.S. EPA, 1999), this is a very pertinent issue and solutions should be investigated. As shown in **Table 2-1**, the recent losses caused by shrimp viruses are already significant, and have the potential to increase even more if the outbreaks are not controlled (Lightner, n.d.).

Table 2-1 Shrimp viruses that have caused significant financial losses for shrimp aquaculture (Lightner, n.d.).

Estimated economic losses since the emergence of certain diseases in penaeid shrimp aquaculture.		
Virus	**Year of emergence to 2001**	**Product Loss (dollars)**
WSSV - Asia	1992	$4-6 billion
WSSV-Americas	1999	>$ 1 billion
TSV	1991-92	$1-2 billion
YHV	1991	$ 0.1-0.5 billion
IHHNV*	1981	0.5-1.0 billion
* Includes Gulf of California fishery losses for 1989-1994.		

In the following section, spreading methods, particular viruses that could potentially affect Costa Rican shrimp farmers, and solutions used to combat outbreaks of those viruses will be discussed.

2.4.4.1 Means of Infection

Viruses that have recently afflicted shrimp farms are found to be easily spread by production, aquaculture practices, and environmental factors.

The production process can quickly spread these diseases merely by the transport of shrimp, which often causes outbreaks on farms of importing countries (Lightner, n.d.). The fishing and transport vessels themselves transport the viruses from port to port when they empty contaminated ballast water into the body of water near wild supplies or shrimp farms (U.S. EPA, 1999). Additionally, once the shrimp has been unloaded at the dock, viruses can spread when the shrimp are being cleaned and their heads removed for market retail (Lightner, n.d.). Lightner (n.d.) states that even frozen shrimp can carry dormant forms of viruses.

Certain aquaculture practices have also been found to facilitate the spread of the viruses causing outbreaks on shrimp farms throughout the world. According to the United States EPA (1999), escapement of shrimp culture from ponds or tanks on farms into wild populations, pond flooding, sediment and solid waste disposal, and pond or tank effluent can spread viruses from one farm to another downstream or even to wild populations of shrimp. Also, transport of harvested shrimp to the processing facility can carry disease (U.S. EPA, 1999). Additionally, contaminated feed or shrimp stock added to a pond or tank can infect the existing shrimp culture (U.S. EPA, 1999).

Finally, as Brock (1997) states, certain environmental factors can naturally spread the viruses. For example, when infected shrimp die or are about to die, they float to the surface of the pond or tank, where, if there is no net over the water, seabirds will freely feed on the shrimp (Brock, 1997). Then, when the birds fly from the farm, they can carry the virus to another farm or to wild populations of shrimp (Brock, 1997). Also, insects that may escape when the ponds are flooded or through pond effluent, as mentioned before, could harbor disease. As can be seen, there are many opportunities for wild shrimp to become infected with these viruses, and since many farms obtain stock from nearby oceans or estuaries, these viruses pose a very real threat (Brock, 1997).

2.4.4.2 Baculovirus Panaei (BP)

Baculovirus panaei (BP) is a viral disease affecting both cultured and wild shrimp throughout the Pacific and Caribbean coasts of Latin America, ranging from Mexico to Brazil. This virus and similar strains of it can infect various panaeid shrimp species, including Litopanaeus vannamei which is farmed in Costa Rica (http://www.pac.dfo-mpo.gc.ca/sci/shelldis/pages/bpvdsp_e.htm).

BP is such a dangerous infection because it is more difficult for farmers to visibly diagnose than other diseases. The disease is most easily diagnosed by using a microscope to observe the live tissue of the shrimp. **Figure 2-12** shows the microscopic view of the Baculovirus that affects cultured shrimp.

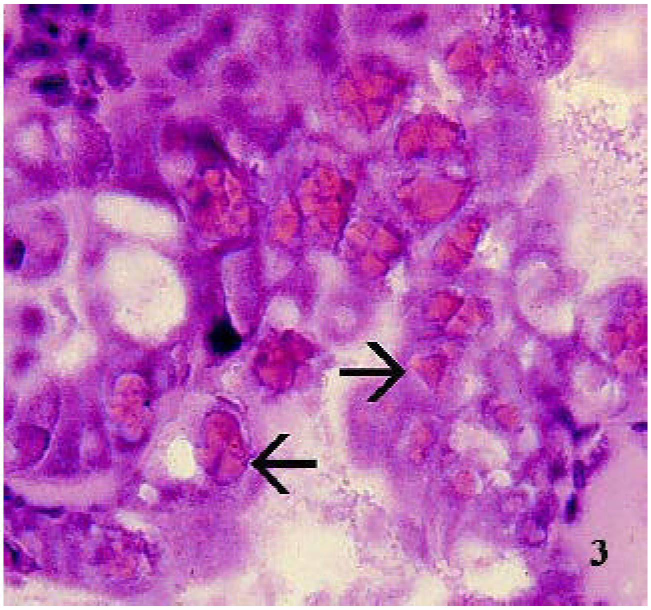


Figure 2-12 An example of Baculovirus panaei as visible under a microscope. The arrows indicate the signs of the virus (González & Prado, 2003)

However, certain behavioral characteristics of the shrimp can be observed that may indicate an infection. For example, growth rates of shrimp may decrease and feeding patterns may alter with a lack of appetite. Additionally, gill and body surface fouling from the virus may be present, and necrosis and loss of hepatopancreatic and mid-gut cells are often observed (http://www.pac.dfo-mpo.gc.ca/sci/shelldis/pages/bpvdsp_e.htm).

BP has an extremely high mortality rate between 70% and 90% depending on the stage of the life cycle of the shrimp. Furthermore, BP has no immediate treatments and only the proper sanitary and disease control procedures can prevent outbreaks. Additionally, it has been shown that BP outbreaks can be onset if the shrimp are stressed by other diseases or poor water quality (http://www.pac.dfo-mpo.gc.ca/sci/shelldis/pages/bpvdsp_e.htm). Therefore, it is very important that farmers maintain the proper water conditions and practice sanitary precautions to prevent any outbreaks of BP.

2.4.4.3 Gregarinas (Nematopsis sp.)

Gregarinas are a form of protozoa that affect the mucus of the middle intestine as well as the hepatopancreas of cultivated shrimp, which causes damage to the intestinal epithelium and affects the absorption of food. The infection occurs when the shrimp consumes mollusks and "poliquetos" of the Polydora sp. genus. These contain parasite spores that can be found at the bottom of the pond. Nepatopsis penaeus is the species of gregarinas that is mostly widely reported around the world (González and Prado, 2003).

The protozoa can be identified by a yellowish color on the top part of the shrimp's stomach, also when the degree of severity of the infection is very high it causes destruction to the epithelium of the stomach and the intestine. Other signs of are the reduction in growth, as well as the increase and proliferation of "epicomensales" and bacterias causing death in the ponds which occur in a few days. The gregarinas can be diagnosed by an analysis of the whole intestine of the live, infected shrimp (González and Prado, 2003). **Figure 2-13** illustrates four examples of gregarinas as viewed under a microscope in the shrimp intestine.

Figure 2-13 Examples of gregarinas found in the shrimp digestive system as viewed under a microscope (González and Prado, 2003).

For the control of the gregarinas it is important to completely wipe out the mollusk that is host to the protozoa. To do this, it is important to better the quality of the water, and between each growout period make sure to plow the earth and use some types of disinfectant such as lime.

2.4.4.4 Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV)

IHHNV was first discovered on Hawaiian shrimp farms in 1981. The virus quickly spread throughout the Western hemisphere in the following years and caused a severe drop in L. stylirostris (blue shrimp) cultures in the Americas. The virus also spread to the shrimp species P. monodon (giant tiger shrimp) commonly farmed in Asian nations.

The shrimp species L. stylirostris (also referred to as P stylirostris or commonly blue shrimp) is most vulnerable to this particular virus and suffers 90% or greater mortality rate when infected (Lightner, n.d.). According to Lighnter (n.d.), the paneid species L. (or P.) vannamei (Pacific white shrimp) can also contract the virus. However, the symptoms are significantly different. In the Pacific white shrimp, IHHNV does not necessarily cause mortality, but because of this is passed on from generation to generation in the genetic material of the shrimp (Lightner, n.d.). This often results in runt deformity syndrome (RDS), which produces shrimp cultures with growth defects and malformed cuticles (Lightner, n.d.). Even though the Pacific white shrimp is not killed, RDS caused by the virus greatly decreases the value of the culture and production of the farm and is cause of much concern for the farmer (Lightner, n.d.) (**Figures 2-14 and 2-15**).

Figure 2-14 IHHNV in juvenile blue shrimp. Note deformed tail fan and sixth abdominal segment (http://www.disease-watch.com/documents/CD/index/html/cv005ihh.htm).

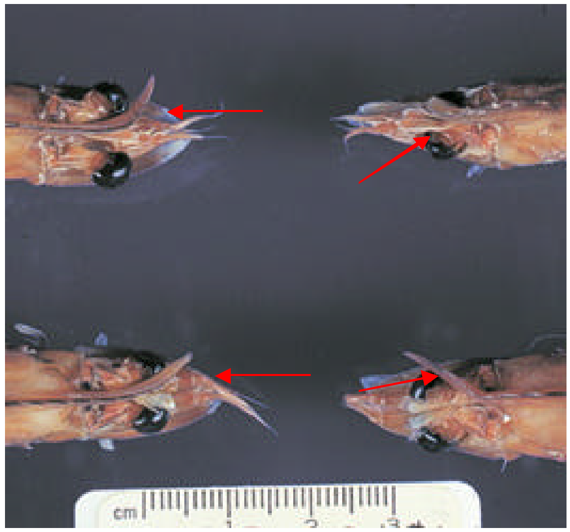


Figure 2-15 IHHNV in juvenile blue shrimp. Note rostrum deformation (http://www.disease-watch.com/documents/CD/index/html/cv005ihh.htm).

To combat the outbreak of this virus, resistant L. stylirostris and L. vannamei cultures (called specific pathogen-free or SPF lines) are often used to stock ponds (Lightner, n.d.) and prevention techniques previously discussed with the TSV are implemented on vulnerable farms.

2.4.4.5 Infectious Myonecrosis Virus (IMNV)

IMNV has only been recently identified in northeastern Brazil in 2003, so little is definitively known (Lightner, n.d.). L. vannamei (Pacific white shrimp) appears to be the most vulnerable to this disease, and exhibits discolorations in the striations of muscle tissue (**Figure 2-16**) as a symptom (Lightner, n.d.). IMNV virus can have a high or moderate mortality rate (Lightner, n.d.). This virus definitely poses a threat to Costa Rican shrimp farming considering Brazil's proximity and the fact that Costa Ricans primarily farm Pacific white shrimp.

Figure 2-16 IMNV in juvenile white shrimp. Note focal to extensive white necrotic areas on the abdomen. The necrotic muscle may also become reddened (http://www.iq2000kit.com/news_017a.htm).

2.4.4.6 Necrotizing Hepatopancreatitis (NHP)

The Necrotizing Hepatopancreatitis (NHP) was first reported in Texas in 1985, and since then has been reported in shrimp ponds in Central and South American countries (Vincent, 2004). Its main presence is found in Brazil, Costa Rica, Ecuador, Panama, Peru, the United States in Texas, and Venezuela (Fisheries & Oceans Canada, 2004). NHP is a severe bacterial disease affecting the penaeid shrimp farming (Vincent, 2004). The species it is known to infect are only the American peneaids: Penaeus vannamei, Penaeus aztecus, Penaeus setiferus, Penaeus stylirostris and Penaeus californiensis (Fisheries & Oceans Canada, 2004).

Gross signs of the bacteria on shrimp include reduced feed intake, empty gut, lethargy, anorexia, discoloration and atrophy of the hepatopancreas (Vincent, 2004), soft shells, flaccid bodies and black gills (Fisheries & Oceans Canada, 2004) (**Figure 2-17**).

Figure 2-17 Shrimp affected by NHP. Note pale hepatopancreas and empty gut (Vincent, 2004).

Some recommended methods to control NHP are the avoidance of high water temperatures (more than 29 – 31°C) and elevated salinities (more than 20 - 40 ppm) for periods of several weeks. These conditions have been shown to precede the development of the bacteria. Elevated mortality rates may approach more than 90% within 30 days of it being detected if left untreated (Fisheries & Oceans Canada, 2004).

Treatment with oxytetracycline - medicated feed is effective only in the early stages of infection, although the FDA does not approve of the use of oxytetracycline in the United States shrimp aquaculture (Vincent, 2004).

2.4.4.7 Taura Syndrome Virus (TSV)

The Taura Syndrome Virus (TSV) was first discovered on a shrimp farm in Ecuador in 1992 (Brock, 1997). It was originally thought by Ecuadorian officials to have been caused by shrimp exposure to certain toxic fungicides used to prevent fungal growth on the feed, but scientists soon discovered that the shrimp culture deaths were caused by a virus (Brock, 1997). TSV spread throughout Central and South America in 1994 and 1995 by means of insects present in the water and birds transporting the virus over short distances (Brock, 1997). The virus continued to the rest of the Western Hemisphere, afflicting farms as far north as South Carolina and Texas by May of 1995 (Brock, 1997). The first Costa Rican outbreak occurred in 1996 (Brock, 1997). However, as of 1997, this virus had not infected any shrimp farms in the Eastern Hemisphere (Brock, 1997).

According to Brock (1997), Penaeus vannamei, Pacific white shrimp, is most susceptible to this virus, and P. schmitti (southern white shrimp) is also extremely vulnerable. However, Brock (1997) states that other species, such as P. setiferus (Northern white shrimp) and P. stylirostris (blue shrimp) are less sensitive, while P. monodon (giant black tiger prawn), P. japonicus (Kuruma prawn), P. duorarum (Northern pink shrimp), and P. aztecus (Northern brown shrimp) are mostly resistant. As a result, many farms in the afflicted areas have phased out the white shrimp species and have decided to farm more resistant species such as the blue shrimp (Brock, 1997). This is yet another important factor in considering which species farmers in Costa Rica should choose to raise and alternative species and treatments should be considered.

For TSV and many other viruses that afflict shrimp cultures on farms, the shrimp are most vulnerable as juveniles (.1-5grams) or during molt stages when the shells are very soft (Brock, 1997). As Brock (1997) explains, infected shrimp can be identified by lesions or discolorations in "buckshot" formation on their cuticle, gills, or appendages. Clinical signs also include pale red body surface and appendages, and tail fan and pleiopods particularly red (**Figures 2-18 & 2-19**) (http://www.disease-watch.com/documents/CD/index/html/cv025tau.htm)**.** TSV has two stages: acute and chronic, both of which are eventually fatal to the shrimp.

Figure 2-18 TSV in white shrimp. Note darkening of body from infection (http://www.disease-watch.com/documents/CD/index/html/cv025tau.htm).

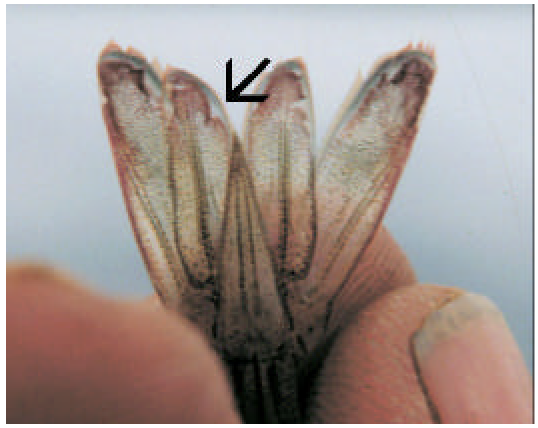


Figure 2-19 TSV in white shrimp. Note distinctive red tail fan. Rough edges around tail fin are also common for TSV.

For this particular virus, a number of options remain for the farmers to help prevent the spread of TSV. Firstly, the ponds or holding tanks may be stocked with adult shrimp harvested from the wild or with juveniles from cultures that have survived TSV and possess genes resistant to the virus (Brock, 1997). As stated before, the farmer also may choose to stock a less vulnerable species of shrimp or even a fish, such as tilapia (Brock, 1997). Also, seabirds have been found to have evidence of the virus in their excrement, implying that the birds feed of the dead or dying shrimp as they float to the surface of the tank or pond and have thus been identified as a possible means of transport for TSV (Lightner, n.d.). Therefore, simply placing nets over the tanks or ponds to prevent seabirds feeding on the shrimp could easily curb the spread of disease (Lightner, n.d.). Finally, careful maintenance of water conditions and water flow into and out of the farm, making sure no contaminants exit into the natural water supply and infect nearby farms and wild populations, is crucial to curb TSV outbreaks (Brock, 1997).

2.4.4.8 Vibriosis

Vibriosis is the common name for any number of bacteria of the Vibrio genus that frequently infect cultivated shrimp. The most common of these bacteria are Vibrio harveyi, Virbrio alginolyticus, Vibrio parahaemolyticus, and Vibrio vulnificus (http://www.info.com.ph/~fishfarm/d_s_v_general.html). There are also a number of other

Vibrio bacteria that can affect shrimp, but they are not as serious and are less likely to result in large mortalities.

Vibriosis is one of the most common diseases found on shrimp farms in Costa Rica, and therefore its successful diagnosis by farmers is very important. Some of the early behavioral signs of Vibriosis include general lethargy of the shrimp, movement towards shallow portions of the ponds, accompanied by a lack of appetite. Visible signs of infection include an empty gut, necrosis of internal organs, and a swollen hindgut. Discoloration of the shrimp is also commonly observed, particularly the darkening or reddening of the body, yellow/red/brown gills, and white patches on the shrimp's abdominal muscle. Finally, certain strains of the bacteria can cause luminescence of the shrimp, which can be more easily visible during the night (http://www.info.com.ph/~fishfarm/d_s_v_general.html). See **Figures 2-20** and **2-21** for examples of Vibriosis in shrimp.

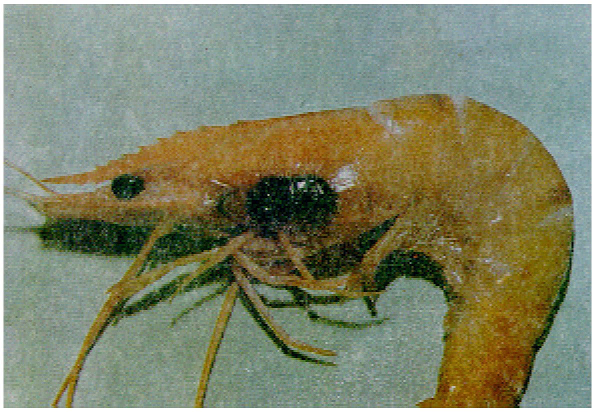


Figure 2-20 Example of Vibriosis in P. Monodon (Black Tiger Shrimp). Note the discoloration and necrosis of organs (http://www.indian-ocean.org/bioinformatics/prawns/GIF/DISEASE/Vibriosi.htm).

Figure 2-21 Another example of Vibriosis in shrimp. Note the luminescence that can be observed at night (http://www.info.com.ph/~fishfarm/d_s_lv_growout.html).

Vibriosis is so widespread amongst Costa Rican shrimp farms and so often a problem because the Vibrio bacteria are always found at certain levels in the pond water and the shrimp themselves (http://www.info.com.ph/~fishfarm/d_s_v_general.html). Therefore if the shrimp become stressed by another disease, water conditions out of the optimal range, lack of feed, or any other circumstances, they are very vulnerable to infection by the Vibrio bacteria.

Therefore, it is very important that farmers maintain high water quality and monitor all other behaviors of the shrimp in order to prevent the disease. Additionally, medicated feed can be applied to the ponds to help fight off infection.

2.4.4.9 White Spot Syndrome Virus (WSSV)

WSSV (or WSV) first appeared in eastern Asia between 1992 and 1993 (Lightner, n.d.). The virus quickly spread, primarily by infected feed and stocking cultures, to the remainder of Southeast Asia, China, Japan, and India, where the shrimp aquaculture industries took a major plunge in production (Lightner, n.d.). WSSV has also been identified in the United States, Spain and other nations in southeastern Europe, the Middle East, and Australia in the mid-to-late nineties (Lightner, n.d.). According to Lightner (n.d.), WSSV finally appeared in Central and South America in 1999, striking Ecuador particularly hard.

Clinical signs of disease include: loose shell, white calcium deposits embedded in shell, causing white spots 0.5 to 2.00 mm in diameter, darkened (red or pink) body surface and appendages, heavy surface and gill fouling by external parasites, white midgut line through abdomen of severely affected larvae and postlarvae. (**Figure 2-22**) (http://www.disease-watch.com/documents/CD/index/html/cv005ihh.htm)

Figure 2-22 White spots on shell are signs of WSSV (http://www.usm.edu/gcrl/research/shrimp_disease.php)

WSSV is also very dangerous because it has been found to affect nearly all paneid shrimp species, not singling out one above the other (Lightner, n.d.)

Treatment and prevention techniques are similar to techniques describes for TSV, and as a result, WSSV has successfully been eradicated in certain areas of Spain and the southeastern United States (Lightner, n.d.).

2.4.4.10 Yellow Head Virus (YHV)

YHV was first identified in Thai shrimp farms in 1991 and has been found in shrimp cultures throughout Asia (Lightner, n.d.). According to Lightner (n.d.), as of 2003, no definitive cases of YHV have been identified in the Americas, but there have been reports of symptoms characteristic of the virus.

YHV has been shown to primarily affect P. monodon (giant tiger shrimp), which is the main species farmed in Asia (Lightner, n.d.). As Lightner (n.d.) identifies, the symptoms in P. monodon are a yellow head on the shrimp in addition to a general bleaching of the cuticle and body. (**Figure 2-23**) However, in other paneid species farmed in the

Americas, particularly blue and Pacific white shrimp, the symptoms are not as obvious as in tiger shrimp, but the virus can still result in mortality and infection (Lightner, n.d.).

Figure 2-23 YHV. Note yellow heads of infected shrimp on left. On right side normal shrimp (http://www.disease-watch.com/documents/CD/index/html/cv010yhd.htm#)

Although this virus is not definitively infecting shrimp populations in the Americas, findings have shown that it is potential issue that must be addressed.

