
**RISK ANALYSIS OF TILAPIA RECIRCULATING AQUACULTURE SYSTEMS:
A MONTE CARLO SIMULATION APPROACH**

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Risk Analysis of Tilapia Recirculating Aquaculture Systems: A Monte Carlo Simulation Approach

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(ABSTRACT)

The purpose of this study is to modify an existing static analytical model developed for a Re-circulating Aquaculture Systems through incorporation of risk considerations to evaluate the economic viability of the system. In addition the objective of this analysis is to provide a well documented risk based analytical system so that individuals (investors/lenders) can use it to tailor the analysis to their own investment decisions—that is to collect the input data, run the model, and interpret the results. The Aquaculture Economic Cost Model (AECM) was developed by Dr. Charles Coale, Jr. and others from the department of Agricultural and Applied Economics at Virginia Tech. The AECM is a spreadsheet model that was developed to help re-circulating aquaculture producers make strategic business decisions. The model can be used by potential producers interested in investing in re-circulating aquaculture through development of a financial analysis that in turn will help them obtain funding for the enterprise. The model is also useful for current producers who want to isolate inefficient aspects of their operation. AECM model consists of three major sections which include the Data Entry, Calculations and Analysis. The first section requires that the producer conducts background research about their operation to ensure accurate calculation and analysis. The calculation section provides a great deal of information about the operation's finances, while the analysis section provides information about the operation's financial stability. While the AECM is a powerful model, it is based on single, usually mean, values for prices, costs, and input and output quantities. However, market, financial and production uncertainties result in fluctuating prices, costs and yields. An individual who is making management decisions for a re-circulating aquaculture system will be faced with some or all of these uncertainties. By adding simulation to the AECM model to account for these uncertainties individuals will be able to make better management decisions. Information of the varying likelihoods or probabilities of achieving profits will be of crucial interest to individuals who plan on entering into or modifying an existing aquaculture system. Risks associated with six variables were examined in this paper: feed cost, feed conversion, mortality rate, capital interest rate, final weight, and output price. Data for the Interest Rate and output price were obtained from the Federal Reserve System and NMFS website respectively. Expert opinion was the source of data for the other variables. After probability distributions were applied to the random variables to account for the uncertainty the model was simulated for ten thousand iterations to obtain expected returns for three years in advance that the model calculates an income statement. In addition to that, sensitivity analyses were carried out in order to inform the producer which factors are contributing the most to the profitability of the operation. In this way the producer will have a better idea as to which aspects of the operation to monitor closely and consider

modifying. The analysis shows that the mean income for the three years will be negative and thus the business would be losing money. The simulated mean net incomes were: -\$216,905, -\$53,689, -\$53,111 for year1 through year3 respectively. Sensitivity analysis confirmed that output price is by far the most significant input that makes the overall bottom line to fluctuate most. Output price was on top of the list for all the three years analyzed in this study. Feed cost and Feed conversion were the next most significant inputs. The other inputs were also significant in explaining the fluctuation of the bottom line; however both their regression and correlation coefficients were small.

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement And Study Justification

With a world population over 6 billion and a continuing population growth, finding alternate economically viable sources of food is becoming a world-wide challenge. Seafood has only recently been promoted as an ideal alternate source of food that provides a good portion of the dietary proteins for many people around the world. Over recent years, the world has experienced a steady increase in consumption and production of seafood, making aquatic products a good substitute for meat and poultry.

However, there is strong evidence that shows that the world's fisheries are in crisis. Natural stocks of finfish and shellfish have been declining for years, mounting scientific evidence has shown dramatic decline in global catches (Pauly, Christensen, Guenette Pitcher, Sumaila, Walters, Watson and Zeller 2002; Meyers and Worm 2003).

According to the Food and Agriculture Organization of the United Nations, nearly 70 percent of the world's commercial marine fisheries species are now fully exploited, overexploited, or depleted (FAO 2002). In addition, there is also evidence that shows most of the world's natural fisheries have been in decline since the 1970s as a result of aquatic habitat

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degradation and fishing technology improvements. This overall slow down in global catches combined with the steady increase in consumption of sea food products¹ have led to declining fish stocks and contributed to higher world fish and seafood prices² (Aquaculture Production Technology 2005).

Given this background, in order for the world to ensure a stable seafood supply for the coming years the development of aqua-farming, otherwise called aquaculture, is considered to be of great importance. Aquaculture has the potential to reduce harvest pressure on natural stocks and support local communities that have for years relied upon fishing. Also, as consumer awareness about safety and quality of imported aquaculture products continues to rise, domestically produced aquaculture products will be able to guarantee quality. It is perceived that domestically produced aquaculture products are safer and have better quality (McLean 2007). In addition aquaculture has the potential to satisfy some of the domestic demand for seafood, thereby helping to reverse the U.S. national seafood trade deficit.

As defined by the United Nations Food and Agricultural Organization, aquaculture is the *“farming of aquatic organisms (e.g. fish, shellfish, crustacean, aquatic plants, etc) in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated”* (FAO 2005)³. While scientific

¹ Based on anticipated population growth it is estimated that world’s demand for seafood will continue to increase at about 1.5 – 3 percent per year. This would mean that by the year 2030 the world per capita consumption will increase to 20-21 kg compared to 14-15 that it currently is. (Aquaculture Production Technology 2005)

² Referring to the same source as above, nominal seafood prices from 1970 to 2003 have increased by 566%, compared with 297% increase in red meat and 194% in poultry.

³ A definition FAO obtained from several information sources; as such the definition was suggested or amended by the compiler or validator.

evidence shows that fish farming was practiced in China as long ago as 2000 B.C., modern aquaculture has only recently developed into the fastest growing segment of agriculture in many American Nations (Costa-Pierce, Rakocy 1997). Increasing fish prices acted as a stimulus for the production of a variety of cultured fish products not only in the United States but also all around the world. Referring to FAO, worldwide aquaculture output has averaged an annual increase of 8.9 percent over the past thirty or so years. From 1970 to 2003 global aquaculture production has increased from 5 million metric tons in 1970 to over 54 million metric tons in 2003, which translates into an increase of aquaculture contribution to global supplies of fish from 3.9 percent of total production by weight in 1970 to almost 30 percent of the total production by weight in 2003 (see figure 1.1) (FAO 1998a, FAO 2004).