2.4.4.11 Treatment Options

There are the obvious treatment options for other diseases, particularly treating tanks and ponds with antibiotics or other medications. However, as Doré (1993) explains, many countries, including the United States, do not allow any traces of antibiotics in imported shrimp. In order to rid the shrimp of antibiotics that might be added to the culture, farmers must stop application of medications a considerable time before the shrimp are harvested (Doré, 1993). This makes the shrimp much more vulnerable to any bacterial diseases that the antibiotics were treating, and the farmer risks losing a large portion of his harvest. Thus, new ways to prevent disease that don't necessarily require treatment with antibiotics must be studied. Additionally, the viruses mentioned above are resistant to most, if not all, medicinal treatments, so innovative, preventive measures must be taken to prevent outbreaks.

Common management practices, as stated previously, often facilitate the spread of these viruses, but simple techniques can prevent transmission of disease. For example, if nets are constructed over tanks or ponds, seabirds cannot feed on the dead or dying shrimp affected during an outbreak, and the spread of viruses can be curbed. Also, release of contaminated effluent into the environment where it can infect wild shrimp populations or other shrimp farms downstream that use the water as influent. The high rate at which wild shrimp populations are becoming infected with these diseases give much cause for farmers to stop harvesting wild postlarvae to farm and instead breed the shrimp in captivity. However, this is often a complex process involving artificial insemination, and is particularly difficult for L. vannamei, the species most commonly farmed in Costa Rica (Otoshi et al., 2003).

Nonetheless, new techniques such as raising only specific pathogen free (SPF) or specific pathogen resistant (SPR) cultures and farming shrimp in recirculating aquaculture systems (RAS) have shown to greatly prevent viral infections (Otoshi et al., 2003). As Otoshi et al. (2003) explain, SPR and SPF technology involves stocking only shrimp resistant to these viruses or raising shrimp in sterile, or biosecure environments where they could not come in contact with any viruses or other diseases. These biosecure processes often employ RAS to prevent infection and outbreaks (Otoshi et al., 2003). RAS completely recirculate all water and nutrients through a system of tanks used to grow the shrimp, eliminating contamination through influents or effluents (Otoshi et al., 2003). Furthermore, these systems commonly have a plastic covering over the tops of tanks to prevent infection that also doubles as a greenhouse, maintaining a desirable temperature above 29°C for the entire day (Otoshi et al., 2003). Additionally, Otoshi et al. state that these systems are better for the surrounding environment, as they don’t harm wild populations and don’t release any wastes into local bodies of water. However, their studies did find that growth rates were decreased in RAS as opposed to natural pond systems, possibly because there are not as many natural food sources such as diatoms found in the artificial systems (Otoshi et al., 2003).

2.4.5 Best Locations

Shrimp can be very sensitive to the climate and quality of the water they are raised in. Typically, they prefer warm and salty areas near the tropics. This is what attracts most farmers to build costal or estuarial farms near the equator.

Having the warmer temperatures allows for longer growing seasons, which allows for more harvests. According to Bob Rosenberry (2004), many farmers can produce 1 crop a year in the northern areas, further south, 2 crops can be cultivated, and close to the equator, even 3 can be produced. The shrimp thrive in a stable environment, which the tropical regions can provide.

Having the ponds near the sea allows for good water exchange and waste removal. Some farms have their growout phases (the growth from postlarval to full adulthood) in netted areas of the sea or estuary. This allows for natural aeration and removal of unwanted wastes. Netting off the shrimp also has many bad sides, including catching viral strains from other wild shrimp. Because of this, many farmers use ponds or tanks nearby. The preferred locations for the extensive, semi-intensive, and intensive were shown in **Figures 2-5, 2-6 and 2-7**. Most Costa Rican farms fall under the semi-intensive category of construction, meaning they have regularly shaped ponds near the estuary from which water is pumped in, but the heights of the ponds do not depend on the tides.

2.4.6 Training Programs

As in any trade or job, some kind of training is necessary, whether it is provided by the government as training programs or in private universities. Aquaculture, and more specifically shrimp farming, is not different in this case. In the United States, universities such as the University of Arizona or the University of Washington have specific curriculums dedicated to aquaculture, but in developing countries such as Costa Rica these programs are not as readily available and affordable to the average farmer. This is why INCOPESCA's mission has been to better train existing farmers as well as train new farmers. In 2001, INCOPESCA gave 5 training courses on the basics of aquaculture to

103 technicians. It also gave 7 courses in different areas of the country from which a total of 396 people, including farmers, fisherman and technicians benefited (http://www.mideplan.go.cr/odt/Plan%20Nacional/Desarrollo%20Regional/Agropecuario/recursos_humanos.htm).

INCOPESCA bases its programs on technology transfer that involves technical assistance, talks, and courses for the farmers. They also try to organize and coordinate events of scientific and technical character related to the specific activity (http://www.red-arpe.cl/document/Otarola-Costa_Rica.pdf). INCOPESCA's extension agents are responsible for going out to the farms and talking to the farmers. They provide guidance in practices and ask the farmers what help they need so that INCOPESCA can work with them and try to provide what they need. In 2002, INCOPESCA had 10 extension agents, but had 719 aquaculture farms to support. Of these, 76 of them were shrimp farms. Having 10 agents for 719 farms really stretches the amount of help the agents can provide. There have been past programs that have been suggested to INCOPESCA in which it was recommended to use leader farmers. These are farmers who are more experienced, and have helped INCOPESCA by providing guidance and recommendations to new farmers or less experienced ones. By doing this, extension agents can focus on the leader farmers and provide them with more accurate information and also teach them techniques on training farmers. It is also important to offer incentives to the leader farmers to want to participate in these types of programs. Types of incentives could include tax breaks or discounts on feed. (Graham, Johnson IV, Lee, 2002)

2.5 Government Involvement

Aquaculture and particularly shrimp farming are quickly growing industries in the global economy. As a result, an international trend of government involvement has been affecting aquaculture enterprises worldwide. Governments are increasing the amount and scope of laws and regulations, requiring certification and registration of farms, and offering an increasing number of assistance programs to regulate and expand the industry.

2.5.1 Laws and Regulations

Throughout the world, aquaculture is a growing industry and many countries are developing laws to regulate its operation within borders. These laws mainly address land and water ownership issues, disease control, product quality, genetically modified organisms, registration, environmental regulations, and sustainable practices (Van Houtte, 2000).

Many nations have laws that regulate what land or water may be used for aquacultural purposes. As Van Houtte (2000) states, where a site may be established depends greatly on the location of the land or water and whether it is public or private property. For example, in Costa Rica, there are most likely many more regulations concerning the construction of shrimp farms in areas containing or surrounding mangrove forests, which are easily disrupted ecosystems. Similarly, regulations may be very different for pond construction along an estuary or the coast as compared to construction of inland shrimp farms. Also, as has been previously stated, nearly 25% of Costa Rican land is protected. However, in certain locations industry is still allowed, so laws applicable to protected areas would most likely be more restrictive than those for land that is not protected by the government. These laws must be thoroughly investigated so INCOPESCA is able to provide Costa Rican shrimp farmers with information concerning the best locations to construct their farms.

Both countries that are importers and countries that are producers of aquaculture products are very stringent with regulations concerning disease control and product quality, which often are very closely related. Particularly concerning the shrimp farming industry, there are a number of viruses that are easily spread by simple transport of products, which was discussed in section 4.4.4. Thus, many nations and production facilities carefully inspect incoming and outgoing shrimp for any of these viruses, because even contaminated frozen shrimp could cause an outbreak on shrimp farms in an importing country. For Costa Rica in particular, it is important that farmers and processing factories understand the regulations for shrimp imported into the United States, which is the largest importer of Costa Rican shrimp and also has shrimp aquaculture that could be damaged by a viral outbreak.

Certain shrimp farms stock specific pathogen free (SPF) or specific pathogen resistant (SPR) shrimp postlarvae, which are genetically modified to be more resistant to certain viral infections, as discussed earlier. However, some nations, particularly European nations, have regulations concerning selling these genetically altered organisms. Thus, depending on where Costa Rica's major markets are, laws concerning genetically modified organisms should be considered when purchasing postlarvae.

Most nations require registration of aquaculture facilities with different government organizations. By doing this, these nations assure that government officials have permission to enter and inspect the grounds of a particular farm to see if its operation is up to specifications (Van Houtte, 2000). Additionally, if a farm is required to register with a government organization, then that farm is obligated to supply production information that can be used to identify any problem areas or particularly successful farms that others can be modeled after (Van Houtte, 2000). In Costa Rica, it is INCOPESA's role to register farmers, including shrimp farmers, and they possess data concerning farm locations, size, and other specifications which we will utilize in our interview selection process.

As stated by Van Houtte (2000), a growing trend in aquaculture law is establishing environmental regulations and sustainable development. Environmental regulations for shrimp farming could concern effluent waste levels, construction near mangroves, and wild population depletion among many other issues. These environmental and sustainable development laws are perhaps the most applicable to this project because they concern the best management practices that a farm should be following. Ideally these practices should be both environmentally safe and economically efficient, but, as Van Houtte (2000) emphasizes, there is often a trade off. It is important, particularly to a very environmentally conscious nation like Costa Rica that a farm does not harm its surroundings, but it is also important that the farmers receive an income that can cover their expenses. Thus, our research into the most appropriate management practices that both benefit the farmer, but are not detrimental to the environment or local communities, is very relevant to problems encountering aquaculture in Costa Rica and the rest of the world.

2.5.2 Certification

Many countries and seafood corporations world-wide are beginning to require that shrimp farms be certified before they will purchase any product from them. One of the primary certification agencies is the Aquaculture Certification Council (ACC), a portion of the Global Aquaculture Alliance (http://www.aquaculturecertification.org/). This organization has employees that act as certifiers who travel to shrimp farms throughout different nations. These certifiers charge a certain amount, depending on the size of the farm, and inspect the practices and conditions on each farm. They will often look into farm production and worker records, inspect pond pH, salinity, dissolved oxygen among other conditions, and observe procedures. A farm has to meet each of these standards in order to be certified, and the farm must pay and be recertified every two years.

As stated by B. Crawford (personal communication, April 27, 2006), a professor at Rhode Island University's Coastal Resources Center who has much field and research experience concerning shrimp aquaculture of extensive and semi-intensive farms in Latin America, specifically Nicaragua, many of the smaller farms have difficulty with the certification process. B. Crawford (personal communication, April 27, 2006) continued that oftentimes these smaller farms do not meet the specifications set by the certification agency, or don't follow the best management practices the agency supports and cannot receive certification. Also, he stated that many small farms cannot afford the fees required to pay the certifier to inspect the grounds. Thus, many small farms, like the ones that will be our main focus in Costa Rica, cannot become certified on their own.

However, the Aquaculture Certification Council offers another opportunity for small farms to become certified. As stated on their website (http://www.aquaculturecertification.org/), if all the farms in a certain area join in a co-op like organization, then the whole group of farms in that area can become certified together. These farms can split the costs and the organization as a whole must meet the standards as opposed to one farm, which is much more attainable for smaller extensive or semi-intensive farms. Since this situation could be applicable to many of the shrimp farms in Costa Rica, it is important that farmers are offered the option of joining a co-op to ease the process so they can sell their product to customers who require certification.

2.5.3 Government Assistance Programs

As aquaculture is becoming an increasingly lucrative but at the same time expensive industry, the governments of many countries are providing assistance to aquaculture farmers.

Internationally, one of the main organizations assisting aquaculturists worldwide is the Food and Agriculture Organization (FAO) of the United Nations. This organization conducts a multitude of conferences, lectures, and workshops throughout the world on topics including aquaculture (http://www.fao.org/). Additionally, FAO collects and provides production statistics for aquaculture products throughout the world.

The United States has many programs that offer financial and practical assistance programs to aquaculturists nationally and internationally. Within borders, a major government agency that has been helping shrimp farmers recently is the United States Department of Agriculture (USDA). Recently, shrimp farms in the Mississippi River region that were affected by Hurricane Katrina have received significant amounts of financial assistance from the USDA to re-establish their shrimp farms (http://www.usda.gov/wps/portal/usdahome). Additionally, the USDA conducts and funds research on aquaculture issues, including shrimp farms, and distributes this information through workshops, lectures, pamphlets, and many other ways to farmers throughout the country. The National Oceanic and Atmospheric Association (NOAA), particularly its Fisheries sector, is another American organization that provides assistance to aquaculturists through funding research such as profiles of farmed species and studies concerning best practices (http://www.noaa.gov/fisheries.html). The United States Agency for International Development (USAID) similarly funds research and programs within borders, but also funds training and research programs internationally (http://www.usaid.gov/). Concerning aquaculture, USAID focuses on "integrated coastal management," combining concern with the environment with shrimp mariculture practices (B. Crawford, personal communication, April 27, 2006). Finally, many universities throughout the United States including the University of Hawaii, University of Rhode Island, Auburn University, and University of New England, have training and research programs aimed at domestic and global aquaculture.

In Costa Rica, the primary government organization that will assist shrimp farmers and other aquaculturists is INCOPESCA. See **Appendix A** for a detailed description. INCOPESCA itself should look at these other organizations to see what problems they have encountered and what successful procedures could be applied to Costa Rica.

2.6 Manual Writing and Document Design

The main deliverable of our project, as stated before, was be a manual of best management practices for Costa Rican shrimp farmers. Thus, it was very important that we research the best methods of writing and composing a manual before distributing it to the farmers.

We first had to determine what kind of writing would be appropriate for the manual. According to Flanders (1997) in the proceeding from a Society for Technical

Communication (STF) conference, few people devote the time and attention to completely read though manuals. Therefore, it is crucial that the document be well-organized and easy to understand. Flanders (1997) suggests that the manual be organized with headings that clearly convey the topics about to be discussed and are organized in a manner moving from general to specific. If the manual is organized in this manner, the farmers can quickly and easily find the topic they wish to find more information on or are experiencing problems with.

It is also important that the writing in the manual itself is concise and easy to understand. Long sentences should be avoided because they can become cumbersome and the reader can lose attention (Flanders, 1997). Instead, Flanders (1997) recommends that bulleted lists be used when possible to decrease the amount of text. Additionally, as the American Institute of Chemical Engineers (AIChE) (1996) emphasizes, the manual should be written in common language. Technical jargon that the farmers might not be familiar with should be avoided (Flanders, 1997).

Also, the amount of information should be limited only to what is actually needed (Flanders, 1997). Such information should include safety procedures, practices required for national or international laws or regulations, equipment operation, conditions to be measured and what the optimal levels are, critical levels that conditions should not exceed or fall below, and how to correct them if there is a problem (AIChE, 1996).

According to AIChE (1996), the benefits of a well-written and organized procedural manual include more unified techniques, facilitated sharing of ideas or efficient methods, improved product quality control, movement towards best management practices, and emphasis on practices that are less harmful to the environment. Additionally, a well-written, well-organized, and easy to understand manual can serve as a preliminary training device that INCOPESCA can supplement with other educational programs for the shrimp farmers (AIChE, 1996). Clearly, all of these points are critical to the success of our manual and the shrimp farming industry in Costa Rica, so it was very important that we adhered to the manual writing guidelines as stated above.

The document design and layout of the manual is also very important in order for it to be an effective supplement for Costa Rican shrimp farmers. Flanders (1997) highly advocates the use of visuals as an integral part of the document, not just added in as afterthoughts. Thus, we complemented the text with diagrams, tables, graphs, and pictures to help the farmers better understand certain practices and identify certain diseases that often afflict the shrimp. Additionally, the text layout is important, since large blocks and long lines of text can be visually overwhelming for the reader (Flanders, 1997). It is important to include white space on the page, in addition to visuals because a "grey page," or a page full of closely packed text, is very overwhelming to the reader, as shown in **Figure 2-24** and **Figure 2-25**.

1. VERIFY lubrication system OPERATING.
2. OPEN doors to lubrication system solid state controller.
3. CONNECT battery:
   a. LOOSEN screws on lubrication system electrical enclosure.
   b. OPEN door to electrical enclosure.
   c. PLUG battery wire leads into mother board socket.
   d. CLOSE door to unit electrical control box.
   e. TIGHTEN screws on door to unit electrical control box.
4. VERIFY all electrical connections to lubrication system are securely fastened.
5. VERIFY electrical junction box covers are CLOSED.
6. TURN ON lubrication system power switch on solid state controller.
7. While adjusting air pressure using the air pressure regulator, PRESS and HOLD MIST PRESSURE button on solid state controller keypad.
8. When header pressure is 15 inches H_2O, RELEASE PRESSURE button.

Figure 2-24 "Grey page" with text running from margin to margin and no space between lines (AIChE, 1996)

1. VERIFY lubrication system OPERATING
2. OPEN doors to lubrication system solid state controller.
3. CONNECT battery:
   a. LOOSEN screws on door to lubrication system enclosure.
   b. OPEN door to electrical enclosure.
   c. PLUG battery wire leads into mother board socket.
   d. CLOSE door to unit electrical control box.
   e. TIGHTEN screws on door to unit electrical control box.
4. VERIFY all electrical connections to lubrication system are securely fastened.
5. VERIFY electrical junction box covers are CLOSED.
6. TURN ON lubrication system power switch on solid state controller.
7. While adjusting air pressure using the air pressure regulator, PRESS and HOLD MIST PRESSURE button on solid state controller keypad.
8. When header pressure is 15 inches H_2O, RELEASE PRESSURE button.

Figure 2-25 Open page with shorter lines of text and spaces between lines (AIChE, 1996)

Figure 2-24 illustrates a “grey page” with little to no white space, lines of text extending from margin to margin, and no spacing between the lines of text. However, **Figure 2-25** illustrates an “open page” with shorter lines of text that are easier to read and space between lines. Clearly, **Figure 2-24** is more difficult to read, and users are less likely to take the time to read through it and comprehend all of it, whereas **Figure 2-25** is should serve as a model for text layout in a document, specifically a manual where the details are often very important. Furthermore, text should be arranged into columns, which make organization of the information easy, are simple to read, and look professional (AIChE, 1996). **Figure 2-26** illustrates the T-format method of page layout in which the page is organized into two corresponding columns, one easy to follow and read method of column use.

OPERATION	ACTION
Preparation	1. VERIFY valve V-111 is CLOSED.
	2. OBSERVE ambient room temperature (gauge 3-3).
Charging	3. OPEN discharge V123.
	4. OPEN drum spigot.

Figure 2-26 T-format method of column use in page layout (AIChE, 1996).

Finally, although it might seem quite obvious to some, text and color choice is also crucial, because if the text is difficult to read or the colors incompatible or very bright, users will be distracted and might not read the entirety of the manual. As recommended, we broke up text into smaller blocks, paragraphs, and columns in the manual, used bulleted lists and visuals, and carefully chose text font and color to make the manual as visually pleasing as possible.

As can be seen, just compiling the information is not an acceptable substitute for constructing a manual. Much thought must be put into the audience, the goal of the manual, what information it needs to contain and what information it doesn't, and the document design in order for the manual to be an effective tool for INCOPESCA and the Costa Rican shrimp farmers.

Chapter 3: Methodology

The primary goal of our project was to work with the Instituto Costarricense de Pesca y Acuicultura (INCOPESCA) to improve and unify management practices used on Costa Rican shrimp farms. In doing so, we also aimed to reduce the negative environmental impact of Costa Rican shrimp farming. These improved practices will both increase the efficiency of the farms and decrease detrimental effects on the surrounding environments. Therefore, the long-term goal of this project was to increase production and export levels of shrimp farming in Costa Rica, benefiting both shrimp farmers and the national and local economies.

3.1 Objectives

To achieve the primary goals noted above, the project accomplished the following objectives:

- Identified and evaluated the best management practices for extensive and semi-intensive shrimp farming from around the world, focusing on Latin America. We addressed a variety of issues concerning farm management, including:
    - Pertinent laws and regulations;
    - Pond development and maintenance issues;
    - Equipment costs and requirements;
    - Worker requirements, training, and costs; and,
    - Disease, parasite, and environmental controls.
- Identified and evaluated current practices in shrimp farming in Costa Rica. We evaluated which management practices would work best for Costa Rican shrimp farms by interviewing farmers to see which methods best apply to their conditions.
- Compared and contrasted current practices in Costa Rica with best management practices recommended in Latin America.
- Identified effective training methods used in Costa Rica by INCOPESCA. Additionally, training methods used in the United States by organizations such as

the United States Department of Agriculture (USDA), Food and Drug Association (FDA), National Oceanic and Atmospheric Association (NOAA), and certain universities were analyzed.

- Evaluated the socio-economic and environmental impacts of shrimp farms on surrounding communities in Costa Rica.
- Created and designed a manual recommending best management practices for shrimp farms in Costa Rica to better inform farm owners and producers.

3.2 Archival Research

Archival research, research conducted using published and scholarly viable sources to compile information on a topic or number of topics, was an integral part of this project. Archival research is generally the most accurate and reputable form of information retrieval for facts because it is conducted using scholarly journals as a main source, which are reviewed by other scholars of the same field for validity before they are published. We also relied heavily on archival research because much of the knowledge is very technical, and some of the farmers may not necessarily need information in so great a detail as it is often presented in published studies. Additionally, many of the Costa Rican shrimp farmers may not have access to research libraries or computers where they could find the information themselves, so it was very important that we conduct this preliminary research as part of the project. Finally, before any of our objectives could be achieved, we had to fully understand the topic of shrimp farming and any issues that farms or farmers regularly encounter. In order to be as well-informed and knowledgeable as possible, we researched the following topics, which will be discussed in further detail:

- The current status of the shrimp farming industry and market
- Laws and regulations pertinent to shrimp farming in Costa Rica
- Previously published studies on best management practices in other Latin American nations
- Diseases and other problems commonly affecting shrimp farms

- Environmental effects and socio-economics implications of Costa Rican shrimp farming
- Document design and manual writing
- Effective training methods

3.2.1 Current Status of Shrimp Farming

We first examined the current status of the shrimp farming industry in a global context. We compared production levels of major producers in Asia, such as China, Thailand, and Taiwan, with production levels in Latin America and more specifically Costa Rica. Even though production numbers were greater in nations such as China, shrimp farming and aquaculture in general were shown to be more important to the Costa Rican economy than these sectors are to other nations. Additionally, we investigated the growing shrimp farming industry in Latin America and noted trends of increasing production in the region, which indicated much promise for Costa Rican farms. By doing this research on how the shrimp industry has evolved in the last decade, we determined what factors have shaped the direction of the industry and where it is likely to move and change in Costa Rica.

3.2.2 Laws and Regulations

We also researched any laws or regulations particularly relevant to Costa Rican shrimp farming. The process to obtain a permit to construct a shrimp farm in Costa Rica is governed by the Ministerio de Ambiental y Energia (MINAE) is very rigorous. MINAE is concerned with the detrimental effects of shrimp farming on surrounding ecosystems, so permit issuing is very strict and currently permits are only being renewed. Nearly 25% of all of Costa Rican land is protected by the national government, which also contributes to the problem of new farm construction, because there is little space where farms can legally be built. We then investigated certification programs that many food production companies and nations are requiring before they will import shrimp from farms. Also, food production and processing requirements by agencies such as the United States Food and Drug Association (FDA) and a similar international association, Codex, were studied.

Knowing all of these national and international regulations, we could then determine what farming methods were acceptable and which would not be acceptable if Costa Rican farms wished to export their products to foreign nations. This information is particularly important, because, as stated previously, the long-term goal of this project is to increase export levels of farmed shrimp farms in Costa Rica.

3.2.3 Best Management Practices (BMPs) in Latin America

We studied shrimp farming in countries neighboring Costa Rica, primarily examining manuals of best practices for those nations as well as published studies on the industry. We focused on Latin American nations because shrimp farming techniques used in Asian nations, such as Taiwan, Thailand, and China, don't necessarily apply to the Costa Rican situation. Firstly, the shrimp species primarily farmed in Latin America, L. vannamei, is not farmed at all in Asia. Specifications such as water temperature, salinity, pH, and diseases that affect the shrimp vary from species to species, and it would be difficult to apply certain Asian practices to Costa Rican shrimp farming. Similarly, many viruses affecting cultivated shrimp species are found only in the Western Hemisphere but absent in the Eastern Hemisphere and vice versa, so problems farmers encounter could be very different. Finally, much of the shrimp farming in Asian nations is extremely primitive, relying primarily on the tide for postlarvae supply and water exchange and lacking many of the sanitary procedures currently being used in nations such as Mexico, Honduras, and Nicaragua. Thus, these neighboring nations not only have a similar climate and culture, but are also good examples for the Costa Rican shrimp farming industry to model itself after.

By compiling information on shrimp farms in Latin America, we found common trends that seemed to work and compared these to the current practices in Costa Rica. We then recommended options to INCOPESCA concerning how successful practices could be adapted and implemented on Costa Rican farms. By collecting this archival information, combined with information and recommendations from local farmers, we constructed a comprehensive manual of practices that will benefit Costa Rican farmers. Thus, the best management practices of Latin American nations were very important to research since they were the basis of our comparison to Costa Rican farms and served as a model example.

3.2.4 Diseases and Common Problems

In recent years many Costa Rican shrimp farmers have witnessed outbreaks of bacterial or viral diseases such as White Spot Syndrome Virus (WSSV), Taura Syndrome Virus (TSV), and Necrotizing Hepatopancreatitis (NHP), resulting in high mortality in farmed shrimp populations. Information concerning these diseases, in addition to a number of other infections, is important for farmers to know in order for their farm production levels to remain at a desirable level. Therefore, we researched the details of each disease and methods of diagnosis, treatment, and prevention to inform farmers and avoid future shrimp disease outbreaks in the Costa Rican shrimp cultivation industry.

3.2.5 Environmental Effects and Socio-economic Implications

As has been stated previously, Costa Rica is a very environmentally conscious nation, with a very large portion of protected lands and water throughout the nation. However, shrimp farming has the potential to be very harmful to surrounding ecosystems if care is not taken by farmers. We researched the environmental impacts of shrimp farming, such as effluent release, depletion of wild shrimp populations as a result of farming methods, and destruction of mangroves to construct ponds. We addressed these problems by also studying practices that are less detrimental to the environment and how they could be applied to Costa Rican shrimp farms. Additionally, we examined the effects shrimp farming has been shown to have on local economies and societies in other Latin American nations, and how positive outcomes could be achieved and negative consequences avoided in Costa Rica. It was very important that we address these environmental and socio-economic issues because if the development of shrimp farming is extremely harmful to local communities and surroundings, it should be avoided or improved before the situation worsens.

3.2.6 Document Design and Manual Writing

One of our objectives and the main deliverable of the project was do inform farmers of best management practices, and working with our liaison at INCOPESCA, Sr. Alvaro Otarola, the director of the aquaculture sector, we determined that the best way to do this would be designing and writing a manual. However, before we began to write or construct this manual, we decided to research document design and manual writing. In this way the manual would be written in language that the farmers would understand, and would be aesthetically pleasing. Further details concerning the manual construction process are discussed in more detail later in the methodology.

3.2.7 Effective Training Methods

The research also gave our sponsor an idea about the scope of information INCOPESCA needs to provide in order to help prospective and current shrimp farmers. Further addressing the issue of educating current farmers, we evaluated training methods used by INCOPESCA, particularly those used when the organization was promoting the development of the tilapia industry in recent years. Additionally, we analyzed training and education methods used by organizations in the United States such as with the USDA (United States Department of Agriculture), NOAA (National Oceanic and Atmospheric Administration), and various aquaculture programs at universities. Using this information, we recommended different training programs that could prove successful for the shrimp farming industry.

Finally, our team used the compiled archival research to construct a relevant questionnaire to use when interviewing a sample of farmers in the Gulf of Nicoya region with questions that addressed the current practices used at the shrimp farms.

3.3 Interviews

To obtain as much information as possible about current practices, best management practices, and developments in the shrimp farming industry, we interviewed:

- Aquaculture professionals and experts
  - Dr. Brian Crawford of University of Rhode Island (URI)
  - Dr. Jim McVey of NOAA
  - INCOPESCA employees
  - MINAE official
  - Biologists employed on the shrimp farms
- Shrimp farmers

In the following section, we will discuss the reasons we conducted these interviews and the procedures followed.

3.3.1 Reasons Interviews Were Conducted

For our project, we interviewed not only Costa Rican shrimp farm owners, but also professionals or experts in the aquaculture or shrimp farming, and officials in INCOPESCA. We decided to conduct these interviews, as opposed to other methods of data retrieval, for a number of different reasons. The main reasons we interviewed aquaculture and shrimp farming specialists were because we did not have access to the most current developments in the aquaculture field or because there was information concerning certain practices or processes that we could not find during archival research. In other areas of study, the information conveyed to us by experts supplemented the data from the archival research and provided a different view point on the issue.

We interviewed employees of INCOPESCA get perspectives on the current situation of shrimp farming in Costa Rica. The INCOPESCA employees provided a point of view supporting Costa Rican shrimp farming development, and also supplied information concerning the organization and activities of INCOPESCA. We determined the resources

INCOPESCA allocated to help shrimp farming and how we could use them to their full potential.

Finally, even though we could have obtained information concerning current practices from the farm proposals we previously studied or from two the co-operatives in the area, we chose to interview the actual farmers and use this other data as a supplement. Furthermore, we decided on a structured interview, but an interview conducted in-person on-site at each of the farms. This way, there was a more personal feel and farmers were more likely to elaborate and share information. Also, we could then observe the farm in person and take notes on different conditions or practices we saw being performed. By conducting the interviews in this way, we incorporated the farmers themselves into the solution, which would make them more prone to follow the recommendations. Also, by interviewing the farmers we could determine any particular concerns or recommendations they had, tailoring the objectives of the project to fit the needs of the farmers, who will be the main beneficiaries of the project.

3.3.2 Aquaculture Professionals and Experts

We first interviewed a professionals or expert in the aquaculture industry, specifically concentrating on shrimp farming. The specialist we interviewed was Brian Crawford at the University of Rhode Island: Coastal Resource Center.

Additionally, we interviewed professionals employed by INCOPESCA about the status of current shrimp farming, any current problems in the field, the training procedures used for shrimp farming and for tilapia farming, and any details about the organization we could not determine in another manner.

3.3.3 Shrimp Farmers

Interviewing farmers was very crucial to our project, since we aspired to deliver useful information to INCOPESCA and the farmers. Our sponsor Sr. Otarola chose between 35 shrimp farms in the Golfo de Nicoya area for us to visit and interview owners. This is an important region of Costa Rican shrimp farming, the other main location of farms being the Golfo Dulce region. However, Golfo Dulce was not a practical location for us to travel to from San Jose, so we only visited farms surrounding the Golfo de Nicoya. More specifically, we interviewed in the Nepanto and Jicaral region of the Puntarenas province and the Colorado region of the Guanacaste province. In the Nicoya region, there are 118 shrimp farms in total, so 35 represents approximately a third of the farms in the area. Ideally, we would have interviewed all of the farmers in the region, but due to time constraints, we only had approximately two weeks to visit and interview farmers. Additionally, many farms are advised by each biologist and oftentimes owners manage more than one farm. As a result, practices of farms in each given area don't vary dramatically and this sample size is still a valid representation of the different methods used. We interviewed between four and six farmers per day, for an hour to an hour and a half each. Sr. Otarola chose the farms by geographical location, mostly trying to choose farms closer together for logistical reasons. The procedure was random on all other accounts such as size and owner.

Our questions, which can be viewed in **Appendix E**, fell into the following categories:

- **Background:** Many of the preliminary questions were about the size of the farm, how many employees they have, their annual income or revenue, and other statistical questions. These questions were used to start the interview and to categorize the farms as to simplify our final analysis.
- **Management Practices:** A majority of the questions were about practices. These included questions about equipment, feed, water conditions, and the procedures used to prepare ponds and harvest. From these, farmers advised us as to which methods worked and which ones did not.
- **Markets:** Common concerns of farmers include the market their stock will be sold to and the profit they can make from their product. We asked the farmers where they sell the shrimp, how they fight competition, how to keep costs down, where to buy good materials or brood stock.

- **Legal Issues:** INCOPESCA officials and other farmers also know what other international regulations need to be followed for exporting shrimp to other countries. Therefore, we asked INCOPESCA and shrimp farmers what permits and other policies are needed for shrimp farming in Costa Rica. Another issue to address is the formation of a collective and the legal implications of forming one.
- **Training and Recommendations:** The farmers were aware of some areas in which they lacked information or resources. We found common gaps with farmers and used this to focus our research and training recommendations.

3.4 Data Analysis

Once the interviews of the shrimp farmers were conducted, we began to compile and analyze the information we gained from answers to our questionnaire and combined it with the information gained from the archival research. The main objective was to provide INCOPESCA with a scope of the current situation of shrimp farming in Costa Rica, but also to recommend what areas need improving and what can be done to improve them.

We first examined production levels not only for the country over all, but also in specific areas or farms, particularly the Gulf of Nicoya region where we performed interviews. This area is important because it is one of the main regions for shrimp farming in Costa Rica, as explained previously. The production information was tabulated and graphed to determine relationships between regions and between Costa Rica and other nations. The production information we obtained helped us understand the current level of shrimp farming in the country and how and where improvement was needed.

We then analyzed the current practices using responses from the farmer interviews. We categorized each practice into all the alternative techniques that were used on the different farms. Also from the interviews, we identified and assessed common problems encountered by many or all of the farmers and successful techniques certain farms were using that could be implemented elsewhere in the area. In this manner, we determined exactly what the current methods used for shrimp farming in the area were, so we could easily compare and contrast these to the recommended best management practices. We analyzed where best management practices used in other Latin American nations could be applied to Costa Rican shrimp farming and what problems in particular needed to be addressed by our manual.

Next we analyzed the level of training or education the farmers have received concerning shrimp cultivation, from INCOPESCA or elsewhere, and its relationship to the practices used on the farms. If no further training was provided, then the farmers have the information, but may not be able to apply it to their own farms. Therefore, this data was important to understand so we could recommend effective training methods for INCOPESCA to institute.

Finally, we evaluated the environmental and socio-economic impacts shrimp farms had on surrounding communities, and how improved practices could decrease detrimental effects. It was vital to determine the environmental and socio-economic effects because the industry would not be sustainable in the long-term unless it was viewed favorably in these aspects. This provided more criteria to examine which best management practices should and could be applied to shrimp farming in Costa Rica.

3.5 Cost Risk-Benefit (CRB) Analysis

In order to determine the feasibility of our recommendations, we decided to complete a cost risk-benefit (CRB) analysis. We constructed three different scenarios, one for a relatively small farm with a total area of 5 hectares, one for a medium-sized farm of 15 hectares, and one for a relatively large farm of 30 hectares. For each of these scenarios, we assumed equal stocking densities of postlarvae (PL) per square meter, sizes at which the shrimp are harvested, and prices that the farmers would get per kilogram of shrimp.

For each farm, we calculated the total revenue for a 70% survival rate, the average survival rate interviewed farms reported. We also calculated the total revenue for a 40% survival rate, the survival rate that interviewed farmers reported if there was a disease breakout on the farm. It should be noted that the survival rate when a disease hits, depending on how serious the outbreak is, can result in anywhere between a 40% and 0% survival rate. However, we chose to analyze the revenue at the better case scenario because it is more likely, and because the financial numbers make an impact. Even for a mild disease outbreak, so much revenue is lost. We calculated the revenue if the farm operated at an 85% survival rate, the projected target survival rate if farms consistently use our recommendations and good management practices.

Finally, we calculated the yearly costs of four different materials on a farm. We calculated the costs of installing bird nets on the farms of different sizes. This was compared to the amount lost if there was a disease outbreak and the amount that could be gained if good management methods were consistently practiced. We also calculated the money required to purchase a year's supply of chlorine used to disinfect equipment and instruments used during the grow-out process. Once again, this price was compared to the amount that could be lost by a disease outbreak or the amount gained by good management practices. Additionally we determined the yearly costs of feed and diesel fuel used for pumps on farms, to provide a price comparison to the bird nets and chlorine and illustrate the amount that has to be invested to implement good management practices.

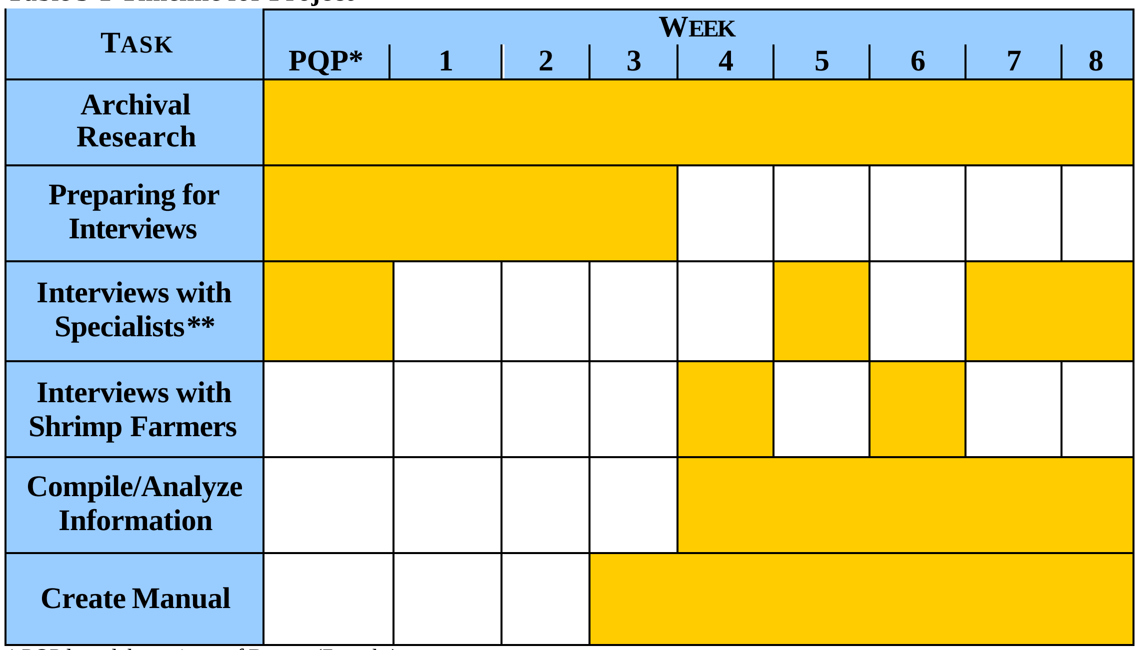
3.6 Manual Design and Composition

Our main deliverable consisted of a manual (Spanish or English) of best practices for Costa Rican shrimp farmers. We could have simply made recommendations or submitted a report only to INCOPESCA, but we wanted to inform the farmers themselves. Additionally, we could have composed a pamphlet of information, but did not feel this would have been expansive enough. Therefore, we decided to compose a manual as a means of conveying all of the information obtained and data analyzed directly to the farmers. This manual was started early on in the project because of time constraints. First, we compiled the information gained from previously published studies concerning best management practices used for shrimp farming in other Latin American nations such as Mexico, Honduras, and Nicaragua. We then adapted this information to the Costa Rican shrimp farms. We emphasized improvement of current practices that were especially detrimental to the environment and surrounding communities. We also researched document design topics such as layout, picture and diagram use, size, and writing techniques for our specific audience. For the final product, the writing was detailed and comprehensive, but also easy for the farmers to understand in order for it to be most effective.

3.7 Project Timeline

The following table details the timeline for the main tasks we completed during the development of our project. The archival research was conducted throughout the whole project, including PQP. Interviews were prepared as soon as possible as to have enough time to revise the questions. Farmers were interviewed during the fourth and sixth weeks of the term, and the specialists were consulted mainly during the fifth and seventh weeks to assist us with the analysis, which lasted the final four weeks. Work on the manual was also started early during the project to save time, even though the main points were not introduced until the final weeks.

Table 3-1 Timeline for Project



* PQP lasted the entirety of D-term (7 weeks)

** We kept in touch with specialists, as questions arose later during the project

Chapter 4: Results and Analysis

The information we have collected through the archival research has given us many ideas of how shrimp farms can operate. Not until we went out to the farms of Costa Rica and saw the practices ourselves did we know the local farmers' methods. We have now taken these methods and used the knowledge from our literature to categorize and analyze the data obtained. This organized collection is shown in this segment.

We collected data from Jicaral and Colorado within the Golfo de Nicoya region and conducted 19 interviews to shrimp farmers and biologists (see **Appendix F** for a map of the Golfo de Nicoya). Through these interviews, we acquired general information for a total of 35 farms, this was possible since some farmers manage more than one farm, and biologists oversee the running of various farms as well as own farms themselves (see **Appendix F** for a map pinpointing the location of visited farms). From the data obtained from farmer interviews, we determined the current practices in use on farms and common problems often encountered by farmers, which will be discussed in further detail in the following sections.

4.1 Current Practices

The average size of a farm in our sample was approximately 16 hectares, with the smallest farm comprised of 1.5 hectares and the largest farm 170 hectares. Farms had an average of approximately 5 ponds, with a mean pond size of 2.7 hectares. This general information assisted us understanding the status of shrimp farming in the region. **Figure 4-1** illustrates the size distribution of the shrimp farms we obtained information for in the Jicaral and Colorado regions. As can be seen, most farms fall within the range of 6 to 10 hectares.

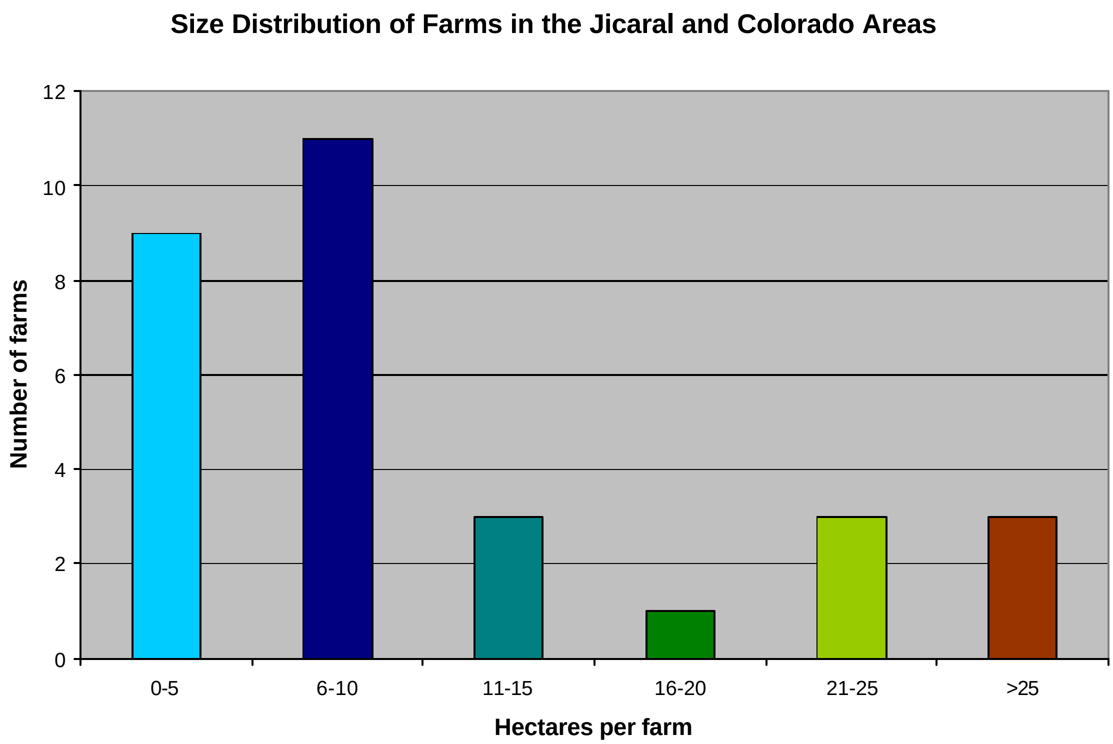


Figure 4-1Size distribution of shrimp farms in the Jicaral and Colorado regions.

Our interviews and data collection led us to the conclusion that most farms in the area follow very similar farming practices, this includes everything from the stocking and acclimating of postlarvae to the running of the farm, to the harvesting procedures. All these practices vary little from farm to farm. For example, the average stocking density in farms is approximately 15 postlarvae per square meter, varying between 15 and 20 postlarvae per square meter. Additionally, the survival rate of 60 to 70 percent is consistent on almost all of the farms. However if a disease hit, farmers reported survival rates of 40% and lower.