The vast majority of world aquaculture production takes place in developing countries, particularly in Asian countries. China alone in 2002 produced over seventy percent of the total 53 million metric tons of global aquaculture production and over fifty four percent of the total value of aquaculture production (FAO 2002). In China 1.9 million ha of ponds are devoted to fish farming, and an additional 1.7 million ha are used for rice and fish culture (NOAA 2000). In addition to that, Southeast Asia produced around 2.5 million metric tones of aquaculture products from an estimated 4.6 million ha of inland ponds used for fish and rice-fish culture (SEAFDEC 2000).

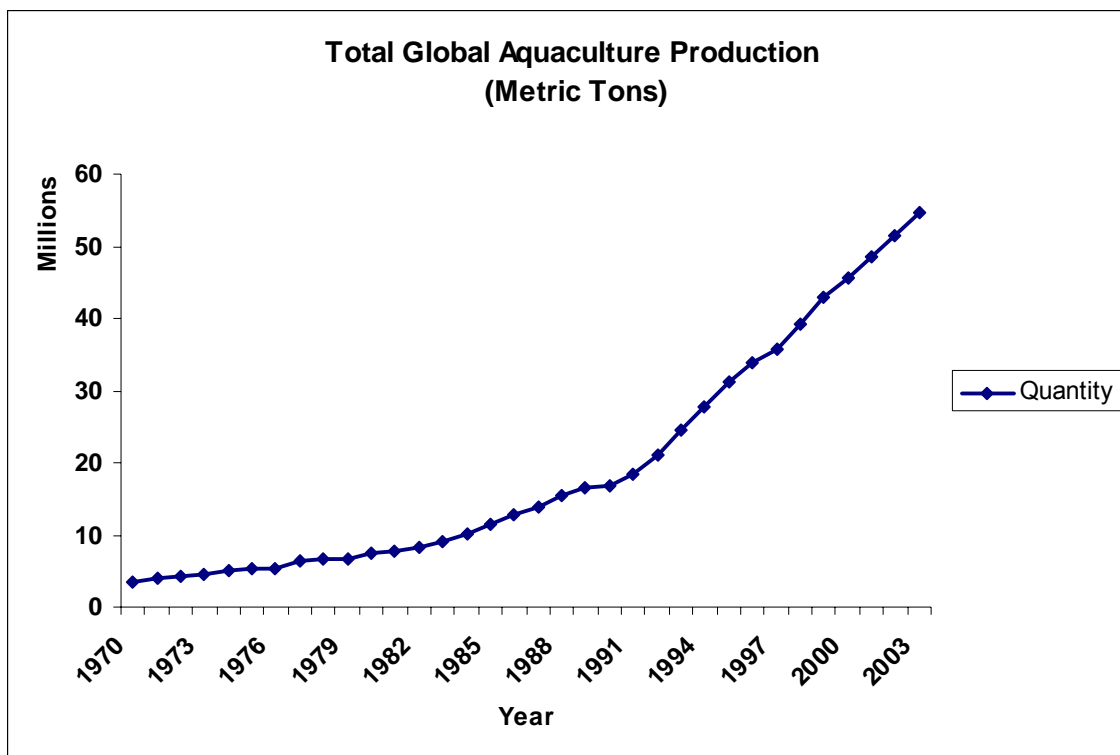


Figure 1.1 Trend in Total Global Aquaculture Production (1970-2003)

Source: *Computed based on FAO/FIDI c2002 data*

Among the industrialized countries in 2002 the leaders in aquaculture production were, Japan with over 0.8 million metric tons, an increase of over 12 percent since 1986, followed by Norway with over 0.5 million metric tons and the United States with almost 0.5 million metric tons, an increase of 4.4 percent since 2000. In fourth place was France with 0.28 million metric tons (FAO 2004).

While increases have occurred in the U.S. total aquaculture production, U.S. total production has been growing at a slower rate compared to the world average production growth (see figure 1.2). The estimated U.S. total aquaculture production (including freshwater) has more

than doubled from 326,453 metric tons with a total value over \$487 million in 1984 to a total of 544,329 metric tons with a total value of over \$804 million in 2003. Despite this, the U.S. rate of growth is still lower than the rest of the world. Figure 1.2 superimposes the two graphs (U.S. and rest of the world on the same scale) clearly the world production (pink line) is increasing faster than the U.S. production (blue line) (FAO 2004).