4.1.1 Preparation and Stocking of Ponds

The current shrimp farming management practices can easily be divided up into different categories, first starting with the preparation of the ponds. All farms in the Jicaral area dry their farms before the stocking begins. This is mainly because most farms only have one farming cycle through out the year. Although this is also the trend in the Colorado area, some farms do 2 or more cycles throughout the year. The farming is done basically in the winter, which in Costa Rica can run from March to November. Therefore, the ponds are dry during the summer months. During the drying process, farmers rake and plow the land to aerate the soil. On 20 out of 35 farms, farmers test the conditions of the soil before or during the drying process. Farmers then apply calcium carbonate to help disinfect and regulate the pH of the soil measured previously. Farmers generally allow the pond soil to dry for an average of 3.0 months, ranging between .5 and 6 months.

All of the shrimp farms in the Jicaral and Colorado areas obtain water directly from the estuaries around the Golfo de Nicoya. Most of the estuaries do not have a specific name and are just known as “the estuary”. However, none of the farms have a permit from MINAE to use this water source. This is mainly because the farmers do not know a permit is required. This is important because this shows that the amount of water the farms use is not regulated. MINAE should be enforcing this for obvious environmental reasons, but also farmers need it since it would help to prove that their farm is running correctly and has all the necessary permits to do so. This is important when the farm is selling its product to processing plants, and this way can prove its legitimacy. Generally, the water is pumped into a reservoir and then gradually pumped into the ponds. See **Figure 4-2** for examples of pumps found on the shrimp farms in Jicaral and Colorado of the Golfo de Nicoya region.

However, before any of this is done, only 4 out of 35 farms test the water conditions. On those four farms, salinity, dissolved oxygen, temperature, visibility, and presence of red tide are tested. All of the farmers we interviewed stated that they visibly examined the condition of the water to see if it was clean and whether it had red tide before filling the ponds and reservoirs. As can be seen, the majority of the farms don’t thoroughly measure water conditions before adding it to the ponds. As a result, water that is either not up to specifications for shrimp farming or contaminated with diseases from wild shrimp populations could be accidentally used. This may be one of the means of transport of infections such as vibriosis, NHP, or White Spot Syndrome Virus (WSSV) into ponds. Therefore, careful monitoring of the water as it enters the farm system could help prevent infections in the cultured shrimp.

Figure 4-2 Examples of pumps used on shrimp farms.

4.1.2 Postlarvae

All of the 35 farms we conducted interviews on in the Jicaral and Colorado regions purchase their postlarvae (PL) from laboratories throughout the Latin American area. Farmers then buy the PL at an average age of 9.75 days in the postlarval stage, ranging between 5 and 22 days. Most of these laboratories either hatch the nauplii themselves or buy it from another laboratory and then grow it out to the PL stage to sell. Because they buy PL from laboratories and do not rely on catching it from the wild, farmers can stock their farms with specific pathogen free (SPF) or specific pathogen resistant (SPR) shrimp. These shrimp are guaranteed to be free of diseases such as NHP, WSSV, and vibiriosis, and some even bred to be resistant to them, and therefore greatly reduce the risk of disease outbreak on a farm.

Currently, 12 farms out of 19 buy their PL from laboratories located in Costa Rica, while the remaining 7 purchase PL from laboratories located in other nations, primarily Nicaragua and/or Guatemala. So many farms in Costa Rica purchase PL from other Latin American nations because in recent years, farmers have found diseases and deformities in Costa Rican grown PL. Therefore, many farmers have opted to buy PL from the larger, more experienced laboratories in Nicaragua and Guatemala. This increased competition has driven down the price of PL in the past five years, and most of the farmers we interviewed purchase their PL at $4(USD) per million PL, a marked decrease of between 2 and 3 USD per million PL. Even though competition has driven down prices, there are still very few laboratories that farms can purchase PL from. Farmers have attested problems with supply of PL not meeting their demand, and that often they cannot get as much PL as they want or need for their farm at the time they need it.

All of the interviewed farms acclimate the PL they purchase before adding them to the growout ponds. The PL arrive by truck in plastic bags full of water and are then placed into large tubs full of pond water (see **Figure 4-3**).

Figure 4-3 Tubs that the PL are placed in to acclimate to pond water conditions.

The bins or tubs with the bags of PL sit in the pond water in the tubs and adjust to the temperature of the water. Next, water from the tubs is gradually added to the bags in order for the PL to slowly acclimate to the temperature, salinity, and dissolved oxygen levels of the pond water. They also try to keep a constant volume of water in the bins so at the same time water is added water is drained. During this time, the survival rate of the PL is carefully monitored by the biologist to ensure successful acclimation. This whole process takes between 3 and 5 hours with the assistance of the biologist hired by the farm. The biologist not only helps over see the procedure but also checks the PL upon arrival to make sure it is not very stressed, diseased or deformed. Next, the PL is added to an enclosed region of the pond so survival rates, feeding, and fertilization of the water can be carefully monitored during the initial grow out period. **Figure 4-4** shows an example of an enclosure for PL in the main pond. Clearly, the acclimation process is rather developed already on farms that work closely with biologists and has shown to be successful if the PL is already healthy when purchased, but problems occur when the PL is already diseased or deformed when purchased and then exposed to this stress.

Figure 4-4 An enclosure that PL are kept in during the initial growout period.

4.1.3 Feed

Feed is a very important part of shrimp farming, not only the time and the way it's distributed but also what type of feed is being used. All the farms we gathered information from used Aguilar y Solis as their feed, which is a feed that is specially made for shrimp farming. **Figure 4-5** shows Aguilar y Solis shrimp feed bags and their contents.

Figure 4-5 Bags of Aguilar y Solis shrimp feed and their contents.

However, some farms stated that this year they have been having problems with this feed because it arrives to the farms in already damaged. This has caused some farmers to start buying feed from other suppliers. Farmers stated that this new feed which could either be Nicolita or Diamasa was better than Aguilar y Solis feed but was more expensive approximately ¢1000 colones per sack. This may not seem as much money but for the amount of feed that is used this is a considerable expense. To get an idea of how much feed is used, at the beginning the shrimp start out with approximately 200g per feeding tray, farmers use an average of 35 feeding trays per hectare. This comes to 7kg per hectare. This is 14 kg per day per hectare since the shrimp are fed twice a day. Since the average size of all farms interviewed is 16 hectares in a day, an average farm uses 112 kg in a day. Even though the amount of feed varies through out the grow-out period if the average grow-out period is 7 months or 240 days then a total of feed is used is approximately 26,880 kilograms. So if there is an increase of ¢1000 colones per sack and each sack is 25 kg then the farmer will be spending approximately an additional $2150 dollars.

Although farms consider Aguilar y Solis their main feed, 13 out of 19 farmers interviewed use a fertilizer, the most common being Plancton. Fertilizers help the growth of algae, which is a primary source of food, then the algae helps grow the population of phytoplankton which the shrimp actually feed off. This provides an alternative on the commercial feed which is the main source of food for the shrimp.

The feed and fertilizer are kept in wooden sheds, this way they are protected from the rain and sun. Although, it is important to note that some farms only had a small roof to cover the feed, which can cause the feed to mold and make it useless and even harmful if still used to feed the shrimp. Also the feed in most places was not off the ground this is another cause for potential mold. See **Figures 4-6**, **4-7**, and **4-8** for examples of correct and inadequate locations for feed storage and a photograph of moldy feed that results from incorrect storage.

Figure 4-6 Shrimp feed correctly stored completely inside a shed and elevated on wooden risers so it's not in direct contact with the ground.

Figure 4-7 Feed inadequately stored outside of the shed, under only a small roof, and in direct contact with the ground.

Figure 4-8 Moldy feed that can result from inadequate storage and leaving feed bags open.

The commercial feed, Aguilar y Solis, is administrated to the shrimp twice a day. All farms administer the morning supply between 6AM and 7AM. In the afternoon, the times vary more between farms and range mainly from 2PM to 4:30PM. All the farms use round feeding trays, where they place the food. The trays are made out of netting and have a diameter between 50cm and 75cm. Trays are distributed evenly in the ponds and farms have approximately 25 or 30 trays per hectare. **Figure 4-9** shows an example of the feed tray design used on all of the farms in the Jicaral and Colorado regions and **Figure 4-10** illustrates and example of feed tray layout in a shrimp pond.

Figure 4-9 An example of a feed tray used on a farm in Jicaral.

Figure 4-10 An example of feed tray layout in a pond on a shrimp farm in Jicaral. The feeding trays are drying after being removed from the water. The trays are attached to the poles in the water and then submersed during feeding.

The dosage of feed that should be administered to the shrimp is determined mainly using tables and the help of a biologist that helps producers determine rations, as well as analysis of water conditions and to check on the health of shrimp. It is also important to note that almost all 35 producers have been working on shrimp farms for at least 3 years, so by now they have an idea on when to increase the amount of feed or lower it. The biologist that helps them visits about once a week to over look the operation of the farm and make sure everything is going smoothly and gives recommendations on diseases and feed.

An important issue is what is done with food that is left over or that is not consumed by the shrimp. We were actually surprised to find that most farms stated that they don't have any food left over or barely any. This is important since leftover food can contaminate water and harm shrimp as well as the habitat where the water is discharged. The fact that little food is leftover is also very important because it shows how the farms are very organized when it comes to feed and are always keeping good track of how much food is being eaten. This helps the farm because it not only saves money on feed by making sure it only supplies the shrimp with the amount of feed it needs but also shows that the producers have the potential to be organized and orderly about other practices on the farm such as sanitary practices.

4.1.4 Monitoring Water Conditions

Of the farms where we conducted interviews, over 90% (32 out of 35 farms) regularly monitored water conditions such as pH, salinity, dissolved oxygen, visibility and temperature. Farms that measured these conditions measured them every day, some farms measuring them in the morning and the afternoon. This can be easily done by the workers on the farms. The devices are simple to use, the only problem is many times the peons don't have proper instruction on how to use them. Since the devices are very delicate, many times they break and become useless, causing big expenses for the farmers since monitoring devices are not cheap. **Figure 4-11** shows the distribution of farms that measured each condition.

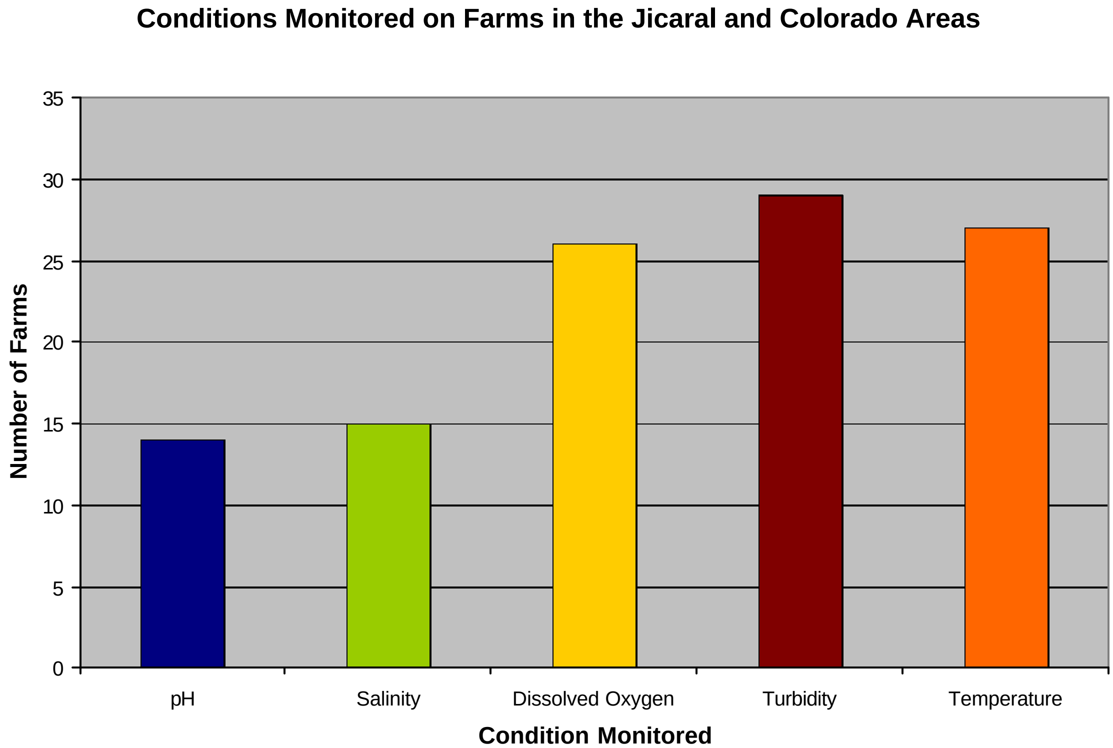


Figure 4-11 A graph of water conditions monitored regularly on shrimp farms.

On the farms that measure these conditions, the preferable range for pH is between 6 and 8, where the water is neutral. Salinity is maintained between 15 and 35 ppm because L. vannamei is very adaptable to different salinities. Additionally, visibility is maintained between 30 and 40 cm on farms that use a Secchi disk to measure visibility (see **Figure 4-12** for a picture of a Secchi disk).

Figure 4-12 A Secchi disk.

The Secchi disk is held beneath the water, and if the bottom is visible within the given range, then the algae level within the water is optimal. If it is outside the range, then farmers will change the water. Farms exchange water by letting water out at certain points in the pond where gates are located and pumping in fresh water from the estuary. **Figure 4-13** shows and example of a water exit gate. The water is let out of the gate by removing the slats of wood, either from the top if there is excessive rainwater that must be drained off, or from the bottom if the water must be exchanged or cleaned. Additionally, netting is placed in front of the gate so no shrimp are accidentally removed along with the water.

Figure 4-13 A water exit gate used for water exchange.

As was seen in **Figure 4-11**, certain farms measured some conditions but not others, but all of the farms that did monitor water conditions measured dissolved oxygen and temperature. These are two of the most important conditions to measure because the consequences are dire if levels fall out of a certain range. If temperature is either too high or too low, many shrimp may become stressed and die. Most farms keep the temperature of the pond water around 30°C. **Figure 4-14** illustrates the temperature range that most farms keep their pond water within.

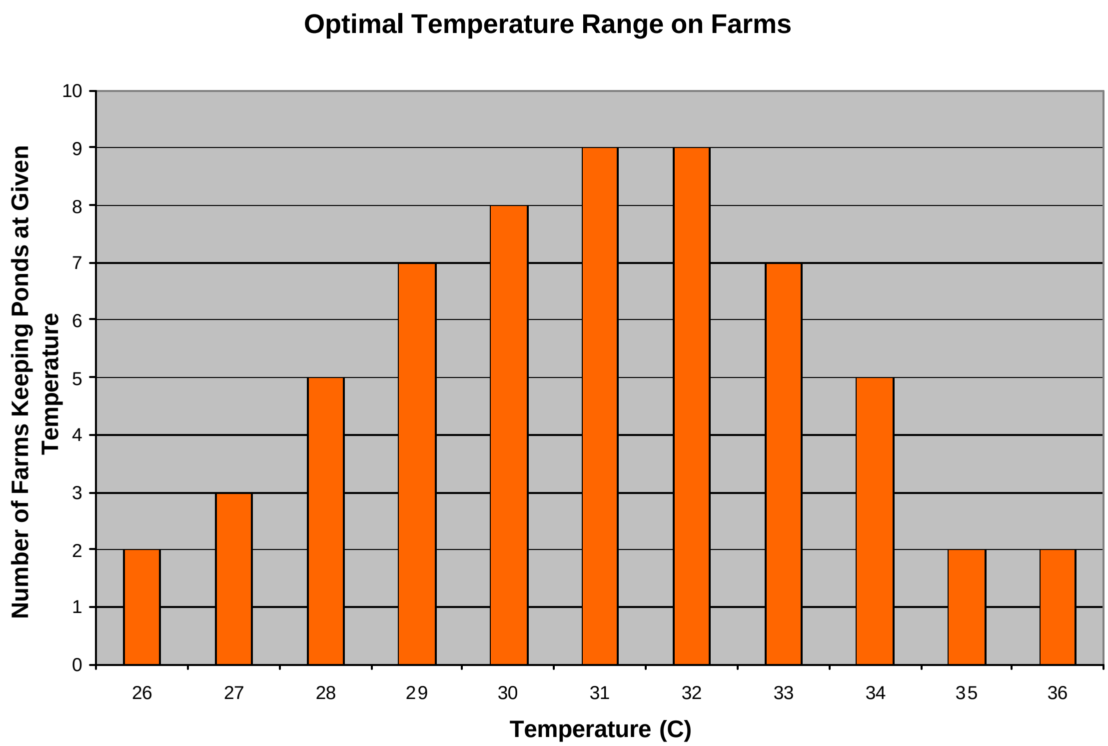


Figure 4-14 A graph of optimal temperature range maintained on shrimp farms.

If the temperature is either below or above the desired range, most farmers state that they decide to exchange the water for fresh water from the estuary at that point, however, temperature is usually not as much of a problem as dissolved oxygen.

If dissolved oxygen falls below a certain threshold, many shrimp mass mortality may result. Therefore, the range of dissolved oxygen maintained in the water is generally between 4 and 8 mg of oxygen per liter of water in the morning, after oxygen levels decrease at night. In the afternoon the oxygen level is between 7 and 12 mg/L. However, some farms only have one range for morning and afternoon. If dissolved oxygen falls too far below the desired levels, farmers often exchange the water, as explained previously. Additionally, some farms possess aerators to increase the dissolved oxygen in the water. Some farms use the aerators frequently in large ponds that don't have as much water flow, while some only use aerators if the dissolved oxygen falls below a certain level. See **Figure 4-15** for examples of aerators used on farms that were visited.

Figure 4-15 Examples of aerators used on shrimp farms.

As can be seen, some aerators are electrically powered and float in the water, so can be turned on at any time, while others are much larger and are run by attaching them to a tractor or tractor axel. Farmers have stated many problems with maintaining dissolved oxygen at the optimal level, and use of aerators on more farms could help with this issue and avoid frequent water exchange and pollution from effluent.

4.1.5 Equipment and Maintenance

Equipment is very important to the farmers especially since financial resources are limited to producers. All farmers have the basic equipment, at least one pump for the filling of ponds and reservoirs, kayaks and small boats, nets for harvesting, netting for the entrances and exits of the ponds, feeding trays, tanks or bins for acclimating the postlarvae or to be used during the harvest. See **Figure 4-16** for examples of boats and kayaks used for feeding.

Figure 4-16 Examples of boats and kayaks used on shrimp farms, mainly for feeding.

Very few farms have tractors and they usually have to borrow one to be used during the preparation of ponds or any other time they need one. As mentioned before some farms have aerators as well, but this type of equipment depends from farm to farm. Also, all but one farm have the basic equipment for monitoring the water which is made up of a dissolved oxygen meter which measures dissolved oxygen and temperature.

One of the major problems farmers face when dealing with equipment is with the pump which they use to fill in reservoirs and ponds. The problem the producers have is that pumps break down regularly, and if it is a big problem the motor has to be taken out using a tractor because of the size. This involves borrowing a tractor and then looking for a mechanic. This can also become a really big problem if the ponds need a water exchange and there is no pump to gather water for the exchange. It is also very costly to maintain and pay for repairs, so a pump breaking down in the middle of the farming cycle would really hurt the farmer's budget and could potentially be the cause of lost crops.

Another problem one farmer mentioned was that the dissolved oxygen sensors are very sensitive and can easily break and become useless. Dissolved oxygen sensors can range in the United States between $200 dollars to $400 dollars, which means in Costa Rica they are more expensive, and even $200 dollars is a big expense for a small producer. The other problem with the dissolved oxygen sensors is that if they do stop functioning the farmers have no way of knowing if it can be repaired or not, because there are no technicians near by where they can take it to be repaired.

During the summer when there is no farming being done, farmers do routine check ups and wash all their equipment making sure everything is in top shape for the next year's crops. For these basic maintenance farmers sometimes do need a technician or a mechanic to check on the pumps and motors of the boats and make sure everything is in perfect condition, as to minimize the probability of problems occurring during the farming season.

4.1.6 Sanitary Procedures

One area that the farmers would like to learn more about is the sanitary procedures. One aspect that was mentioned in our literature review research was the cleaning of vehicles before entering the farm to keep the spread of disease down. This was not done at any of the farms we visited. Some farms did have a bio-secure signs posted to prevent other shrimp or other products that may be contaminated by disease out from entering the farm. Another prevention measure that is used in other countries is the use of nets to keep the birds from eating the shrimp. The easiest way for disease to spread is by having the birds eat contaminated shrimp, and defecate in the water of other ponds. None of the farms we visited had any kind of bird deterrent.

Some of the farms we visited cleaned all their equipment before use. One example is, at the Camaronera Jiménez and Salines Copasl, where the farmer cleaned his boat with calcium carbonate (also referred to as agricultural lime) before loading feed. Calcium carbonate is just un-burnt lime and has the same properties, but is less detrimental to the environment. The canals and pumps are also cleaned before each harvest to minimize the risk of foreign organisms growing with the shrimp. See **Figure 4-17** for a picture of calcium carbonate.

Figure 4-17 Calcium carbonate, or "agricultural lime."

Farms in Costa Rica have had some problems with diseases. Some common diseases that have been found in the Gulf of Nicoya region are vibriosis, NHP, gregarina, taura syndrome virus, and white spot syndrome virus. See **Figure 4-18** to see specifically what diseases have affected shrimp farms in the Golfo de Nicoya region of Costa Rica.

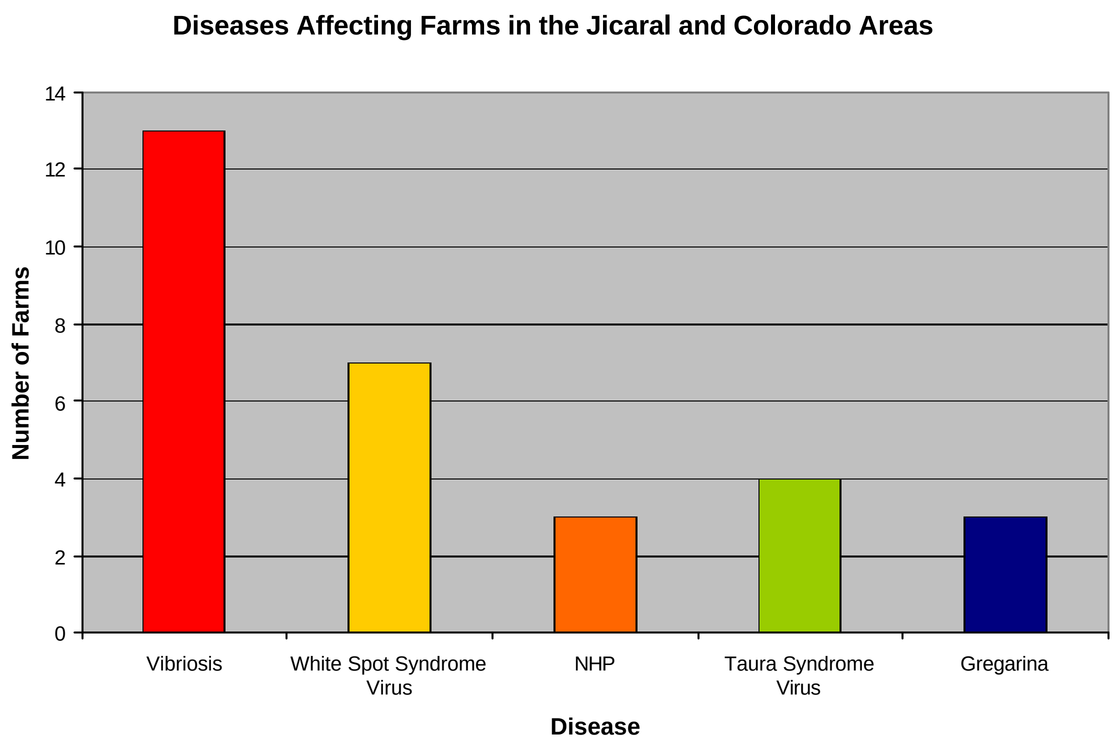


Figure 4-18 Graph showing common diseases and how many farms in the Golfo de Nicoya region were affected.

There have been significant problems with the white spot syndrome. It hit Puntarenas and Guanacaste very hard about five years ago and killed many crops. Many practices were changed because of this outbreak. For example, the number of crops has been cut back from two to one. The stress on the shrimp during the dry season from the large temperature differences between night and day put them at higher level of risk for disease. Another change is how they harvest. To keep the densities in the pond down when the shrimp grow, the farmers now harvest in three stages, once when the shrimp are about 12-14 grams, again at 20-22 grams, and the final harvest at about 30 grams. This also helps reduce the stress on shrimp and risk for disease. Another way of increasing the survival rate of the shrimp is to use medication or medicated feed. This can be costly, so it is only used when there is an outbreak. Out of the 19 farms we interviewed, 9 used medicated feed to prevent or treat outbreaks of disease. Certain farms that did not use medicated feed stated that they were just careful and used calcium carbonate liberally.

In the regions we interviewed, all the farms used a biologist who would come around and check the farms. The biologist weighs the shrimp from each pond, checks the water quality, and takes samples to check for disease. The biologist can then run tests and visually inspect the shrimp under a microscope for any parasites or other pathogens.

4.1.7 Harvesting

Harvesting is the last part of the farming process, and is very important and can be the most stressing part of the whole growout time. As mentioned before when the white spot syndrome virus the shrimp farming practices change in Costa Rica, farmers stopped farming two crops per year and instead focused on one crop. Farmers in Costa Rica stock their ponds starting in the month of March, and may wait until May. The harvest times vary as well but depend mostly on the size which the farmers want to sell at. This means farmers usually harvest in stages. Some farmers harvest all of the shrimp at once, but many farmers grow the shrimp and once it reaches a certain size they will harvest a certain amount to allow the rest of the shrimp to grow. This way the ponds won't be over stocked, which can cause stress on the shrimp. Therefore, when they are going to actually sell the shrimp they usually have specific sizes they wish to harvest at. Our research showed us that this year that all farms are planning to do their first main harvest when shrimp reach at least the size of 12 grams and all of them hope to do their last harvest when the shrimp reach a size between 25 and 30 grams.

The actual harvesting procedure is very simple. An average of approximately 4 more employees are needed for the harvesting process. The stocking ponds have exit gates where they usually have netting for when they exchange water, but when they harvest, a type of bags/nets is used to catch the shrimp at the exit. See **Figure 4-19** for an example of a harvesting area on a shrimp farm.

Figure 4-19 Example of shrimp harvesting area.

The shrimp are then put right away on ice which is in bins or big tubs and this way the shrimp die because of thermal shock. The effluent water that comes out of the ponds both during exchanges and during the harvest is not treated at all, and goes directly back to the estuary and environment it came from. This is important because the levels of contamination in the water as it exits are not known and it is not known how much it contaminates the surrounding mangrove forests.

4.1.8 Marketing and Production

All of the farms we conducted interviews on sold their shrimp fresh to the production facilities or other buyers. However, this creates the problem of storing and transporting the product after it is harvested in as little time as possible so the product does not spoil. All of the farmers interviewed sell their product to a local processing plant called PMT, and two of the ten also sell it to the national market. PMT processes the shrimp primarily intended for export and foreign consumption, mainly in Europe. Instead, the national market is usually private market owners or restaurant owners in Costa Rica that wish to purchase the shrimp directly from the farms. In the interviews, 17 out of 19 of the farmers reported that the processing plant or buyer provided transportation, and 15 of those 19 stated that the buyer of plant also provided ice to keep the shrimp fresh during transport. However, a number of farmers still experienced problems with the transportation of their product. They attribute this to the lack of processing plants located within the region. Because there is only one main processing plant that the shrimp farmers in the Golfo de Nicoya region have access to, oftentimes the processing plant becomes too busy during peak harvest times and cannot provide adequate transportation for all of the farmers' crops. As a result, one farmer has attested that his whole crop went bad, losing approximately 15 million colones, equivalent to $300,000 (USD). This occurred when there was a large storm and all of the farmers of the area needed to harvest and transport their crop before the shrimp died due to the large amount of rainwater that could throw off water conditions. PMT could not provide the needed transportation during this swell of incoming shrimp and many farmers lost their crops that season. Additionally, because there is only one processing plant in the area, there is no competition between plants that could increase the selling price of shrimp for the farmers. As a result, the farmers have to sell their shrimp to the processing plant at whatever price the processing plant requests because there is no other place to sell it to. **Table 4-1** shows the most recent price guide for shrimp sold to the PMT processing plant.

Table 4-1 Price guidelines for shrimp sold to the PMT processing plant located in Costa Rica.

Number of Shrimp per Kilogram	$(USD) per Kilogram
20—30	7.75*
30—40	6.20*
40—50	4.20
50—60	3.75
60—70	3.10
70—80	2.75
80—100	2.50
100—120	2.10

*Special prices offered for in-between sizes in these ranges.

4.1.9 Training and Co-operatives

The farms that we interviewed seemed very knowledgeable about the process of shrimp farming. We found that 10 out of 19 farmers had previous training, 5 of those from INCOPESCA. The other training came from courses, the biologist, one of the shrimp farm co-ops,and a feed manufacturer, Aguilar y Solis. The farms generally rely on the biologist in that area, who is highly trained and has many testing resources the farms usually do not have. Most farms would like to have more training to better their practices in sanitation, water quality control, pond management, and diseases. See **Figure 4-20** for the distribution of where farmers would like more training.

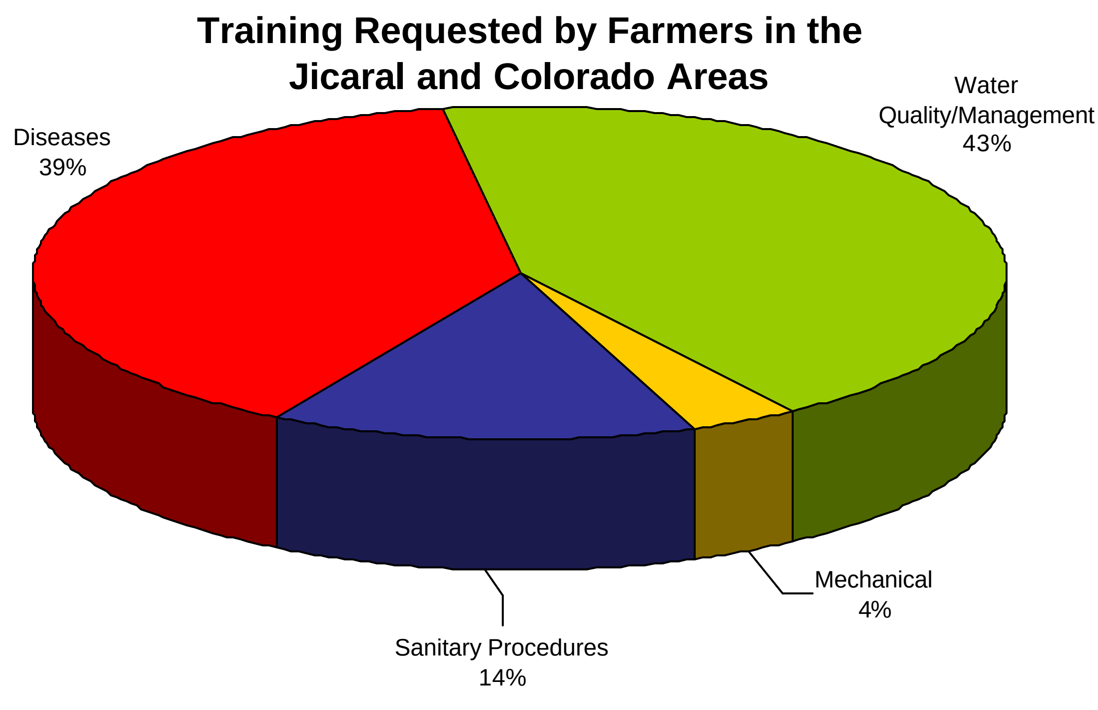


Figure 4-20 Graph of different types of training requested by farmers in the Jicaral and Colorado areas.

Currently, there are two cooperatives in the Gulf of Nicoya region, Cooperativa Nacional de Productos de Sal (COONAPROSAL) and Asociación de Camaroneros de la Peninsula de Nicoya (ASCAPEN). Only 8 of the 19 farms we interviewed are a part of one, or both of these co-ops. Three farms are part of the ASCAPEN, four are in the COONAPROSAL, and the remaining farm participates in both co-ops. Most of the benefits of being a member were said to be the help with equipment, feed, marketing, and financial support. Only three additional farms expressed an interest in joining a co-op. Other farms work with, but are not partners in, the cooperatives.

4.2 Common Problems

Generally, most of the farms seemed to be functioning well and most of the practices seemed to be appropriate for the give situations. However, we noticed a trend of farms lacking adequate sanitary procedures recommended by most other best management practices manuals.

Farms did clean boats and certain instruments with the disinfecting chemical calcium carbonate, or agricultural lime, but few other sanitary measures were taken. Diseases can easily be transported from farm to farm, but certain simple preventative methods were not taken. Infections can be spread between farms by cars, tractors, or even visitors' shoes, but vehicles were not cleaned as they entered farm property and visitors were not required to wash their shoes before entering the premises.

Animal control also seemed to be a problem on many of the farms. Egrets and other water birds could constantly be seen flying around the farms and landing on the edges of ponds to hunt the shrimp. Not only do the birds consume the precious commodity the farmers are growing, but may also spread disease as they travel between farms. No nets over the ponds to prevent the feeding of birds on the shrimp were observed. Domestic animals such as cats and dogs were also found commonly wandering throughout the farms. However, best management practices recommend that domestic animals not be allowed near the ponds, where they could contaminate or infect the pond water.

Additionally, when we observed the measurement of the growth rate of the shrimp on one farm, we noticed a number of sanitary issues that were neglected. Firstly, the farmers failed to disinfect the bucket when using it for samples from different ponds. Secondly, once they were done measuring the growth rate, they returned the shrimp to the nearest pond, not the pond they retrieved them from. This could easily inadvertently spread disease if one of the ponds was infected and the others weren't. This unsanitary practice could easily compromise an entire crop of shrimp, when otherwise one pond could be quarantined and outbreaks prevented in other ponds.

As stated before, feed storage locations on farms were often inadequate. Feed was often kept outside, only under a small roof, in direct contact with the ground. Feed bags were also observed sitting open in or outside of the sheds. In these conditions, it was very easy for the feed to become damp and grow mold. Mold in feed is very unprofitable because farmers are forced to throw away the feed. Moldy feed can also be dangerous if farmers use it, because it could contaminate the water and infect the cultivated shrimp with any number of diseases.

Finally, certain environmental precautions were not taken on many of the farms. For example, pumps were often located in direct contact with the ground beneath them, with no cement or metal platform serving as a barrier. As a result, any fuel or oil that leaked from the pump would directly leach into the ground and eventually the water supply. This could possibly contaminate the water of the ponds and the water of the estuary itself, compromising the water supply for all of the farms downstream as well. Additionally, the effluent exiting the farms during water exchange was not treated in any form and then added directly back to the estuary and the surrounding ecosystems. There are many chemicals present in the effluent water such as calcium carbonate used in the ponds and also the chemicals present in the commercial feed that could contaminate the estuary. Additionally, the effluent water is highly populated in plankton and algae, which could cause an algal bloom and result in a fish-kill in the estuary where the pond water is released. Finally, nitrogen and phosphorous in the shrimp waste and leftover fertilizer are released into the water as well, which can also result in an algal bloom as explained previously.

Thus, most farms are relatively efficient when it comes to feeding, monitoring the water, and keeping track of growth and survival rates. However, the farms we visited do require improvement in the area of sanitation. Nonetheless, the desire and the capacity for improvement is present on most farms, so we feel progress towards better management practices is very feasible on shrimp farms in Costa Rica.

Chapter 5: Conclusions and Recommendations

Shrimp farming is a rapidly developing and lucrative industry throughout the world. As a result, Costa Rican shrimp farming has much promise to grow into a highly profitable and beneficial industry. However, global examples of shrimp farming in similar settings have revealed a number of problems inherent to the industry. For example, shrimp farming can displace communities, jobs for fishermen, deplete wild stocks of shrimp, and harm the environment. Additionally, many of the practices currently used by farmers worldwide are not the most efficient and environmentally sound. As a result, we researched and evaluated methods to minimize the detrimental effects of shrimp farms on local communities and surrounding environments and maximize production and efficiency. Additionally, many laws and regulations apply to aquaculture, particularly shrimp farming, so these laws were taken into consideration when recommending the most applicable practices.

The following section outlines the conclusions that have been reached from the analysis of the information gathered during this project. It also presents recommendations for the Costa Rican shrimp farmers, INCOPESCA, and the Costa Rican government that may help improve the management practices for shrimp farming in Costa Rica. Conclusions and recommendations were made concerning the following topics:

- Manual composition and implementation
- Current Costa Rican practices
- Environmental precautions
- Cost risk-benefit (CRB) analysis
- Co-ops and Government
- Processing facility development

5.1 Manual Composition and Implementation

Currently, most of the shrimp farms operate with a significant degree of experience and proficiency. Most farms work in conjunction with a biologist who helps them develop a feed plan, maintain a strict regimen of measuring water conditions, acclimate postlarvae (PL), and keep detailed records of growth and survival rates. In these aspects, Costa Rican shrimp farms follow closely with the best management practices recommended for other Latin American nations. However, even though most of these farms consult a biologist, a number still do not, and all of the farms still only operate using basic procedures.

The main problem, we have concluded, is that farmers and even some biologists may lack the information necessary to make the next step towards efficient production. Currently, the manual of best management practices primarily being used by INCOPESCA to help farmers and biologists is a manual written specifically for the Mexican shrimp farming industry. Therefore, certain practices recommended in the Mexican manual may not be applicable to Costa Rican shrimp farms, and producers may lack the necessary information. Additionally, the Mexican manual currently in use is very long, extremely detailed, written in overly-technical language, and therefore very impractical for use on site by an actual farmer.

In order to address the limitation of current informational resources, we composed a manual to outline good management practices specifically designed for Costa Rican shrimp farming. The manual in its entirety can be viewed here: Spanish or English (If the hyperlinks do not work go to PDF folder on the CD, to view the manual). We recommend that INCOPESCA conducts an exhaustive review of the manual in the following manner:

- Have a group of biologists currently employed on Costa Rican shrimp farms review the manual to ratify the feasibility and applicability of the recommended practices. The biologists, together, should be able to recommend changes and revisions for INCOPESSCA to make where necessary.
- Assemble an accurate, randomly selected sample of Costa Rican shrimp farm owners and producers to review the manual and determine whether it is practical and understandable.

- Conduct a detailed cost analysis of the benefits of sanitary precautions and good management practices.
- Use the recommended good management practices to assist technicians in construction of model shrimp farms using the stated techniques, as is currently being done with tilapia farming.
- Incorporate distribution of the manual amongst farmers with training sessions conducted by the previously mentioned technicians. The technicians should teach recommended practices, particularly those that differ significantly from current practices.

The detailed good management practices recommendations can be viewed in the manual, and general recommendations concerning practices will be outlined in the next section.

5.2 Current Costa Rican Practices

As stated above, many aspects of current operation on Costa Rican shrimp farms correspond with the best management practices outlined in manuals written for other Latin American nations. However, improvement is needed in a number of areas before Costa Rican shrimp farming can truly compete with the more experienced farms of Honduras, Panama, Nicaragua, and Mexico. The following are the areas that we concluded are most important and need the most improvement, and will be discussed in more detail in this section:

- Animal control
- Feed and chemical storage
- Water quality maintenance
- Disease control and sanitary procedures

5.2.1 Animal Control

As stated in the results and analysis portion of the report, all farms exhibit some form of problem with animal control. One main problem that was visible on every farm we visited was the presence of predators such as birds and crocodiles feeding on the shrimp.

Not only do these predators deplete the amount of product that can be harvested, but birds or crocodiles that consume shrimp on a number of farms can spread disease between them. Therefore, we recommend that farmers take measures to keep birds away from the ponds by using bird nets and/or sound devices. The bird nets prevent the birds from land on or around the pond and the sound devices scare the birds away from the property. To prevent crocodiles from feeding on the shrimp, we recommend that vigilant watch be kept of the pond areas and possibly fences constructed around the ponds or farm premises. Each of these methods should prevent the invasion of predators without introducing other risks to the farms.

Domestic animals such as cats, dogs, cattle, horses, and chickens are often found wandering freely about the premises on shrimp farms. These animals can contaminate ponds with diseases such as salmonella, E. coli, and certain forms of hepatitis, all of which can affect human consumers, if they defecate in or around the ponds. They can also spread other diseases affecting the shrimp between ponds and possibly between farms. As a result, we recommend that farmers keep the farm property fenced off from such domestic animals to maintain the biosecurity of the product. If these animals cannot be kept completely off of farm property, they should be kept completely away from the ponds or fencing be placed around the ponds so they cannot infect the shrimp and compromise the integrity of the product.

Additionally, we have concluded that wild shrimp entering a pond pose a significant risk to farm production. Wild shrimp are often carriers of viruses, such as the White Spot Syndrome Virus (WSSV) which has wiped out many crops of cultivated shrimp in Costa Rica and Latin America, and any number of other diseases. If infected wild shrimp escape into the ponds of farmed shrimp, they can easily cause an outbreak and compromise a whole harvest. Wild shrimp PL or eggs often enter ponds through holes in the netting that is placed over inlet gates. Therefore, we recommend that farmers diligently maintain the netting in front of these water inlet gates, constantly checking it for tears or large holes, and replacing it when necessary to prevent the invasion of wild shrimp. Additionally, two levels of netting can be used to further filter water entering the pond, first netting with larger openings, and then finer netting.

5.2.2 Feed and Chemical Storage

Although farms comply with best management practices concerning their general feed plans, many farms exhibited problems with inadequate storage of feed and other chemicals. We recommend the following methods for maintaining acceptable storage facilities:

- Storage area should be completely out of the sun, rain, extreme temperatures, and sheltered from general exposure to the elements.
- Feed and chemicals should be stored completely within a building, and not just under an overhang or small roof.
- Area should be well ventilated, with good air circulation.
- Feed bags and other chemical bags should be elevated from the ground on wooden pallets, and direct contact with the ground should be avoided.
- Bags and other containers of feed or chemicals should not be left open. Leaving these containers open could result in mold, contamination, and pollution.
- Moldy feed should never be used.
- One container should be completely used before opening another.
- Storage area should be kept free of mice, rats, insects and other pests.
- Medicated feed and all chemicals should be clearly marked and kept separately from regular feed.
- Regularly placed feed trays should be used to administer feed.

5.2.3 Water Quality Maintenance

On nearly all of the farms visited, dissolved oxygen and temperature were routinely measured. However, other parameters were less frequently measured, or not measured at all. We recommend that farmers regularly monitor:

- Dissolved oxygen,

- Temperature,
- pH,
- Salinity, and;
- Turbidity (or visibility).

It is recommended that these conditions should each be measured at least twice a day, once in the morning between 6am and 7am, and once in the afternoon. Additionally, we suggest that detailed records be kept of all measurements, and that farmers routinely consult a biologist to analyze the conditions, particularly if there are any problems. Working with a biologist, farmers should also determine the optimal range for the mentioned parameters, and any actions to be taken if measurements fall outside of the range. Optimal ranges and necessary actions for extreme conditions are discussed in more detail in the manual.

Additionally, before water is pumped into reservoirs or ponds, it should be checked to see if it contains any harmful chemicals. Specifically, the water should be checked for heavy metals and pesticides or herbicides, particularly if it is located near farmland where these chemicals could leach into the soil and be washed into the estuary. Also, if the farms are located near industrial plants, water conditions should be monitored for pollutants that might be released into the water.

5.2.4 Disease Control and Sanitary Procedures

We have concluded that disease is a major concern of shrimp farmers and a serious problem on many farms. There are numerous ways that disease can spread into and within a shrimp farm, so we recommend the following general sanitary procedures to help prevent and treat outbreaks:

- Control of both domestic and wild animals, as outlined above.
- Proper feed and chemical storage, as stated previously.
- Careful maintenance of optimal water conditions, as explained above. If the conditions of the water conditions of the ponds are out of the preferable range, the

stress levels of the shrimp can become elevated, and they are more susceptible to disease.