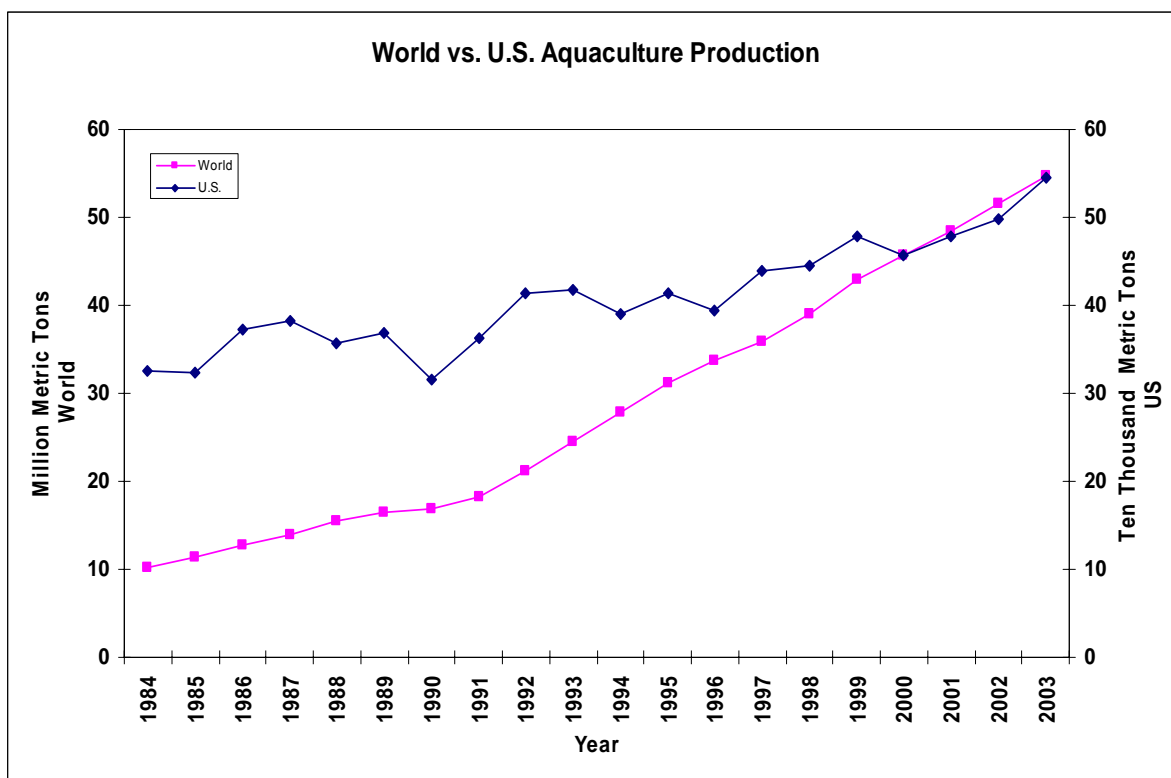


Figure 1.2 Total U.S. vs. World Aquaculture Production from 1984-2003

Source: Computed Based on FAO data

A consistent increase is also seen in the demand for fish and shellfish products. U.S. annual per capita consumption of fish and shellfish has increased since estimates were first made

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in 1910. At that time the estimated per capita consumption was 11 lbs., in the 1950's and 1960's it dropped well below 5 lbs., thereafter total consumption has constantly increased. In 2002 the rate was 15.2lbs, in 2003 it was 15.6lbs and in 2004 the per capita seafood consumption reached its historical high at 16.6 lbs (U.S. Department of Commerce/NOAA 2005).

As a goal, the National Fisheries Institute (NFI) had set a seafood consumption goal of 20 pounds per capita by 2000 a target yet to be accomplished (Anon., 1990),.

A wide variety of aquatic species are grown in the United States, and there is an increasing demand for commercially produced aquaculture products. Catfish production is by far the most important sector of U.S. aquaculture, as forty three percent⁴ of total U.S. aquaculture production is channel catfish (*Ictalurus punctatus*), grown in 73,000 ha of ponds. The ponds are located primarily in the Mississippi River valley in the states of Mississippi, Arkansas and Louisiana, which is where eighty seven percent of commercial channel catfish production occurs (FAO 1998a, USDA 2000). Total US catfish production in 1996 was 214,154 metric tons (FAO 1998a). Other important aquaculture species grown for food in the U.S. are Salmon, Trout, Shrimp, Oysters, Crawfish and Tilapia (FAO 1998b).

Tilapia, the fish this thesis concentrates on, has recently been considered as one of the most important aquatic species groups that have shown a tremendous increase in worldwide output. Global tilapia output increased from 295,162 metric tons in 1987 to 801,118 metric tons in 1996 (FAO 1998a). U.S. Tilapia production has seen a considerable increase also, from a little over 2,000 metric tons in 1990 to over 7,000 metric tons in 1996 (FAO 1998a).

⁴ Forty three percent in terms of total weight of aquaculture production

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Despite the increase in total aquaculture production in the U.S, most of the United States' demand for seafood is still met by imports. It is estimated that only ten to fourteen percent of the fishery products currently consumed in the United States are actually aquaculturally derived (USDA/ERS 2002). According to the USDA, United States is the second largest importer of seafood products in the world (USDA 2002).

The value of imported fisheries products has seen a spike since 1980. During the 1980's the value of imports more than doubled to \$9.6 billion in 1989. Imports reached a historical record high of \$11.1 billion in 2003. This increase in imports resulted in a significant trade deficit of \$4.9 billion for all fisheries products and \$3.1 billion for edible fish and shellfish in 1989. Imported fisheries products contribute more to the United States' trade deficit than any other agricultural commodity. After petroleum products, imported seafood contributes more to U.S. trade imbalance than any other natural resource product (NMFS 2003).

Despite the trade imbalance, some fish and seafood products are still exported. The U.S. fish and seafood markets have been increasing since 1998. U.S. exports reached \$3.1 billion in 2001, and U.S. market that year was boosted by increased shipments of pollock roe to Japan and South Korea and pollock fillets to Germany (USDA/FAS 2003).

The aquaculture industry supports an infrastructure of hatcheries, feed mills, processing plants, equipment manufacturers, and suppliers of specialty services and products, as well as enhancing the natural fishery with juvenile finfish and shellfish seed spat. Ensuring continuous

growth and development of aquaculture is a matter of its ability to operate profitably. Conducting economic analysis which evaluates the range and likelihood of positive profits becomes imperative at this stage for current and prospective aquaculture growers. The purpose of this study is to conduct quantitative risk analysis of a tilapia Recirculating Aquaculture System(RAS), which in turn will provide guidance on how to conduct economic feasibility analysis to current and prospective entrepreneurs interested in starting or modifying an aquaculture production system. In addition, this analytical procedure will provide guidance to lenders to help them to decide whether or not to lend money for a proposed aquaculture enterprise.

1.2. Study Problem And Objectives

The continued growth and development of aquaculture production will be determined by its ability to make profits. Estimates of net returns and their probability of occurrence are of great importance for both current and prospective entrepreneurs who are considering starting an aquaculture production system and for the lenders to understand whether or not the proposed enterprise is expected to be profitable. The final product of this analytical procedure will be a well documented risk-based analytical illustration for an aquaculture production system that users can use to tailor their own investment/management decisions. This thesis will focus on the role of six major variables: Feed cost, Mortality rate, Feed conversion, Final weight, Output price

and interest rate on the expected net return from the system for three years into the future. This will be done by incorporating risk and simulating the Aquaculture Economic Cost (AECM) model previously developed by Charles Coale, Jr. and others(Coale et.al 2003).

The AECM is a spreadsheet excel based model that helps growers identify the overall level of returns and the level of costs that will be required to run an indoor re-circulating aquaculture venture. The model provides a means for analyzing a potential enterprise before resources are committed to it. AECM is based on single, usually mean values for prices, costs, and other major factors included in the model, and thus it is a deterministic/static model. That is to say, users of the model can modify various factors to see the effect of these changes on costs and returns but in so doing, they do not get a comprehensive view of the risk associated with these costs and returns as only a limited number of possibilities/scenarios are likely to be evaluated. The production and marketing of products produced in a re-circulating aquaculture system is a dynamic process with many sources of risk and uncertainty. Given the deterministic nature of the current AECM model, producers and in particular potential producers with little experience in the industry, could develop naïve expectations about the profitability of the proposed aquaculture system. By incorporating risk analysis with @Risk for key parameters of the model(six variables outlined above), users can evaluate the likely distribution of costs and returns of existing or proposed systems considering all possible outcomes in order to determine if they represent an acceptable level of risk. After the model is simulated with @Risk a distribution of outcomes for the targeted factors will be obtained. However this is the point the use of @Risk breaks down in that the researchers are not the decision makers. In the real world decision

makers will have to consider the distribution of results given their risk preferences and make their production/investment decisions. Instead of making decisions and or recommendations in this thesis, the process of obtaining data, generating and interpreting the results will be documented so that real world decision makers can conduct the analysis using the AECM with the @Risk or other risk analysis add on software for their operations.

1.3 Who Will Benefit From This study?

The primary direct beneficiaries of this study will be the existing and potential aquaculture producers and lenders. This analysis will provide a well documented report on how to conduct risk analysis in a re-circulating aquaculture system and interpret the results. In addition, the sensitivity analyses, carried out together with the simulations, will further shed light on how robust the estimates of net returns are and what factors are more critical and most likely to affect the profitability of this prototype tilapia venture.

Secondary beneficiaries will include university and extension personnel. Aquaculture ventures just like all other businesses rely upon enterprise budgets as the basis for discussions of the cost and profitability. This study will provide the budgets (the AECM model) and the guidance on how to incorporate the uncertainty and risk into the model. These budgets then will be available for others to modify as appropriate for use in the classroom and by extension personnel as they work with existing and prospective aquaculture producers.

Virginia and the region will benefit from the availability of these enterprise budgets as well as the mechanism of incorporating uncertainty into these budgets. Lenders will be a secondary beneficiary because a more complete foundation of economic information on the profitability and risks of aquaculture production will assist lending institutions in making decisions on loan applications. This information should result in improved success rates of aquaculture loans and in turn this could result in growth of the local and regional aquaculture industry.

1.4 Brief Overview Of Methods

The previously developed, Excel based, Aquaculture Economic Cost Model and the @Risk 4.5 professional edition (Palisade Corporation) Excel add on are used in order to conduct the analysis. The inputs bearing the most uncertainty are evaluated by applying probability distributions available in @Risk, a total of thirty two distributions are currently available in @Risk. Due to lack of historical data, expert opinion was used in collecting the data to quantify some of the variables including: Feed Cost, Mortality Rate, Conversion Rate, and Fish End Weight. Historical series were obtained on tilapia whole prices and capital interest rate. After probability distributions were defined for each of the random variables analyzed in this study the AECM model was analyzed with Monte Carlo simulation. The model was simulated for about

ten thousand iterations and results on the probabilities for the range of all possible outcomes were obtained. The number of times that the model was simulated was pre-specified by the modeler; however it can also be set to iterate as a specified stopping rule is satisfied. The stopping rule states that the simulations are stopped when the results stabilize within an acceptable range (Morgan and Henrion, 1990)

1.5 Assumptions And Data Sources

In order to narrow the problem down and make this research feasible, several assumptions were made. First, it was assumed that the existing Aquaculture Economic Cost Model (AECM) contains reasonably representative information. Second it was assumed that the AECM model represents a large operation. This assumption is important for input prices; as large operations buy inputs, like feeds, in large quantities and thus receive a lower price. Third, it is assumed that the only sources of risk are production and marketing risks. It is acknowledged that other forms of risk and uncertainty exist: such as technical failures. In this study it was assumed that the probability of having technical failures in the facility is zero. Also, the Federal Reserve Prime Rate was the rate that was assumed the growers will receive for their capital borrowings.

It is natural in a risk analysis model, as in any other models, for its variables to be negatively or positively correlated with each-other. For example, in the context of the current study, experts agree that there is a negative correlation between conversion rate and mortality

rate. Meaning that as mortality rate increases, the conversion rate tends to decrease (less feed is fed for one pound gain) resulting in a decrease in the overall feed cost. Also one could argue that there is a positive correlation between final weight and output price, consumers tend to pay more for bigger fish. However, the current study assumes zero correlation or independence among the variables. At first this might seem like a very restrictive assumption, however as discussed later, this assumption was relaxed without any major impacts on the results.

Information and the data needed to conduct the analysis were obtained from various sources. The main source of data were personal interviews with fish growing experts in the area including Peter Van Wyk of the Saltville aquaculture recirculating center and Darin Prillaman of the Martinsville recirculating center. In addition to that, historical series on capital interest rate and final output price were collected.

CHAPTER 2

Background Information On Life, Biology And Economics Of Tilapia

2.1. General Information On Tilapia

Tilapia, is a family of fish that originates in Africa and the Near East. Tilapia is the generic name for the *Cichlidae* family, which contains more than 100 species that are now widely spread in tropical areas of Africa, America and Asia.

Nile tilapia (*Oreochromis niloticus*) was one of the first fish species cultured. Researchers have found that Nile tilapia was cultured more than 3,000 years ago in Egypt. Tilapia is often referred to as “Saint Peter’s fish” in reference to the biblical passages about fish fed to the multitudes. Nile tilapia still continues to be one of the most cultured species in Africa (Popma and Masser 1999).

Aquaculture production of tilapia has expanded tremendously in recent years. Tilapia sales have expanded from their traditional markets in Africa and Asia to the United States and the rest of the world. Worldwide aquaculture production of tilapia has now surpassed 900,000 metric tons and tilapia is now second only to carp as the most widely cultured freshwater fish in the world. Globally, tilapia production is in a dynamic state of expansion and its

commercialization is expected to grow into the foreseeable future. This rapid expansion of tilapia farming is primarily due to its favorable biological properties that make tilapia well suited for aquaculture. Some of these favorable properties are: salinity tolerance, great physical resistance to diseases, excellent resistance to low concentration of oxygen and fast growth. The main biological constraints for tilapia production are their inability to withstand low water temperature (below 50⁰ F) and their early sexual maturity that can result in spawning before fish reach market size (Popma and Masser 1999). In addition, the excellent quality of its firmly textured white flesh color and the limited intramuscular bones make tilapia very attractive and appetizing fish to consumers.