- Knowledge of symptoms and identifying features for each of the diseases commonly found on shrimp farms in Latin America.
- Farmers should make sure that shrimp are not removed from one pond and replaced into another. This could cause cross-contamination between ponds if one contains infected shrimp and the shrimp in the other pond are healthy. It is important to maintain quarantine-like conditions between ponds, particularly if the presence of an illness is suspected.
- Complete drying of ponds between seasons and especially after an outbreak. Agricultural lime (calcium carbonate $CaCO_3$) can be used to disinfect pond bottoms when the ponds are dried between growing seasons. However, it is recommended that hydrated lime (CaOH) or burnt lime (CaO), which are stronger disinfectants that agricultural lime, be used if there is a disease outbreak to completely sterilize the pond.
- Disinfection of car or tractor tires and visitor shoes before entering farm property, particularly if they are coming from another shrimp farm.
- Disinfection of equipment used in the ponds, such as feeding instruments and boats, with chemicals such as chlorine, particularly when used in one pond and then another.
- Strict employee hygiene, including frequent hand-washing, disinfection between ponds, use of rubber gloves and boots when handling shrimp, and wearing of clean clothes when harvesting. Additionally, it is important that employees be in good health when they are on the farm, or else they can spread disease to the shrimp in the ponds.
- Purchase of specific pathogen free (SPF) or specific pathogen resistant (SPR) certified PL from a certified laboratory.

5.3 Environmental Precautions

Shrimp farms in Costa Rica are headed in the right direction when it comes to taking environmental precautions. The farmers and the government know that the farms can cause a significant amount of damage and are attempting to prevent this by using by using techniques like less harmful disinfectants and preventing new farms from being licensed in mangrove forests. Many more measures can be placed into affect if the farmers and INCOPESCA knew more specifics.

Most farms that we interviewed were lacking in some practices that could help reduce their imprint on the surrounding ecosystems. Some of these are:

- Water exchange
- Effluent water release
- Escape of cultivated shrimp into the wild
- Mangroves
- Leaky/poorly maintained equipment

5.3.1 Water Exchange

From our literature review, we have seen that many modern semi-intensive shrimp farms can function with little to no water exchange in the ponds. This helps the surrounding environment by preventing frequent discharge of shrimp waste, feed, and algae. These farms monitor the water closely to make sure that the balance of conditions does not change, and only exchange the water for emergencies where not doing so could mean the loss of a crop.

Farms in Costa Rica use the recycling of water to remove sediment and to keep the water conditions steady. Some farms will exchange most, or all, of their water before harvest. This causes the feed and algae washed out into the environment more often which can cause great damage and the costly wasting of feed and fertilizer.

We recommend that Costa Rican farmers follow the practices we have outlined in our manual, which will allow the ponds to use the water more efficiently. When farmers consistently monitor the water conditions, the need for water recycling and exchange is reduced.

5.3.2 Effluent Water Release

The water discharged from a farm contains many living organisms and a high nutrient content, both of which can cause a large unbalance in the ecosystem. Costa Rican shrimp farms do not treat effluent water before introducing it into the wild. However, best management practices for other Latin American nations recommend that effluent should be both chemically treated and filtered. The chemical treatment kills off any organisms that can cause problems in addition to treating the water for chemicals used during the production process. The water should be filtered to prevent the entrance of suspended solids, such as excessive amounts of shrimp waste, into the water of the estuary. The harm of effluent water on the estuarial ecosystem could also be lessened if water is recycled throughout the pond, as has been discussed previously. It has been shown that recycling the water, as opposed to complete water exchange, is not harmful to production levels, and is also more beneficial for the surrounding environment. The need for large amounts of water exchange occurs only during harvesting.

5.3.3 Escape of Cultivated Shrimp

Another side effect of replacing the water in a pond is the escape of some cultured shrimp. These shrimp may be carrying a disease which could be easily transmitted to the wild population. A disease like this could destroy a large portion of the wild shrimp supply, which could then affect the wild shrimp harvest.

The nets at the exits of the ponds must be well maintained and free of tearing and large holes to prevent this from happening. Sometimes even multiple filters can help reduce the amount of shrimp that escape from ponds. The best way of preventing the loss of cultured shrimp is to reduce the amount of water that is exchanged.

5.3.4 Mangroves

The preferable location for a shrimp farm is within mangrove forests. These forests are delicate ecosystems, where even the wild shrimp postlarvae grow. The destruction of these forests by creation of new farms is already banned, and only the conversion of salt harvesting permits is allowed. Although this restriction is already in place, some farms are trying to expand into the mangroves, or use the water that flows through them.

Farmers should use the mangroves to help improve their farms, and the ecosystem. Not only can they help to repopulate the trees, the trees can be planted on the many roads and retaining walls between ponds to help prevent erosion. The reduction of water exchange needed to maintain water quality in ponds will also prevent erosion and drops in water levels in the forests. Farms should be careful not to destroy mangroves during construction and try to avoid removing them when possible during expansion.

5.3.5 Poorly Maintained Equipment

Many pumps we found at the farms were old and were placed on bare ground. Some were leaking oil and gas where they could leach into the soil or even pollute the surrounding ponds. Not only do the chemicals adversely affect the shrimp, but they also cause harm to the surrounding ecosystem when effluent water is released.

We recommend that the gas and other liquids be stored on a cement pad or in a leak proof encasement. The pump its self should be enclosed in a similar manner to keep the pollution to a minimum. The fuel storage tanks should also be place away from the inlets and outlets of the ponds as to reduce the amounts of chemicals reaching the ponds and the surrounding environment.

5.4 Cost Risk-Benefit (CRB) Analysis

For this project, we conducted a cost analysis of certain good management practices that could be implemented and also costs for current practices. The main conclusion we came to after this CRB analysis was that good management practices require some investment, sometimes a large initial investment but low upkeep costs. However, in most cases the money spent on these practices corresponds with or is less than how much could be lost if the farm experienced a disease outbreak.

For the CRB analysis, we constructed scenarios for three different farms sizes:

- ? Small farm (5 hectares)
- ? Medium-sized farm (15 hectares)
- ? Large farm (30 hectares)

For each farm size, we assumed that the initial stocking density was 15 postlarvae per square meter, the shrimp were harvested at a weight of 25g, and were sold to the processing plant at approximately $6.20 (USD) per kilogram. It is very important to note that these are very general assumptions and that the costs of implementation and operation are also generalized. Certain operating costs are composed of many factors that are specific to each farm or area, and are extremely difficult to determine. Therefore, the numbers may not be exact, but still exhibit the general financial relationships.

For each farm, we determined the total revenue assuming the shrimp were harvested at the previously mentioned conditions for three different survival rates. The total revenue was calculated for a survival rate of 70%, which is the current average survival rate on the farms where we conducted interviews. We also calculated the total revenue for a 40% survival rate, the highest survival rate that interviewed farms reported if there was a disease outbreak, and finally for an 85% survival rate, the projected target survival rate that farmers could achieve if they consistently followed recommendations and good management practices (GMPs). Additionally, we assessed the costs for implementation of certain good management practices and current practices to compare to the amount that could be lost in the case of a disease or gained if GMPs are followed.

5.4.1 Small Farm (5 hectares)

For a relatively small farm 5 hectares in area, under normal conditions, with no disease outbreaks, and making the aforementioned assumptions concerning harvest conditions, a farm can expect to make approximately $81,000. More details concerning the calculations of the total revenue can be seen in **Table 5-1**. As is illustrated in the table, if a disease outbreak hit the farm, and the survival rate fell to 40% or below, the farm's revenue could fall to approximately $47,000 or lower. This would be a loss of approximately $34,000, or nearly 40% of the total revenue.

Table 5-1 Total revenue calculation for Scenario 1: Small farm (5 hectares).

Size of Farm (ha)	Stocking Density (PL/m^2)	Survival Rate	Total # of Shrimp Harvested	Weight of Shrimp at Harvest (g)	Price of shrimp (USD/kg)	Total Revenue (USD)
5	15	70%	525,000	25	6.2	$81,000
5	15	40%	300,000	25	6.2	$47,000
5	15	85%	637,500	25	6.2	$99,000

However, certain practices can be implemented to help prevent disease outbreaks on the farm, the most important of which have been previously discussed in our recommendations. For this particular CRB analysis, we examined two good management practices, the installation of bird nets over ponds and the use of chlorine as a disinfectant for all equipment and instruments used during grow-out. The costs for bird nets were obtained from Christensen Net Works (http://christensennetworks.com/), and prices for chlorine were obtained from industrial cleaner supplier Clean Co. USA (http://www.cleancodepot.com/). See **Table 5-2** for specific costs and units needed for bird nets and chlorine.

Table 5-2 GMP and current costs for Scenario 1: Small farm (5 hectares).

Material	Cost per unit (USD)	Size of Farm (ha)	Units Used per Year	Cost per year (USD)
Bird Nets (per sq. ft)	$0.075	5	54,000	$40,400
Chlorine (per gallon)	$2.00	5	100	$200
Diesel (per gallon)	$3.25	5	40	$130
Feed (bag)	$14.00	5	672	$9,400

As the table illustrates, for a 5 hectare farm, the cost for installing bird nets is approximately $40,400 dollars. Obviously, this is a large investment for a small farm, but comparing the cost of the bird nets to the loss from disease outbreaks that it can prevent, the cost is justified. Although the cost of bird nets is slightly more than how much a farm would lose in one year of disease, the nets can prevent many years of loss from disease. Additionally, assuming a farm is operating at a 70% survival rate and 10% profit, the money spent on the nets will be earned back in 5 disease-free years.

The table also shows the cost of chlorine used for disinfecting equipment and instruments used during the growout of the shrimp. We estimated that a farm would use 20 gallons of chlorine per hectare, costing approximately $200 per year for a 5 hectare farm. Once again, this requires a bit of investment, but when compared to operating costs already in existence on the farm such as feed, the cost of chlorine is very small. Additionally, the money that could be saved by preventing disease by far makes up for the money spent on chlorine.

Table 5-1 also shows the total revenue of a farm with a survival rate of 85%. This is the projected target survival rate if farmers consistently follow the good management practices recommended in the manual that was constructed. By practicing these more efficient and sanitary methods, farmers could gain as much as $18,000 in total revenue, or approximately a 20% increase. This added revenue would pay for the needed improvements in practices.

The price of diesel needed to run pumps is also an important operating cost on farms. Currently, fishermen, including shrimp trawlers, receive government subsidies that give them a discount on diesel fuel. However, aquaculturists, including shrimp farmers, do not receive a discount on fuel prices. We recommend that the government give similar subsidies to aquaculturists for fuel, and then the money saved on fuel could be contributed to payments needed to implement recommended good management practices.

5.4.2 Medium Farm (15 hectares)

The financial relationship between revenue losses due to disease and costs of implementing the previously mentioned GMPs are similar for medium-sized farms. The size of the farm used in this scenario is 15 hectares. Figures for the 15 hectare farm can be seen in **Table 5-3**. The total revenue with a normal 70% survival rate is $244,000. However, if a disease hits a farm, and the survival rate falls to 40%, the farm can lose $104,000, approximately 43% of the total revenue from before. However, the total revenue of the farm can increase by up to $52,000, which is approximately a 21% increase if the survival rate increases to 85% when a farm follows the recommended GMPs.

Table 5-3 Total revenue calculations for Scenario 2: Medium farm (15 hectares).

Size of Farm (ha)	Stocking Density (PL/m^2)	Survival Rate	Total # of Shrimp Harvested	Weight of Shrimp at Harvest (g)	Price of shrimp (USD/kg)	Total Revenue (USD)
15	15	70%	1,575,000	25	6.2	$244,000
15	15	40%	900,000	25	6.2	$140,000
15	15	85%	1,912,500	25	6.2	$296,000

The comparison of prices for implementing good management practices such as bird nets and chlorine to current operating prices of diesel and feed, in addition to the comparison with losses to disease and gains that are possible are similar to scenario 1. **Table 5-4** exhibits the figures for these materials on a farm of 15 hectares.

Table 5-4 GMP and current costs for Scenario 2: Medium farm (15 hectares).

Material	Cost per unit (USD)	Size of Farm (ha)	Units Used per Year	Cost per year (USD)
Bird Nets (per sq. ft)	$0.075	15	1,615,000	$121,000
Chlorine (per gallon)	$2.00	15	300	$600
Diesel (per gallon)	$3.25	15	120	$400
Feed (bag)	$14.00	15	2016	$28,000

5.4.3 Large Farm (30 hectares)

With the large farm of 30 hectares, the basic relationship between total revenue, loss due to disease, gain from good management practices, and costs of implementing good management practices and current operations costs are similar. As **Table 5-5** shows, if a farm operates with a 70% survival rate, it will earn a total revenue of approximately $488,000. If that farm is affected by a disease outbreak, it can lose $209,000, or approximately 43% of the initial revenue. However, if that farm improves its practices to meet good management specifications, it can gain up to $105,000, or close to 22% of the original revenue. As a result, it is worth it for the farm to invest in good management practices shown in **Table 5-6**. See **Table 5-5** and **Table 5-6** for more specific figures.

Table 5-5 Total revenue calculation for Scenario 3: Large farm (30 hectares).

Size of Farm (ha)	Stocking Density (PL/m^2)	Survival Rate	Total # of Shrimp Harvested	Weight of Shrimp at Harvest (g)	Price of shrimp (USD/kg)	Total Revenue (USD)
30	15	70%	3,150,000	25	6.2	$488,000
30	15	40%	1,800,000	25	6.2	$279,000
30	15	85%	3,825,000	25	6.2	$593,000

Table 5-6 GMP and current costs for Scenario 3: Large farm (30 hectares).

Material	Cost per unit (USD)	Size of Farm (ha)	Units Used per Year	Cost per year (USD)
Bird Nets (per sq. ft)	$0.075	30	3,229,000	$242,000
Chlorine (per gallon)	$2.00	30	600	$1,100
Diesel (per gallon)	$3.25	30	240	$800
Feed (bag)	$14.00	30	4032	$56,000

5.5 Co-ops and Government

All of our previous recommendations have been directed to the specific practices that are done on the farm, but it is also important to look at shrimp farming from a different aspect that could help the producers as well. Financial resources are always a problem when farms are trying to implement new practices. Because of this, one of our recommendations is farm involvement in cooperatives. As we mentioned before, there are two main cooperatives in the Gulf of Nicoya region, COONAPROSAL and ASCAPEN, yet not all farms are part of these.

Our main recommendation is that farmers be more proactive in participating in cooperatives. We recommend this for one main reason. As a group farmers can have more influence. A good example of this is when farmers are buying feed. If a group of farmers get together and buy feed together, it is more probable that they can get a discount when negotiating feed prices. For instance, if one farmer just goes and buys 10 sacks of feed, the feed distributor will not be prone to giving a discount, but if for example 20 farmers get together and buy 200 sacks of feed they are more likely to receive a discount. This can be the same with fertilizer or other chemicals that all farmers use. Another example is transportation of the feed Most farmers don't have a truck to go get the feed, so paying to get the feed is more expensive for only one farmer, than if 20 farmers get together and pay for the transportation.

Another example of the benefits of co-ops, is assistance with loans. It can be very hard for a small shrimp producer to get a bank loan. By participating in a cooperative, a bank will be more willing to give out loans since as a group the producers have more financial stability than they do individually. A cooperative can also be very useful when it comes to politics. If there is a need for subsidies or tax breaks, or if the government is trying to take help away from the producers, as a large group, producers are able to apply more pressure to the government to receive this help.

Participation in co-ops allows farmers to apply pressure for subsidies from the government. Currently, fishermen receive subsidies and get a discount on their fuel. If the shrimp farmers get together and pressure the government to give them the same subsidies fishermen receive, it would be to great advantage to the producers, because fuel is one of their main expenditures.

This is just one of the various subsidies or financial help that shrimp farmers could pressure the government for and it clearly shows how cooperatives can be of great use to the individual farmer. Today farmers already share the expense of the biologist that helps them on the farms. If they shared other expenses and worked together more, they would not only save money, but their practices could improve, giving an increase in the total production.

5.6 Processing Facility Development

It is also important for the Costa Rican government to be aware of the current shrimp farming industry and provide necessary information sessions and training to the producers. Also, by being aware of the current status and projects farmers have, the government would be able to help with the development of shrimp farms and projects the producers are interested in. A good example of the Costa Rican government helping the growth of shrimp farming is the shrimp farmers in the Gulf of Nicoya, who have created a proposal for the creation of a processing plant funded by the government to which shrimp farmers can sell their product.

The problem today is that there is only one main processing plant in Costa Rica that farmers are able to sell most of their product to. The rest of their product goes to intermediaries that sell the shrimp in national market. The main problem with having only one main buyer is that the buyer can be saturated, and not be able to buy the product. This can cause a farmer or producer to lose a whole year's worth of product. If the shrimp aren't harvested at the right time, or if there is a problem and the shrimp have to be harvested sooner than expected, and the processing plant can't buy or transport the product, it can be a very big loss for the farmer. Also the processing plant is far away from where the shrimp farms are located. If a farmer has an emergency and has to harvest as fast as possible, but the processing plant can't get the transportation and ice to the farmer, it can be disastrous. All these reasons have made shrimp producers in the Gulf realize that a processing plant that is nearby will not only be very helpful in case of an emergency, but also will create competitiveness which will hopefully result in better prices and service from the other processing plant and future ones as well.

It is important for the Costa Rican government to get involved in this project and any other future project, if it is looking for the greater development of shrimp farming in Costa Rica and the export of the product.

Glossary

Algae: A sea-weed; in *pl.* One of the great divisions of Cryptogamic plants, including sea-weeds and kindred fresh-water plants, and a few aerial species. (Oxford English Dictionary, 1989)

Anorexia: Want of appetite; ‘inappetency.’ J. anorexia nervosa, a condition marked by emaciation, etc., in which loss of appetite results from severe emotional disturbance. (Oxford English Dictionary, 1989)

Aquaculture: The farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some form of intervention in the fish-growing process to enhance growth and survival, such as regular stocking, feeding, protection from predators, etc. (Oceans Alive, 2005)

Diatom: A member of the genus *Diatoma*, or, in a wider sense, of the Diatomaceæ, an order of microscopic unicellular Algæ, with silicified cell-walls, and the power of locomotion, on which account they were formerly placed by many naturalists in the Animal kingdom. They exist in immense numbers at the bottom of the sea, as well as in fresh water; and their siliceous remains form extensive fossil deposits in many localities. (Oxford English Dictionary, 1989)

Epithelium: A non-vascular tissue forming the outer layer of the mucous membrane in animals. (Oxford English Dictionary, 1989)

Hepatopancreas: Klaus's name for the glandular organ, called the liver in Invertebrates, in reference to its twofold functions of secretion and digestion. (Oxford English Dictionary, 1989)

Lethargy: A disorder characterized by morbid drowsiness or prolonged and unnatural sleep. (Oxford English Dictionary, 1989)

Mangrove: any of a genus (*Rhizophora,* especially *R. mangle* of the family Rhizophoraceae) of tropical maritime trees or shrubs that send out many prop roots and form dense masses important in coastal land building. (Merriam-Webster Online)

Necrosis: a. *Pathol.* Death of tissue or cells; an instance or area of this. (Oxford English Dictionary, 1989)

Phytoplankton: Plankton consisting of microscopic plants. (Oxford English Dictionary, 1989)

Plankton: Floating or drifting organisms, esp. very small ones, found at various depths in the ocean and fresh water, comprising chiefly diatoms, protozoans, small crustaceans, and the eggs and larval stages of larger animals. (Oxford English Dictionary, 1989)

Postlarva: belonging or pertaining to those stages in the development of certain animals in which some larval characteristics may be retained, before the adult form is reached. So **post-ˈlarva**, an animal, esp. a fish, during this period of its development. (Oxford English Dictionary, 1989)

Prawn: any of numerous widely distributed edible decapod crustaceans (as of the genera *Pandalus* and *Peneus*) that resemble shrimps and have large compressed abdomens. (Merriam-Webster Online)

Protozoa: one of the two (or three) great divisions of the animal kingdom, comprising animals of the simplest or most primitive type, each consisting of a single cell, usually of microscopic size: correlated with METAZOA (and MESOZOA). (Oxford English Dictionary, 1989)

Tilapia: any of a genus (*Tilapia*) of African freshwater cichlid fishes often raised for food. (Merriam-Webster Online)

Red tide: seawater discolored by the presence of large numbers of dinoflagellates (especially of the genera *Gonyaulax* and *Gymnodinium*) which produce a toxin poisonous especially to many forms of marine vertebrate life and to humans who consume contaminated shellfish. (Merriam-Webster Online)

Appendix A: INCOPESCA Sponsor Description

The Instituto Costarricense de Pesca y Acuicultura (INCOPESCA) was created in March 1994 through law #7384, Creación del Instituto Costarricense de Pesca y Acuicultura (The Creation of INCOPESCA), as an independent institute to regulate the Costa Rican fishing and aquaculture industries. INCOPESCA's mission is the following:

> INCOPESCA, as a governing entity, must promote the fishing and aquaculture development of the country: for this it regulates, protects and administers the marine and aquaculture resources, fostering its sustainable use. This way, contribute with the economic and social development of Costa Rica.

INCOPESCA's primary objectives include the conservation of the marine ecology, enforcing fishing laws, and spreading technology and knowledge to aquaculturists and fishers. More specifically, INCOPESCA studies the marine ecosystems to develop new regulations and restrictions on fishing. It also promotes the aquatic industries by subsidizing fishermen during bans on their products or bans due to dwindling fish populations. Additionally, INCOPESCA encourages internal and international trade. Fishermen and aquacultors are also registered and licensed through INCOPESCA (http://www.cesdepu.com/leyes/7384.16-MAR-1994.htm) .