2.1.1 Taxonomy

The name “tilapia” is the general name for a whole group of cichlids originating in Africa. The group consists of three aquaculturally important sub-groups – *Oreochromis*, *Sarotherodon* and *Tilapia*. The three genera are quite distinctive, but what most separates one from the other is their reproductive behavior. All of the *Tilapia* species are nest builders; after fertilization, the eggs are brought to the nest and guarded by the brood parent. Both *Sarotherodon* and *Oreochromis* are mouth brooders. After fertilization in the nest, the eggs are

picked up by the parents in their mouths and held during incubation and several days after hatching (Popma and Masser 1999).

Today most of the tilapia grown outside of Africa belong to the genus *Oreochromis*, and more than ninety percent of all cultured tilapia outside of Africa is Nile Tilapia. Less intensely cultured species are Blue tilapia, Mozambique tilapia and Zanzibar tilapia.

The scientific taxonomy of tilapia has created some confusion in the last century. So the scientific name for the most popular tilapia, the Nile tilapia has been known as *Tilapia nilotica*, *Sarotherodon niloticus* and currently it has been given as *Oreochromis niloticus* (Popma and Masser 1999).

2.1.2 Biology Of Tilapia

Tilapia has a compact and very strong body. Its body is usually flat and circular in shape, but sometimes it can come in elongated form. Tilapia is shaped much like sunfish or crappie. Its dorsal fin has twenty three to thirty one bones. Tilapia can be identified from perch because it has only one nostril on each side of its head, rather than two as perch do, which serves as an inlet and outlet for the nasal cavity. Tilapia's mouth sometimes extends out or lengthens and it has a wide jaw, which most of the time is bordered by thick lips. Its teeth are cone-shaped and sometimes incisive. In some cases there is a meaty bridge in the lower maxillary, in the

center under the lip. The lateral line is forked; the upper part extends from the operculum to the last radius of the dorsal fin. There are usually wide vertical bars down the sides of fry, fingerlings and sometimes even adults (Popma and Masser 1999).

Tilapia is a type of fish that is able to live in both fresh and brackish waters. Although the vast majority of them live in salty waters, it should be noted that they cannot necessarily tolerate sudden changes in water salinity. Tilapia has bisexual reproduction. They mature sexually between two to three months of age, and at a body length of about ten to fifteen centimeters (Popma and Masser 1999).

2.2 Economics Of Tilapia

2.2.1 Market Overview

As the wild caught fishing industry continues to suffer from dramatic reductions in the supply of traditional species, aquaculture in general is now gaining a competitive advantage in the market place worldwide as well as in the U.S. (Timmons et. al. 2002).

Once viewed as a mystery of the future, today aquaculture is generally recognized as a significant source of product. Due to highly favorable opinions about seafood consumption (most Americans think of seafood as being healthy), it is predicted that the increased supply of cost

competitive aquaculture products may increase overall consumption rates (Timmons et. al. 2002). For example, tilapia consumption has soared because consumers find its flavor to be delicate and its texture flaky compared to other species at a time when reduction in the supply of wild caught traditional species like: cod, haddock, halibut and pollock, is forcing utilization of other species¹.

Tilapia continues to gain popularity as one of the most widely cultured fish. Apart from being a well adapted for a recirculating aquaculture system, tilapia is also becoming well liked by the consumers. Statistics show that tilapia consumption has doubled since 2001 in the U.S. The species is now number 6 among the top 10 types of seafood consumed by the US consumers, which is quite impressive considering the fact that tilapia entered the top 10 list only a few years ago. Table 2.1 on the next page lists the top ten seafood species consumed in the United States from 2000 to 2004.

2.2.2 Tilapia Supply In The U.S.

Even though an overall increasing trend is evident in domestic tilapia production, in particular periods total tilapia supply has seen various ups and downs. In the early 1990's total

¹ In addition to changes in tastes and preferences, recent ethnic changes in the U.S. population(i.e. increase in the Hispanic population) are another reason for this upward shift in the demand for seafood products (McLean, personal interview 2007)

CHAPTER 2
Tilapia Supply In The U.S.

TABLE 2.1: U.S. Per-Capita Consumption by Species in Pounds

Fish Name	2004		2003		2002		2001		2000	
	Cons	Rank	Cons	Rank	Cons	Rank	Cons	Rank	Cons	Rank
Shrimp	4.20	1	4.00	1	3.70	1	3.40	1	3.20	2
Canned Tuna	3.30	2	3.40	2	3.10	2	2.90	2	3.50	1
Salmon	2.15	3	2.22	3	2.02	3	2.02	3	1.58	4
Pollock	1.28	4	1.71	4	1.56	4	1.21	4	1.59	3
Catfish	1.09	5	1.14	5	1.10	5	1.15	5	1.08	5
Tilapia	0.70	6	0.53	9	0.32	10	0.35	10	Not Ranked	
Crabs	0.63	7	0.61	7	0.55	8	0.44	8	0.38	8
Cod	0.60	8	0.64	6	0.66	6	0.56	6	0.75	6
Clams	0.47	9	0.54	8	0.57	7	0.44	7	0.47	7
Flatfish	0.33	10	<i>Not Ranked</i>		0.40	9	0.39	9	0.42	9
Scallops	<i>Not Ranked</i>		0.33	10	<i>Not Ranked</i>		<i>Not Ranked</i>		0.27	10

Source: Raw data from NMFS. Top Ten List was calculated by Howard Johnson, H.M. Johnson & Associates for NFI: Available at:
http://www.aboutseafood.com/media/top_10.cfm

tilapia production and value had a steady growth (figure 2.1). This growth was strong until 1997-1998 when total tilapia value decreased drastically. Production dropped as well in response as many new entrants found it hard to meet obligations associated with the start-up financing (Lutz 2000). By the year 2000 total production and value had returned to 1997 levels for another drastic drop in total value and production in 2002.

Industry observers indicate that there are a number of failed tilapia operations sitting idle ranging from small facilities to large-scale enterprises. Reasons for prior business failures of these systems may involve both technical and marketing errors (Lutz 2000). This domestic supply shortage for tilapia in the market created an opportunity for international growers to

CHAPTER 2
Tilapia Supply In The U.S.

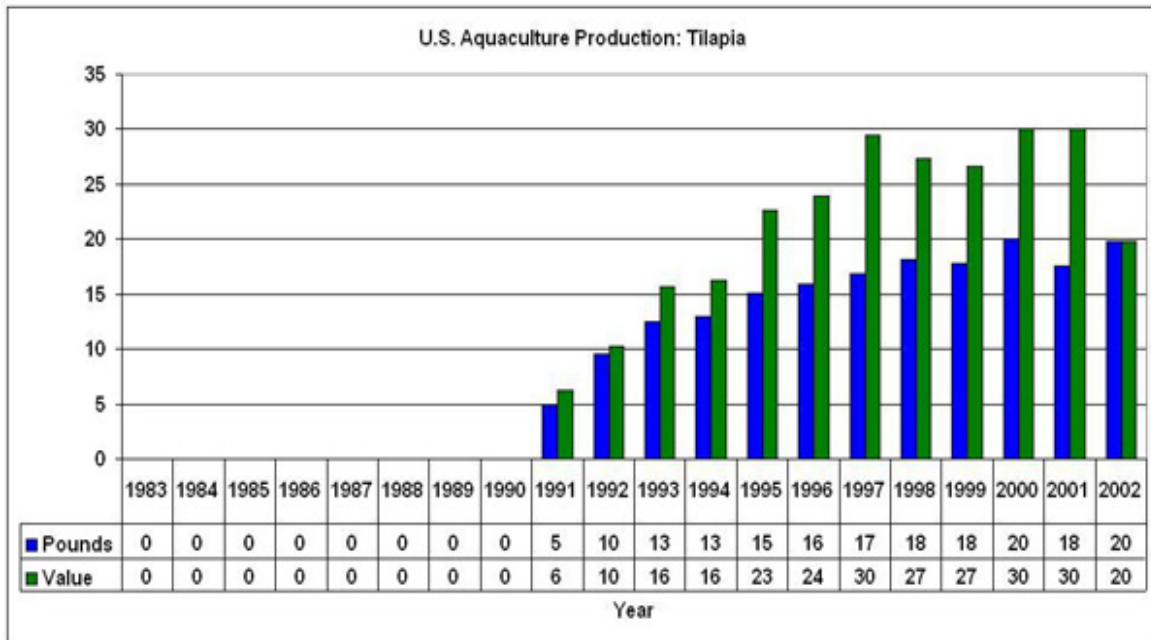


Figure 2.1 Total U.S. Tilapia Production from Aquaculture (in millions)

Source: Dr. Benedict Posadas, <http://www.msstate.edu/dept/crec/aquatilapia.html>

export tilapia products to the US. U.S. Tilapia imports continue to show a significance increase. Over the past five years tilapia imports have increased by an average of twenty five percent per year. Thus, in 2005 total tilapia imports hit a record high of over 134,000 metric tons compared to only about 25,000 metric tons that it was in 1997 (table 2.2).

Even though whole frozen tilapia continues to lead the list of the imported tilapia forms, it has not been growing at the same pace that other tilapia imported forms have. Whole frozen tilapia imports stayed relatively stable in 2004 - 2005 at about 57,000 thousand tons with China accounting for ninety eight percent of the total imports. Most of the increase in the total tilapia

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Tilapia Supply In The U.S.

Table 2.2 Total Tilapia Imports 1997-2005 (metric tons)

	1997	1998	1999	2000	2001	2002	2003	2004	2005
<i>Whole</i>									
<i>Frozen</i>									
<i>Frozen</i>									
<i>Fillets</i>	2,499	2,696	4,971	5,186	7,372	12,253	23,249	36,160	55,615
<i>Fresh Fillets</i>	2,823	3,590	5,310	7,502	10,236	14,187	17,951	19,480	22,729
<i>Total</i>	24,444	27,820	37,574	40,469	56,338	67,188	90,245	112,939	134,868

Source: Globefish: Available at: <http://www.globefish.org/index.php?id=2738>

imports is coming from frozen fillets, while fresh fillet imports also continue to increase. In 2005 frozen fillets accounted for about 42 percent of total tilapia imports to the U.S. (figure 2.2). Fresh tilapia fillets have shown a more interesting trend, growing by 17 percent in 2005 over 2004 this increase is almost exclusively coming from Honduras, with a total of over 6,500 metric tons in 2005 compared to only 164 metric tons that Honduras exported to the US back in 1997. The other source is Brazil which drastically increased its exports of fresh fillets into the US between 2004 and 2005, from 323 metric tons to 963 metric tons. The main fresh fillets supplier to the US continues to be Ecuador with about 10,600 metric tons imported in 2005.

A key player of the tilapia market in the US, however, is frozen fillets from China. Chinese exports to the US grew impressively by 77 and 57 percent in 2003-2004 and 2004-2005 respectively. All other exporters of this product reported some growth, however, China which currently accounts for 80 percent of total frozen fillets represented the bulk of the increase in 2004-2005: from 28,000 metric tons in 2004 to 44,000 metric tons in 2005. For a detailed list of