INCOPESCA is a public institution established by the government, but is a semi-autonomous and non-profit organization. INCOPESCA is run by a main board of directors which comprises of a President (assigned by the Government), the Minister of Agriculture and Livestock (director of the Ministerio de Agricultura y Ganadería or MAG), the Minister of Science and Technology, and a representative of the State assigned by the Government. This board of directors makes up the Junta Directiva in the diagram below. Three members of the fishing sector (representatives of fishing or aquaculture organizations), a representative of the industrial sector of fishing or aquaculture, and a representative of the National Commission of Fishing and Aquaculture

Consulting are also appointed to run the institution by their respective divisions. See **Figure A-1** for a more detailed breakdown of INCOPESCA's internal structure.

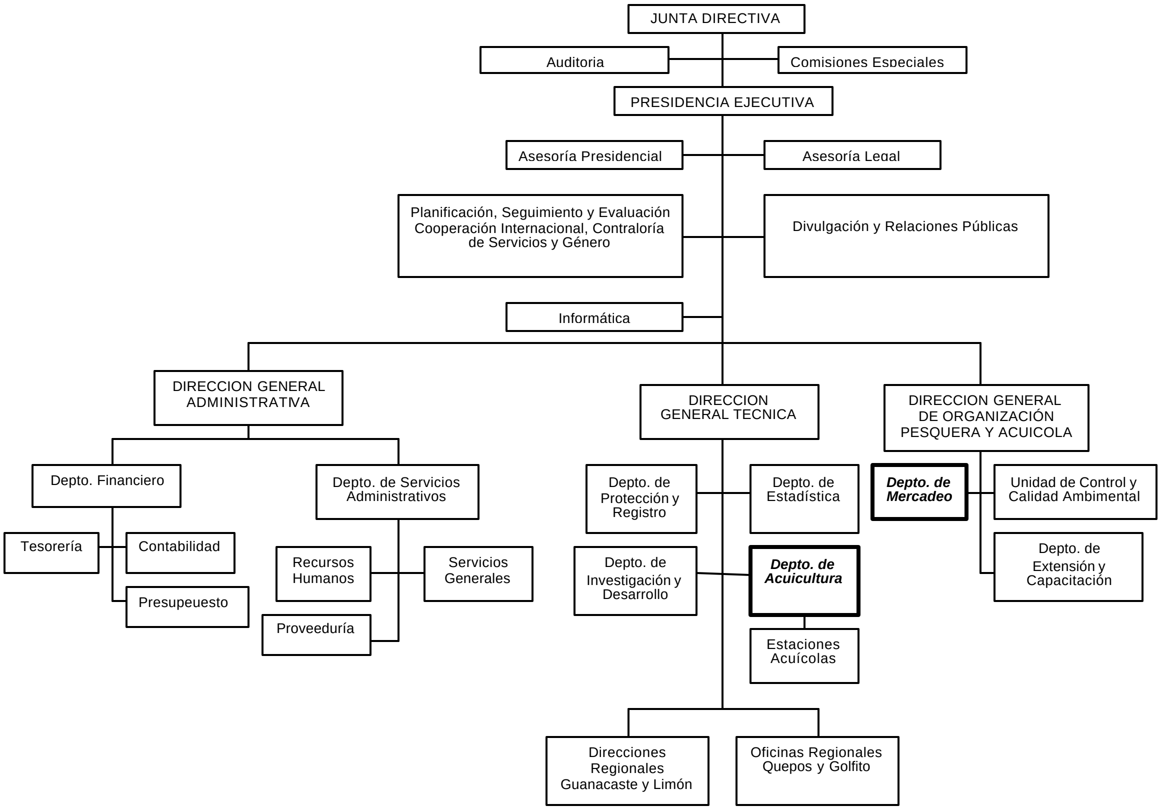


Figure A-1 Organizational Diagram (INCOPESCA, n.d.)

Our primary liaison within INCOPESCA was Sr. Alvaro Otarola, the director of the Departamento de Acuicultura (Department of Aquaculture), which is the highlighted box under Dirección General Técnica in the organogram above. As director of this department he oversees most of the administrative aspects of his department. It is important to note that he is very involved in the training and education of farmers in Costa Rica. Because of this, he organizes and participates in courses that INCOPESCA and the Department of Aquaculture provide. Another contact we had within INCOPESCA was Sr. Rolando Ramirez Villalobos, who is the director of the Departamento de Mercadeo (Department of Marketing), the highlighted box under Dirección General de Organización Pesquera y Acuícola also shown in the figure above. The Department of Marketing is in charge of helping farmers with the exportation and marketing of their products. The department also gives conferences to farmers about regulations and practices for the exportation of their products.

Currently INCOPESCA is independent as noted before hand, but it does have to follow regulations and laws that the government places. The Ministerio de Agricultura and Ganadería (MAG) can place regulations on different aspects of agriculture and livestock, this includes aquaculture and fishing as well, which independent institutions such as INCOPESCA have to follow.

It is important to note though that this year Costa Rica has had elections, and a new administration has come into power. This administration is looking towards restructuring various aspects of the government and its agencies. The government is planning to create a new ministry which would be known as the Ministry of Production, this new ministry would absorb MAG as well as other independent institutions such as INCOPESCA. If this happens, INCOPESCA will lose its autonomy and independent budget. Currently, the people working at INCOPESCA are divided on the subject, but many are fighting for keeping their own finances and budget even if INCOPESCA is absorbed into the Ministry of Production.

INCOPESCA's funding comes from various sources, which include all of the following: government support, contributions from national and international institutions, fines, taxes and contributions associated with Law 7384, donations from other governments, private donations, and income of the Ministry of Agriculture and Livestock (http://www.cesdepu.com/leyes/7384.16-MAR-1994.htm). According to the Sección de Presupuesto of INCOPESCA, the organization received a total of 1,032.66 million colones in the year 2005. Of this, 595 million colones were received from transfers from the Central Government, 73.7 million colones were from sales of goods and services, and 363.9 million colones were received from sales of licenses. The 2006 budget was projected at a total of 1,928 million colones. Of this budget, it is estimated that 711 million colones will be appropriated to other "entities" according to the new Ley de Pesca y Acuicultura. After this is subtracted from the budget, 1,217 million colones will remain for operation of INCOPESCA. Of this last number, 614 million colones will be provided by the Central Government, a marked increase from the previous year. Finally, 603 million colones are estimated to be generated by INCOPESCA by sales of permits, goods and services rendered (INCOPESCA, n.d.).

The issues of shrimp farming are becoming increasingly important to environmental foundations, INCOPESCA, and even the farmers themselves, considering the major growth in the industry in Central and South America, Africa, and Southeast Asia. Certain aspects of shrimp farming, particularly at an industrial level, have been found to be detrimental to the surrounding environment. The chemicals, particularly phosphates and nitrates used in many of the farming processes, are very dangerous, especially when seepage from the holding tanks contaminates other bodies of water. Also, large shrimp farms are frequently constructed in coastal areas, often destroying rare mangrove forests. Scientists are currently studying the possibility, however, of farming in brackish areas that would not otherwise be used in order to preserve the mangroves. Additionally, industrializing shrimp farms can be harmful to local communities, as it may cause socio-economic dislocations and rising tensions. The small, traditional farmers often suffer as the new commercial farms begin for flourish (Hishamunda & Ridler, 2002).

INCOPESCA recently encountered a number of very similar issues when they worked to commercialize Nile tilapia fish farming in Costa Rica. Only a few years ago, there were few tilapia farms in the nation, and those that existed were very small. However, between 1999 and 2000, INCOPESCA initiated an extensive program to provide research funding, develop technology, and share the best techniques amongst small farmers. This greatly increased the size of the industry in Costa Rica, as shown by the 5,797 metric ton increase in production between 2002 and 2005, and the nation is now a leading global exporter of the fish and the chief supplier of tilapia to the United States (Alceste & Jory, 2002).

INCOPESCA has recently been working to regulate shrimp farming by requiring farmers to register with them, the preliminary steps of commercializing the production. As the next step, INCOPESCA has requested us to investigate the success of the tilapia industry and the success of shrimp farming in other nations. With this information, we will develop a plan with INCOPESCA to improve shrimp farming in Costa Rica, also working with local farmers to identify possible problems and most efficient methods.

In recent years, shrimp farming in Costa Rica has shown to be an increasingly productive and profitable industry. Between 2001 and 2005, total shrimp farming production increased from 1,800 metric tons to over 5,700 metric tons. Currently, new shrimp farming permits are not being issued due to the detrimental environmental effects on mangroves. However, permits are still being renewed, and there is a growing trend of transferring permits from salt extraction to shrimp farming, a more lucrative industry. Since new permits are not being issued, INCOPESCA has been working with current farmers to improve practices and integrate newer, more efficient, and less harmful technology. Working with INCOPESCA, we researched the most applicable good management practices for farmers to follow and interviewed farmers to determine the status of current practices and developing problems or solutions. We recommended a set of best management practices to INCOPESCA and effective training methods that could be used to convey this information. Additionally, we analyzed the environmental and socio-economic effects of shrimp farming on surrounding ecosystems and communities. Ultimately, the information we compiled and analyzed was made available to Costa Rican shrimp farmers in the form of a manual of best practices.

All of these objectives that our project fulfilled will greatly impact both INCOPESCA as an organization and the Costa Rican shrimp farming industry. The manual that we have compiled is a first step of many towards improving Costa Rican shrimp farming. It is our hopes that the organization will continue research and encourage further development. Additionally, we hope that INCOPESCA will see shrimp farming as a profitable and beneficial industry, and hope to assist farmers with government subsidies and grants that will help them further improve their practices. Our project will most directly impact the actual shrimp farm owners and producers by improving their everyday techniques, with the hopes of increasing efficiency and production.

This project was related to many aspects of INCOPESCA's mission and objectives. Firstly, our recommendations upheld INCOPESCA's aim to conserve marine ecology by recommending and advocating farming methods that are sustainable and also not harmful to the surrounding environment. Secondly, INCOPESCA encourages the social and economic development of Costa Rica, and helping to promote sustainable shrimp farming is one way to do so. Most importantly, however, this project's main deliverable was to inform the farmers of the best management practices applicable to shrimp farming in Costa Rica, which directly follows INCOPESCA's objective to help spread technology and knowledge throughout aquaculture.

Appendix B: Shrimp Importations of USA

Table B-1 Shrimp Importations of USA (2001)

CAMARON: IMPORTACIONES EN ESTADOS UNIDOS

PERIODO: 2001, TM, MILES DE DOLARES

PAIS	CANTIDAD	VALOR	PRECIO KG
Argentina	2296	28291	12.32
Aruba	176	729	4.14
Australia	275	3562	12.95
Bahamas	5	140	28.00
Bangladesh	8726	92244	10.57
Belize	2762	20622	7.47
Brazil	9815	63623	6.48
Burma	2601	24262	9.33
Canada	1764	10063	5.70
Chile	88	691	7.85
China	25731	171103	6.65
Colombia	3160	31174	9.87
Costa Rica	1029	10280	9.99
Denmark	6	30	5.00
Ecuador	25637	214967	8.39
El Salvador	1573	16227	10.32
Fiji	1	3	3.00
France	32	314	9.81
Gambia	7	106	15.14
Greece	1	11	11.00

Greenland	50	302	6.04
Guatemala	2686	19121	7.12
Guyana	11690	53189	4.55
Haiti	2	33	16.50
Honduras	9407	70362	7.48
Hong Kong	43	190	4.42
Iceland	24	199	8.29
India	28844	243418	8.44
Irán	223	2031	9.11
Indonesia	14607	143649	9.83
Ireland	4	35	8.75
Italia	1	4	4.00
Japan	152	410	2.70
Macao	34	152	4.47
Malaysia	1447	14669	10.14
Mexico	29789	379715	12.75
Morocco	1	32	32.00
Holanda	1	7	7.00
New Caledonia	95	1047	11.02
Nueva Zelanda	11	146	13.27
Nicaragua	5034	36267	7.20
Nigeria	36	655	18.19
Norway	19	106	5.58
Oman	17	74	4.35
Pakistan	1497	10939	7.31
Panama	5756	60896	10.58

Peru	729	5996	8.22
Filipinas	1318	16506	12.52
Portugal	1	9	9.00
Yemen	28	171	6.11
Arabia Saudita	629	7159	11.38
Senegal	9	72	8.00
Singapur	360	4273	11.87
España	5	92	18.40
Sri Lanka	791	8040	10.16
Suriname	2405	11629	4.84
Taiwan	233	1481	6.36
Tailandia	84598	799810	9.45
Emiratos Arabes	270	1192	4.41
Reino Unido	99	743	7.51
Venezuela	9511	78581	8.26
Vietnam	26048	296086	11.37
Total	324189	2957930	9.12

FUENTE: DEPARTAMENTO DE AGRICULTURA USA

http://www.mercanet.cnp.go.cr/SIM/Frutas_y_Vegetales/documentospdf/camar%C3%B3n_Mayo02.pdf

Table B-2 Shrimp Exportations of Costa Rica (1999-2001)

CAMARON: EXPORTACIONES DE COSTA RICA

PERIODO: 1999, 2000, ENE-NOV.2001, KG

	1999	2000	2001
ENERO	378281	152091	228144
FEBRERO	193885	180243	134438
MARZO	623675	174481	123379
ABRIL	206653	101094	91561
MAYO	386123	106517	117879
JUNIO	173655	84200	157273
JULIO	164510	155376	173647
AGOSTO	219895	176918	214105
SETIEMBRE	1046878	231928	217728
OCTUBRE	139150	165303	188268
NOVIEMBRE	241977	181702	333993
DICIEMBRE	283754	180763	-
Total	**4058438**	**1890617**	**1980415**

FUENTE: PR0COMER
http://www.mercanet.cnp.go.cr/SIM/Frutas_y_Vegetales/documentospdf/camar%C3%B3n_Mayo02.pdf

Appendix C: Shrimp Feed Plans

Kuruma shrimp (Penaeus japonicus) - dry diet, pellet

Table C-1 Three feed plans for Kuruma shrimp from (Tacon, 1986)

Ingredient (%)	Post larvae/juveniles		
	1	2	3
Fish meal	-	20	15
Fish solubles	-	-	5
Fish protein concentrate	-	1	-
Shrimp meal	-	11	30
Mysid shrimp meal	15	-	-
Squid meal	47	-	-
Petroleum yeast	20	-	-
Lactic acid yeast, dried [1]	-	11	-
Brewers yeast, dried	-	4	4
Meat meal	-	5	-
Algae meal (Spirulina)	-	-	8
Soybean meal	-	10	8
Corn yeast extract (Mazoferm)	-	4	-
Fish autolytic paste (PNF)	-	4	-
Fish oil	-	4	4
Corn steep (Roquette)	-	6	-
Distillers dried solubles (Solufactor)	-	-	6
Wheat gluten	3	15	15
Active sludge	5	-	-
Alpha-starch	2	-	-
Soya lecithin	-	1	-
Vitamin premix [2]	3	-	-
Protector vitamin premix [3]	-	2.5	2
Mineral premix [4]	5	-	-
$CaHPO_4$: $CaCO_3$ (1:1)	-	-	3
$CaHPO_4$	-	1.9	-
Antioxidant (BHT)	-	0.01	-
Nutrient content, %			
Moisture	6.8	6	10
Crude protein	61.4	58	52
Lipid	4.9	10	8
Ash	4.9	14	14

Giant tiger shrimp (P. monodon) - dry diet, pellet

Table C-2 Four feed plans for giant tiger shrimp from (Tacon, 1986)

Ingredient (%)	Post larvae/juveniles			
	1	2	3	4
Fish meal	30	30	27.5	29.3
Shrimp meal	-	-	27.5	17.4
Shrimp meal	15	15	-	-
Soybean meal	15	-	-	-
Copra meal	-	-	-	10
Ipil-ipil leaf meal (dried soaked leaves)	-	20	-	-
Wheat/bread flour	10	10	15	15
Sago palm starch/corn starch	-	-	5	5
Rice hulls (filler)	-	-	-	5.9
Rice bran	14.8	9.8	20	10
Potato starch	5	5	-	-
Cod liver oil	9	9	-	-
Corn oil	-	-	4	2.6
Vitamin/mineral premix V-22 [1]	0.95	0.95	0.95	-
Vitamin premix [2]	-	-	-	1
Mineral premix [3]	-	-	-	1
Dicalc ium phosphate	-	-	-	2.8
Vitamin C	0.05	0.05	0.05	-
Antioxidant (BHT)	0.2	0.2	-	-
Nutrient content, % dry matter				
Crude protein	41.9	40.7	35.7	NA
Lipid	14.1	15.9	7.4	NA
Crude fibre	3.4	4.9	8.0	NA
Ash	10.6	10.6	16.9	NA

Giant tiger shrimp (P. monodon) - dry diet, pellets

Table C-3 Four additional feed plans for giant tiger shrimp from (Tacon, 1986)

Ingredient (%)	Post larvae/juveniles/production			
	1	2	3	4
Meat meal	-	-	-	21.5
Fish meal	7	10	27	-
Soluble fish protein concentrate	5	5	-	6
Shrimp meal	12	15	-	8
Meat and bone meal	7	7	10	-
Soybean meal	-	-	15	-
Soybean cake	24	20	-	-
Sesame cake meal (expeller)	-	-	5	-
Groundnut meal (expeller)	-	-	5	17
Copra cake	5	-	10	-
Leaf meal	-	-	5	-
Rice bran (solvent extracted)	-	-	10	-
Maize	-	-	4	-
Rice	-	-	-	6
Wheat gluten	7	7	-	10
Tapioca	-	-	8 [3]	-
Blood meal	3	2	-	11
Alkane yeast	10	-	-	-
Brewers yeast	-	10	-	-
Cod liver oil	6	-	-	4
Fish oil	-	6	-	-
Cereals (wheat, corn, rice)	-	10	-	-
Spirulina	2	-	-	-
Peptonal	5	-	-	-
Snail meal (Trocus or Achatina)	2	2	-	-
Vitamins and salt [1]	5	6	-	8
Vitamin and mineral premix [2]	-	-	1	-
Antioxidant (BHT)	-	-	0.02	-
Antioxidant (ethoxyquin)	-	-	0.015	-
Methionine	-	-	-	0.5
Nutrient content, %				
Crude protein	52.2	49	37.1	40
Lipid	9.5	10	7.8	NA
Crude fibre	NA	NA	7.0	NA
Ash	NA	NA	12.9	NA

Shrimp (P. californiensis) - dry diet, crumble

Table C-4 Two feed plans for P. californiesis s hrimp from (Tacon, 1986)

Ingredient (%)	Post larvae	
	1	2
Fish meal, 60% protein	20	20
Shrimp meal, 46% protein	20	15
Soybean meal, 48% protein	29.2	34.2
n-Paraffin yeast, dried	10	10
Wheat, whole, ground	18	13
Fish solubles	2	2
Corn oil	0.5	0.5
Cod liver oil	1	1
Cholesterol	0.5	0.5
Choline chloride	1.2	1.2
Antioxidant (ethoxyquin)	0.015	0.015
Vitamin premix [1]	0.06	0.06
Sodium alginate (binder) [2]	1	1
Sodium hexametaphosphate	1	1
Nutrient content, % dry weight		
Crude protein	42.5	44.2
Lipid	4.8	4.8
Crude fibre	3.4	3.2

Appendix D: Features of L. vannamei

Features of L. vannamei

(http://nis.gsmfc.org/nis_factsheet.php?toc_id=141)

Distinguishing Features:

The rostrum is armed with dorsal and usually, 2-4 (occasionally, 5-8) ventral teeth, which are moderately long, and in young distinctly surpassing antennular peduncle. They are shorter in adults, sometimes reaching only to the midlength of second antennular segment. Carapace has pronounced antennal and hepatic spines, and lacks orbital and pterygostomian spines. The postocular sulcus is absent. The postrostral carina is of variable length, sometimes almost reaching posterior margin of carapace. The adrostral carina and sulcus short, extending to, or only slightly beyond epigastric tooth. Gastrofrontal carina are absent, whereas the gastro-orbital carina is relatively short, usually extending (at most) anteriorly about two-thirds of distance between hepatic spine and orbital margin. The orbito-antennal sulcus is well marked, with sharp cervical and hepatic carinae, and deep accompanying sulci. Branchiocardiac carina are lacking and longitudinal and transverse sutures absent. The sixth abdominal somite bears three cicatrices, dorsolateral sulcus extremely narrow or absent. The telson is unarmed. Antennules lack a parapenaeid spine and antennular flagella are much shorter than the carapace. The palp of first maxilla is elongate, consisting of 3 or 4 articles, with distal ones together flagelliform. The basal article is produced into setose proximal lobes on the lateral and mesial margins, which bear 1 or 2 long distomesial spines, and distolateral row of spinules. Basial and ischial spines are present on first pereopod, and a basial on second (Perez Farfante and Kensley, 1997).

In mature males the petasma is symmetrical, semiopen, not hooded, lacking distomedian projections, and has short ventral costae, not nearly reaching distal margin and distinctly gaping (Perez Farfante, 1975; Perez Farfante and Kensley, 1997). The spermatophores are extremely complex, consisting of a sperm mass encapsulated by a sheath and bearing various attachment structures (anterior wing, lateral flap, caudal flange, dorsal plate), as well as adhesive and glutinous materials (Chow et al., 1991).

The mature female has an open thelycum and sternite XIV bearing ridges, prominences, depressions, or grooves (Perez Farfante, 1975; Perez Farfante and Kensley, 1997).

Larval stages: This species has six nauplii stages, three protozeal stages, and three mysis stages in its life history (Kitani, 1986). The CL of L. vannamei postlarvae range from 0.88 to 3.00 mm (Kitani, 1993). The larval stages (1.95 - 2.73 mm CL) can be recognized by the lack of a thoracic spine on the 7th sternite, and relative rostral length against the length of eye plus eye stalk ranges from 2/5 - 3/5, rarely 4/5 (Kitani, 1994). The most distinguishable morphological character is the development of supraorbital spines in the second and third protozoea (Kitani, 1986). Coloration: Translucent white, thus it is most commonly known as the "white shrimp". The body of the species often has a bluish hue that is due to a predominance of blue chromatophores which are concentrated near the margins of the telson and uropods (Eldred and Hutton, 1960). Size: It grows to about 230 mm [9 inches] (Dore and Frimodt, 1987).

Similar Species:

L. vannamei can be distinguished from *L. schmitti, L. setiferus, L. occidentalis*, and *L. stylirostris* on the basis of the external genitalia. In these species, both the thelycum and the petasma, are more primitive that in species of other genera (Perez Farfante, 1969). The five species of the genus *Litopenaeus* are restricted to American waters.