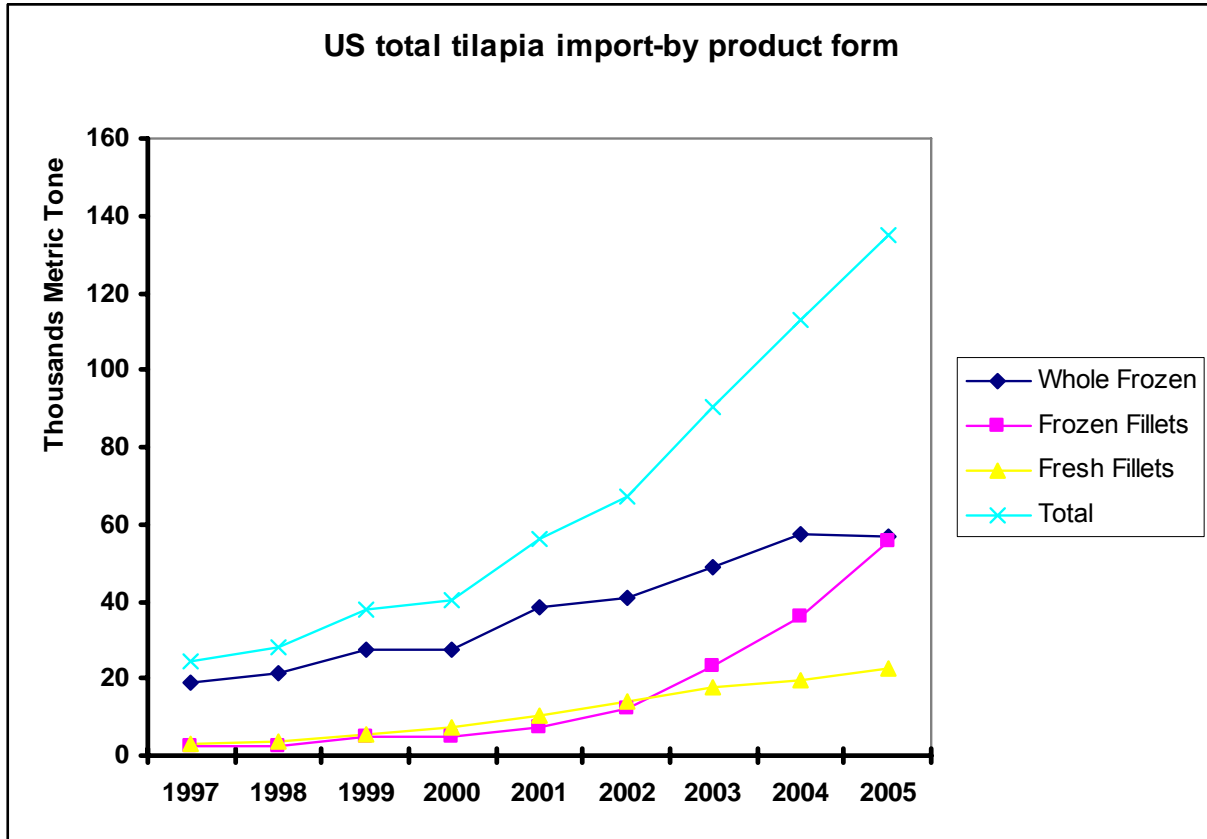


Figure 2.2 Tilapia imports by product form 1997-2005

all the three tilapia product categories and their total imports to the US by country of origin please refer to tables 2.3, 2.4 and 2.5.

By looking at the market structure of tilapia it is obvious that tilapia market is neatly split between two segments, the frozen tilapia market at low prices and the fresh tilapia fillets market at high prices. Prices of fresh tilapia fillets in the US market may have stabilized at \$ 3.85/lb

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(figure 2.3). Prices of frozen fillets are at a much lower level. Prices of frozen fillets may have also stabilized in 2005 after a downward trend since 1998 at \$1.86/lb (figure 2.4).

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Tilapia Supply In The U.S.

Table: 2.3 US Frozen Tilapia Import - By Country of Origin (in tons)

	1997	1998	1999	2000	2001	2002	2003	2004	2005
China	52	435	4,940	11,622	10,870	19,616	28,763	31,782	30,884
Taiwan	18,640	20,995	22,055	15,916	27,599	20,660	19,664	24,935	24,129
Ecuador	171	31	149	24	95	16	143	76	65
Hong Kong	0	0	0	52	0	40	135	100	40
Thailand	4	35	47	20	49	250	121	144	163
Panama	2	0	0	2	2	150	104	102	450
Others	254	37	101	145	114	17	115	160	794
<i>Total</i>	<i>19123</i>	<i>21533</i>	<i>27292</i>	<i>27781</i>	<i>38729</i>	<i>40732</i>	<i>48930</i>	<i>57139</i>	<i>55281</i>

Source: Globefish: Available on the web at: <http://www.globefish.org/index.php?id=2738>

Table: 2.4 US Frozen Fillets Import - By Country of Origin (in tons)

	1997	1998	1999	2000	2001	2002	2003	2004	2005
China	0	38	749	1,810	2,529	6,026	15,857	28,086	44,122
Indonesia	1,095	885	1,146	1,218	2,179	2,572	3,582	4,250	6,428
Taiwan	842	1,334	2,756	1,730	2,133	2,761	2,470	2,666	3,081
Thailand	224	138	115	178	209	338	940	734	870
Ecuador	108	80	56	170	140	272	186	172	267
Viet Nam	0	0	1	18	53	106	73	17	366
Panama	0	0	0	0	0	48	42	94	185
Brazil	0	0	0	0	8	49	27	0	2
Others	229	221	147	60	121	79	72	141	296
<i>Total</i>	<i>2,498</i>	<i>2,696</i>	<i>4,970</i>	<i>5,184</i>	<i>7,372</i>	<i>12,251</i>	<i>23,249</i>	<i>36,160</i>	<i>55,617</i>

Source: Globefish: Available on the web at: <http://www.globefish.org/index.php?id=2738>

Table: 2.5 US Fresh Tilapia Fillets Import - By Country of Origin (in tons)

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Ecuador	602	646	1,806	3,253	4,924	6,616	9,397	10,164	10,600
Costa Rica	1,656	2,206	2,310	2,684	3,109	3,206	3,996	4,090	3,734
Honduras	164	436	771	1,038	1,438	2,874	2,857	4,042	6,572
China	0	0	38	59	191	844	857	0	0
Taiwan	8	85	155	82	76	247	281	90	0
Brazil	1	0	0	2	0	112	208	323	963
E Salvador	0	0	0	0	0	78	189	258	307
Panama	61	4	20	159	350	147	96	93	84
Others	331	213	209	225	148	64	71	420	470
<i>Total</i>	<i>2,823</i>	<i>3,590</i>	<i>5,309</i>	<i>7,502</i>	<i>10,236</i>	<i>14,188</i>	<i>17,952</i>	<i>19,480</i>	<i>22,730</i>

Source: Globefish: Available on the web at: <http://www.globefish.org/index.php?id=2738>