Biology:

Habitat: This marine shrimp likes muddy bottoms at depths from the shoreline down to about 72 meters [235 feet] (Dore and Frimodt, 1987). Phisio-Ecology: Food and Feeding Habits: Reproduction: In L. vannamei the carapace is translucent, permitting the color of the ovaries to been seen. In females, the gonad which is first whitish, turns golden brown or greenish brown on the day of spawning (Brown and Patlan, 1974). The males deposit the spermatophores only on hard-shell females which will spawn a few hours later. The courtship and mating behavior begins in the afternoon in relation to light intensity. Regression of developing ovaries is very rare and development of the ovaries leads almost every time to spawning. The spawning process, begins by sudden jumps and active swimming of the female and the whole process lasts about one minute. The cortical reaction is very rapid and first segmentation occurs in a few minutes (Ogle, 1992). The numbers of eggs varies according to individual size. For L. vannamei of 30 to 45 g size; 100.000 to 250.000. Eggs are approximately 0.22 mm in diameter. Cleavage to the first nauplius stage occurs approximately 14 hours after spawning (Aquacop, 1979). Toxicity: None. Timing and Method of Introduction: The pacific white shrimp was imported in 1985, as postlarvae, by many shrimp farms in South Carolina (Sandifer et al., 1988).

Maximum Size:

Distribution:

type locality: Panama [Golfo de Panama] (Perez Farfante and Kensley, 1997). Distributed in the eastern Pacific from Sonora, Mexico to Tumbes in northern Peru (Perez Farfante and Kensley, 1997).

Appendix E: Interview Questionnaire
(Spanish version)

Información General

Nombre del Productor: ____

Nombre de la Finca: ____

Teléfono: ____________________ Correo Electrónico: ___________________________

Celular: __________________ Fax: ____________________Beeper:_________________

Dirección Exacta: ____

Ubicación coordenadas geográficas: ____________________

Tamaño de la finca (en hectáreas):__________________ Número de estanques: ________

Tamaño promedio de estanque (en hectáreas): ___________

Densidad promedio de camarón (por metros cuadrados): ___________

Número de empleados permanentes: _______ Número de empleados temporales: ______

¿Cuánto tiempo lleva en operación la finca? __________________

Preparación del Estanque

Secado

¿Seca los estanques? Si_____ No_____

¿Por cuanto tiempo los deja secar?___________________

¿Cómo sabe que se han terminado de secarse?___________________________________

¿Hace una evaluación del fondo del estanque? Si_____ No_____

¿Si sí, que evalúa? ____

____

¿Utiliza cal durante el secado? Si_____No_____ ¿Si sí, cuando?____________________

¿Cuánto? ____________________

Relleno del estanque

¿Cuál es su fuente de toma de agua? ____________________

¿Tiene una concesión para usar el agua? Si____ No_____

¿Qué evalúa en el agua antes de llenar los estanques (ej. pH, salinidad, oxigeno disuelto, etc.)? ____

____

Puede explicarme su proceso de llenado de estanques: ____________________________

____

____

____

____

Postlarvas (PL)

¿Donde compra o recibe sus postlarvas? _______________________________________

¿Qué edad tienen cuando las reciben? ____

¿Se hace algo contra la prevención de enfermedades antes de introducir las postlarvas?

____

____

¿Ha tenido problemas con el suministro de postlarvas, si es así cuales? _______________

____

____

¿Contrata o ha considerado contratar un técnico para que evalué la PL antes de hacer la compra? ____

____

____

¿Qué cantidad de PL compra aproximadamente para cada cosecha? __________________

¿Cuánto ha cambiado el precio de PL en los últimos cinco años? ____________________

¿Cuál es el precio aproximado hoy en día de PL? __________________________________

¿Como es transportado la PL a la finca? ____

Por favor explique el procedimiento de adaptación de las PL: _______________________

____

____

____

____

Practicas Generales

Alimento

¿En su finca, usted usa:

alimento comercial,

una fuente de alimento natural,

una combinación de las dos,

otro? ____

¿Dónde consigue el alimento que utiliza para alimentar el camarón? __________________

____

¿Qué usa específicamente como alimento (fitoplancton, fitobacteria, algas, etc.)? ______

____

____

____

¿Administra suplementos de vitamina, si es así de qué tipo? ______________________

¿Administra algún tipo de fertilizante? ____ ¿Qué tipo? _________________________

¿Qué tan seguido? ____

¿Cuándo es administrado (en la mañana, tarde, noche)?__________________________

¿Cuándo alimenta al camarón?____

¿Cómo distribuye el alimento? (¿Usa tablas de alimentación?) ____________________

____

¿Cómo establece la dosis de alimentación? ___________________________________

____

¿Qué se hace con el alimento que no fue consumido? ____________________________

¿Dónde es guardado el alimento? ____

Monitoreo

¿Qué condiciones del agua son monitoreadas regularmente?

pH __________ Salinidad __________ Oxigeno Disuelto _________ Visibilidad ______

Temperatura __________ Niveles de Estrés ___________ Otro_____________________

____

¿Cómo mide estas condiciones?

pH ____

Salinidad ____

Oxigeno Disuelto ____

Visibilidad ____

Temperatura ____

Niveles de Estrés ____

Otro ____

____

¿Qué tan seguido las mide?

pH ____

Salinidad ____

Oxigeno Disuelto ____

Visibilidad ____

Temperatura ____

Niveles de Estrés ____

Otro ____

____

¿Tiene problemas monitoreando ciertas condiciones?____________________________

____

¿A que nivel/rango se mantiene los siguientes parámetros?

pH __________ Salinidad __________Oxigeno Disuelto __________ Visibilidad _____

Temperatura __________ Niveles de Estrés __________ Otro ____________________

____

¿Qué se hace si no están en el nivel deseado (arriba o abajo)?

pH ____

Salinidad ____

Oxigeno Disuelto ____

Visibilidad ____

Temperatura ____

Niveles de Estrés ____

Otro ____

¿Qué otros tipos de análisis se realizan a nivel finca para asegurar la inocuidad de los productos? Por ejemplo: metales pesados, agroquímicos, coliformes.

____

____

____

Equipo y Mantenimiento

¿Qué tipo de equipo usa usted en su finca?______________________________________

____

____

¿Tiene algún problema con su equipo? Si____ No____

Si sí, explique:

____

____

____

¿Cuanto cuesta mantener el equipo en buen estado de trabajo (dinero y horas de trabajo)?

____

¿Necesita que un especialista o un técnico le ayude con el mantenimiento del equipo?___

____

Procedimientos Sanitarios

¿Se lavan o desinfectan los vehículos antes de entrar a la propiedad? Si_____ No_____

¿Se lavan los instrumentos y equipo después de cada uso? Si______ No_____

¿Tiene redes para prevenir que aves consuman el camarón? Si________No________

¿Qué otros procedimientos sanitarios usa o recomienda?__________________________

____

____

¿Ha tenido problemas con enfermedades u otros virus? Si_______ No________

Si es así: ¿Cuáles? ____

¿Cómo los identifica?____

____

¿Qué se hizo para combatir la enfermedad en los camarones infectados? _____________

____

¿Cambió sus prácticas después de la infección para prevenir futuras enfermedades? ____

Si es así: ¿Qué cambió?____

____

¿Ha observado mejoras? ____

____

¿Utiliza alimentos medicados? ____

¿Que fármacos para tratamiento de enfermedades son lo de mayor uso? _____________

____

Cosecha

¿Cuantas cosechas se hacen por año? ____________

¿Cuándo se hace la cosecha? ____

¿Qué tan largos son los periodos de cultivo? ____________________________________

¿Cuánto tiempo se espera entre cosechas?______________________________________

¿Cuál es el tamaño aproximado del camarón cuando es cosechado? _________________

¿Se contratan más empleados durante la época de cosecha?_________

¿Cuántos?________

Explique su procedimiento de cosecha: ____

____

____

¿Cómo es tratada el agua descargada y que se hace con ella?_______________________

____

Mercadeo y Producción

¿Cómo vende su producto?

Congelado

Fresco

Vivo

Otro: ____

¿A quién/es vende usted su producto? ____

____

¿Qué tan lejos esta/n de la finca?____

¿El cliente proporciona hielo? ____

¿Cómo es transportado el producto (en hielo, en tanques, etc.)? _____________________

____

¿El cliente proporciona el transporte? Si______ No_______

¿Si no, como es transportado? ____

____

____

¿A que precio vende normalmente su producto? __________________________________

Capacitación

¿Ha recibido algún tipo de adiestramiento o entrenamiento, o materiales informativos antes o durante la operación de la finca? Si_________ No_________

¿Si es así, por favor explique? ____

____

¿De quién o de dónde lo recibió? ____

¿Le ayudó o benefició? Si_______ No __________

¿Explique porque si o porque no? ____

____

¿Le gustaría tener entrenamiento adicional? Si ________ No __________

¿En que área cree que necesita más adiestramiento? ______________________________

¿Algunas sugerencias para procedimientos de adiestramiento? _____________________

____

¿Pertenece a una cooperativa? Si____ No____

¿Si no, estaría interesado en participar? Si ___No___ ¿Si es así, cuál? _______________

¿Si es así, le es de beneficio? Si_____ No _____

¿Por qué si, por qué no?____

____

Comentarios finales o sugerencias

Appendix F: Maps of Gulf of Nicoya

Figure F-1 Map shows Gulf of Nicoya Region in Costa Rica, and the location of Jicaral and Colorado regions.

Figure F-2 Map shows exact location visited shrimp farms. The square icons represent farms visited in the Colorado area, and the circle icons represent farms in the Jicaral area.

Reference List

Alceste, Cesar C., and Jory, Darryl E. (2002). World Tilapia Farming 2002. *Aquaculture Magazine*. Retrieved March 16, 2006, from http://www.aquaculturemag.com/siteenglish/printed/buyers/web-tilapia.pdf

A.M. Costa Rica staff (2004). Costa Rica Wins OK for Turtle-Safe Shrimping. *A.M. Costa Rica*. San José, CR, Vol. 4, No. 24. Retrieved March 26, 2006 from http://www.amcostarica.com/020404.htm

American Institute of Chemical Engineers: Center for Chemical Process Safety. (1996). *Guidelines for Writing Effective Operating and Maintenance Procedures.* New York: Author.

Barraclough, Solon and Finger-Stich, Andrea (1996). *Some Ecological and Social Implications of Commercial Shrimp Farming in Asia.* United Nations Research Institute for Social Development. Retrieved March 26, 2006 from http://www.unrisd.org/UNRISD/website/document.nsf/d2a23ad2d50cb2a280256eb300385855/a90a3147dd72acc480256b67005b6935/$FILE/dp74.pdf

Boyd, Claude E., Haws, Maria C., Green, Bartholomew W. (n.d.). *Improving Shrimp Mariculture in Latin America: Good Management Practices (GMPs) to Reduce Environmental Impacts and Improve Efficiency of Shrimp Aquaculture in Latin America and an Assessment of Practices in the Honduran Shrimp Industry.* University of Rhode Island Coastal Resources Center. Retrieved April 17, 2006 from: http://www.crc.uri.edu/download/SHR_0040.PDF

Broders, Adam, Slonski, Megan, and Douville, Matt (2005). Best Practices for Small to Medium Scale Tilapia Aquaculture. (IQP Costa Rica E'05) Retrieved March 22, 2006 from: http://www.wpi.edu/Pubs/E-project/Available/E-project-071305-115404/unrestricted/msmdabFullReport.pdf

Brock, J.A. (1997). Special topic review: Taura syndrome, a disease important to shrimp farms in the Americas. *World Journal of Microbiology and Biotechnology*, 13, pp. 415-418. Retrieved March, 29 2006 from: http://www.springerlink.com/media/2g540x56ej3rxh4bbq5r/contributions/j/q/3/r/jq3r853813w23304.pdf

Clay, Jason. (2004). World Agriculture and the Enviroment: A Commodity-by-Commodity Guide to Impacts and Practices. Washington, DC: World Wildlife Fund.

Doré, Ian. (1993). *Shrimp Supply, Products, and Marketing in the Aquaculture Age.* Toms River, NJ: Urner Barry.

Fisheries Global Information System. Updated March 7, 2006. Retrieved March 26, 2006 from http://www.fao.org/figis/servlet/static?dom=root&xml=tseries/index.xml

Fisheries & Oceans Canada. Updated May 11, 2004. *Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish: Necrotizing Hepatopancreatitis of Penaeid Shrimp.* Retrieved May 29, 2006 from: http://www.pac.dfo-mpo.gc.ca/sci/shelldis/pages/nechepsp_e.htm

Flanders, Melanie G. (1997). Document Design: A Brief Primer. *Society for Technical Communication: Theory and Research*. Retrieved May 29, 2006 from http://www.stc.org/confproceed/1997/PDFs/0114.PDF.

Food and Agriculture Organization of the United Nations. (2005) *The State of Food and Agriculture 2005: Agriculture Trade and Poverty. Can Trade Work for the Poor?*. Rome. Retrieved April 16, 2006 from http://www.fao.org/docrep/008/a0050e/a0050e00.htm#TopOfPage

González Benitez, Judith, & Prado, Patricia (2003). Programma de Capacitación: Técnicas de Bacteriología, Análisis en Fresco, Calidad de Agua y Buenas Prácticas de Manejo y Bioseguridad en Granjas Camaroneras. In Proceedings of *Comité Estatal de Sanidad Acuicola do Sinaloa, A.C.* Training Conference. Mazatlán, Sinaloa, Mexico. Retrieved June 22, 2006 from: http://www.uhh.hawaii.edu/~pacrc/Mexico/files/bmp_kwei_lin/mgt_practices.pdf

Graham, David E., Johnson, Walter F., & Lee, Adam B. (2002). *Establishing a Training Program for Aquaculture Extension Agents in Costa Rica.* Interactive Qualifying Project.

Hinrichsen, Don. Updated October 12, 2004. *Ocean Planet in Decline.* Retrieved June 23, 2006 from: http://www.peopleandplanet.net/doc.php?id=429&section=6

Hishamunda, Nathaniel, and Ridler, Neil B. (2002). Macro policies to promote sustainable commercial aquaculture. *Aquaculture International.* Netherlands: Kluwer Academic Publishers, 10(6), 491-505. Retrieved March 16, 2006, from http://www.springerlink.com/media/e7vd27d8ym1ywwe0hb7j/contributions/m/2/3/2/m23241817414w1rx.pdf

Instituto Costarricense de Pesca y Acuicultura. (n.d.). *Memoria Institucional: 2002-2006.* San Jose, Costa Rica: Author.

Johnston, Denise, and Soderquist, Chris and Meadows, Donella H. (2000). *The Shrimp Commodity System.* Hartland, VT: Sustainability Institute. Retrieved March 26, 2006 from http://www.sustainabilityinstitute.org/pubs/ShrimpRpt_7.2000.pdf

Joint Subcommittee on Aquaculture (JSA). (1997). An evaluation of potential shrimp virus impacts on cultured shrimp and on wild shrimp populations in the Gulf of Mexico and southeastern U.S. Atlantic coastal waters. Washington, DC. Retrieved online April 8, 2006 from: http://www.nmfs.noaa.gov/trade/jsash16.pdf

Kumar, D. (1999). Aquaculture Practices and There Relevant to Rural Development. *Trickle Down System of Aquaculture Extension for Rural Development*. FAO Corporate Repository. Received March 26, 2005 from: http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/003/x6946e/x6946e05.htm

Lightner, Donald V. (n.d.). *The Penaeid Shrimp Viral Pandemics due to IHHNV, WSSV, TSV and YHV: History in the Americas and Current Status*. Retrieved April 8, 2006 from: http://www.lib.noaa.gov/japan/aquaculture/proceedings/report32/lightner_corrected.pdf

Merriam-Webster Online. (2006). In *Merriam-Webster Online Dictionary*. Retrieved June 26, 2006 from: http://www.m-w.com/dictionary/red%20tide

Martinez-Cordero, Francisco J., & Leung, PingSun (November 24 2004). Sustainable aquaculture and producer performance: measurement of environmentally adjusted productivity and efficiency of a sample of shrimp farms in Mexico. *Aquaculture*. 241(1-4) p. 249-268. Retrieved March 24, 2006 from Science Direct: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T4D-4D9R8X7-1&_coverDate=11%2F26%2F2004&_alid=381988827&_rdoc=1&_fmt=&_orig=search&_qd=1&_cdi=4972&_sort=d&view=c&_acct=C000005878&_version=1&_urlVersion=0&_userid=74021&md5=0bda135bc39e0e02286062f3b364d5fb

McVey, James (1993). *CRC Handbook of Mariculture: Crustacean Aquaculture*. Boca Raton, FL: CRC Press

National Center for Environmental Assessment Office of Research and Development, U.S. EPA. (April 1999). *REPORT ON THE SHRIMP VIRUS PEER REVIEW AND RISK ASSESSMENT WORKSHOP: Developing a Qualitative Ecological Risk Assessment*. Washington, DC: Environmental Protection Agency. Retrieved online April 6, 2006 from: http://www.epa.gov/ncea/pdfs/shrimp/report/nrep-apa.pdf

Naylor, Rosamond L., Goldburg, Rebecca J., Mooney, Harold, Beveridge, Malcom, Clay, Jason, Folke Carl, Kautsky, Nils, Lubchenco, Jane, Primavera, Jurgenne, & Williams Meryl (October 20, 1998). Nature's Subsidies to Shrimp and Salmon Farming. *Science* 282(5390) p. 883-884. Retrieved on March 24 2006 from: http://www.sciencemag.org/cgi/content/full/282/5390/883

Oceans Alive. (2005) Glossary: Aquaculture. Retrieved July 4, 2006 from: http://www.oceansalive.org/explore.cfm?subnav=glossary

Otarola Fallas, Alvaro. (2002) Producción Acuicola en Costa Rica. Departamento de Acuicultura, INCOPESCA. Retrieved April 27, 2006, from http://www.red-arpe.cl/document/Otarola-Costa_Rica.pdf

Otoshi, Clete A., Arce, Steve M., Moss, Shaun M. (2003). Growth and Reproduction Performance of Broodstock Shrimp Reared in a Biosecure Recirculating Aquaculture System Versus a Flow-through Pond. *Aquacultural Engineering, 29(3-4)*, 93-107. Retrieved April 25, 2006, from http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T4C-4961W7B-1&_user=74021&_coverDate=12%2F31%2F2003&_alid=395246498&_rdoc=1&_fmt=full&_orig=search&_cdi=4971&_sort=d&_st=4&_docanchor=&_acct=C000005878&_version=1&_urlVersion=0&_userid=74021&md5=a438a8048062791a4f9b6b62cb9954e3

Oxford English Dictionary, (1989). Oxford University Press. Retrived July 4, 2006 from: http://dictionary.oed.com/cgi/entry/50185060?query_type=word&queryword=postlarva&first=1&max_to_show=10&single=1&sort_type=alpha

Quirós Arce, Juan I. (May 2002). Camaron: Noticias y Comercio Internacional. Consejo Nacional de Produccion. Retrieved March 25, 2006, from http://www.mercanet.cnp.go.cr/SIM/Frutas_y_Vegetales/documentospdf/camar%C3%B3n_Mayo02.pdf

Rosenberry, Bob (2004). *About Shrimp Farming.* San Diego, CA: Shrimp News International. Retrieved April 9, 2006 from http://www.shrimpnews.com/About.html

Tacon, Albert G. J. n.d. Aquaculture Feeds and Feeding in the Next Millennium: Major Challenges and Issues. Retrieved March 27th, 2005, from http://www.fao.org/ag/aga/agap/frg/econf95/html/tacon.htm

Tobey, James and Clay, Jason and Vergne, Philippe (1998) *The Economic, Environmental, and Social Impacts of Shrimp Farming in Latin America.* Costal Resorce Center, University of Rhode Island. Retrived April 25, 2006 from http://govdocs.aquake.org/cgi/reprint/2003/803/8030160.pdf

Van Houtte, Annick. (2000). Establishing Legal, Institutional and Regulatory Framework for Aquaculture Development and Management. *Aquaculture in the Third Millennium*. FAO Corporate Document Repository, 103-120. Retrieved April 24, 2006 from http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/003/AB412E/ab412e05.htm

Vincent, Amanda. (2004). Advances in Research on NHP. *IndustryBrief: The U.S. Marine Shrimp Farming Program*, 10(1), 3 & 7. Retrieved May 29, 2006 from http://www.usmsfp.org/news/Newsletterpdf/IBJanuary2004.pdf

Websites Used:

http://www.aquaculturecertification.org/

http://www.dec.ctu.edu.vn/sardi/cd_shrimp2/bio/lc1.htm

http://www.fao.org/

http://www.fao.org/docrep/008/a0050e/a0050e09.htm#P44_17874

http://www.fao.org/fi/fcp/en/CRI/profile.htm

http://nis.gsmfc.org/nis_factsheet.php?toc_id=141

http://www.prb.org/pdf05/05WorldDataSheet_Eng.pdf

http://tse.export.gov/

http://www.fao.org/docrep/field/003/AC418E/AC418E01.htm

http://www.mideplan.go.cr/odt/Plan%20Nacional/Desarrollo%20Regional/Agropecuario/recursos_humanos.htm

http://www.fao.org/figis/servlet/TabLandArea?tb_ds=Aquaculture&tb_mode=TABLE&tb_act=SELECT&tb_grp=COUNTRY

http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/007/y5600e/y5600e04.htm@

http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/004/Y2876E/y2876e06.htm

http://www.cia.gov/cia/publications/factbook/geos/cs.html

http://www.st.nmfs.gov/st1/market_news/

http://www.usda.gov/wps/portal/usdahome

http://www.noaa.gov/fisheries.html

http://www.usaid.gov

http://www.info.com.ph/~fishfarm/d_s_v_general.html

http://www.indian-ocean.org/bioinformatics/prawns/GIF/DISEASE/Vibriosi.htm

http://www.info.com.ph/~fishfarm/d_s_lv_growout.html

http://www.pac.dfo-mpo.gc.ca/sci/shelldis/pages/bpvdsp_e.htm

http://christensennetworks.com/

http://www.cleancodepot.com/