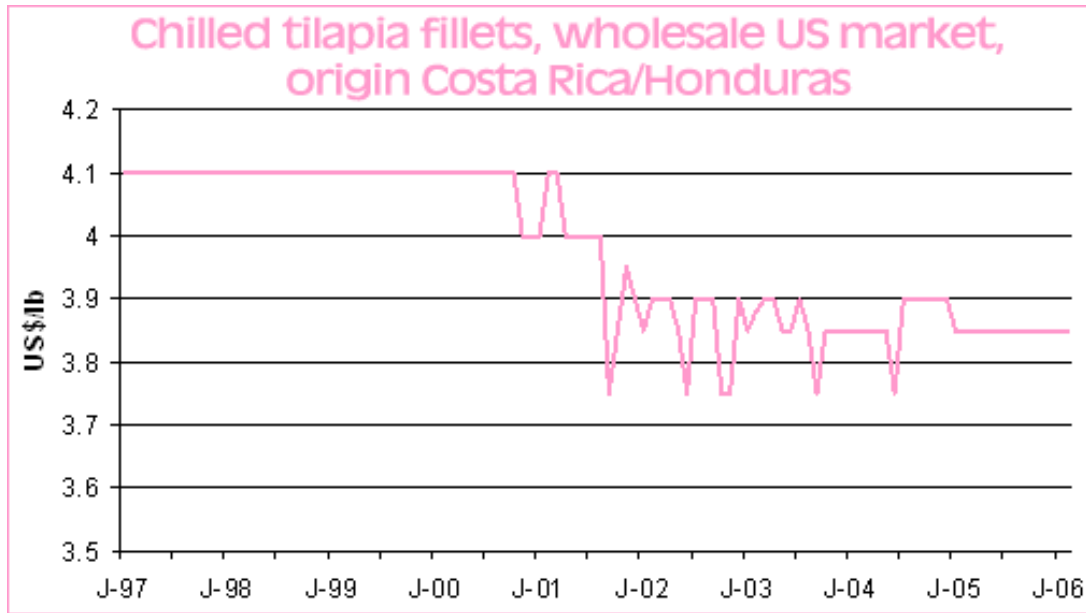


Figure 2.3 Whole sale prices for chilled tilapia fillets, origin Costa Rica/Honduras
Source: Globefish, available at: <http://www.globefish.org/index.php?id=2738>

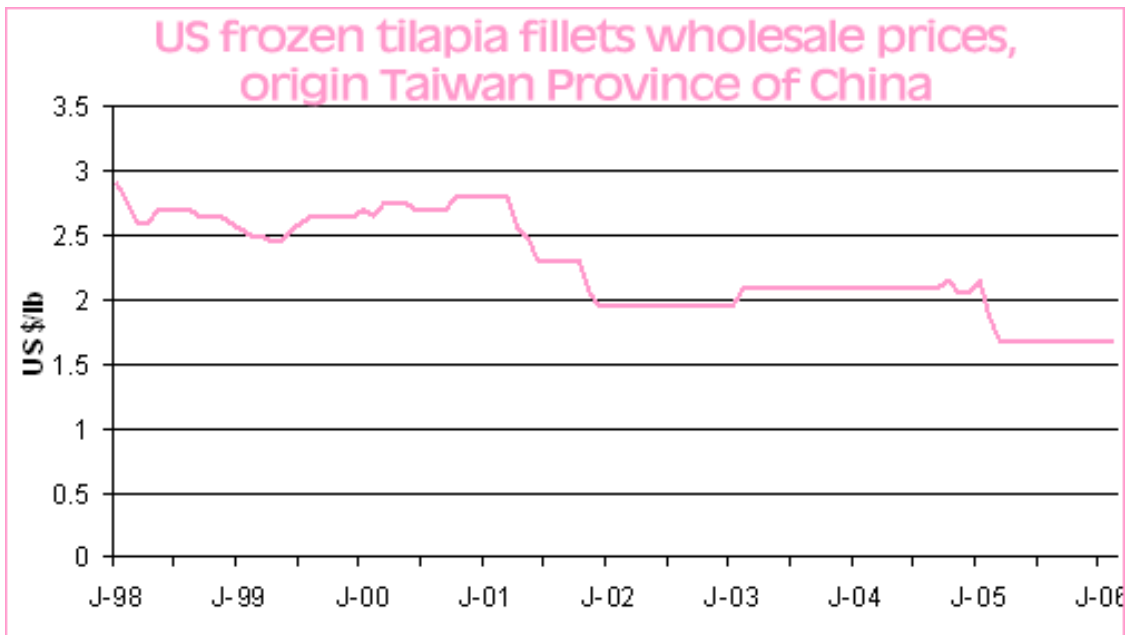


Figure 2.4 Whole sale prices for frozen tilapia fillets, origin Taiwan Province of China
Source: Globefish, available at: <http://www.globefish.org/index.php?id=2738>

CHAPTER 3

Recirculating Aquaculture Systems And Tilapia Production

3.1 Overview Of Recirculating Aquaculture Systems

Re-circulating Aquaculture Systems (RAS) are dynamic systems where fish can be stocked more intensively than in any other aquaculture systems and the total environment is controlled. Fish are raised in tanks which come in round/oval or rectangular configurations. Water circulates throughout the system and only a small percentage of the water is changed daily, making RAS very efficient system in terms of water use. Major water conditions such as: temperature, salinity, pH, alkalinity, chemical composition and oxygen concentration are all continuously or periodically monitored and altered in accordance with fish growth stages and requirements. Solid wastes are filtered and removed, oxygen is added to help maintain sufficient dissolved oxygen levels for the stocking density, and effluent water passes through a bio-filter for a biological conversion of ammonia-nitrogen to nitrate-nitrogen. RAS are complex systems that require numerous simultaneous processes and operations for the fish to grow. Designing and maintaining such a system requires a comprehensive understanding of each one of these

processes and operations. Failure of any of these operations can cause the whole system to fail, usually killing the fish in the process (Simon et. al. 2004).

RAS are very capital intensive; in fact RAS are far more capital-intensive than most of the other types of fish rearing systems. Thus, RAS must rely on high productivity per unit volume of rearing space for profitability. That is, sufficient production quantity must be realized so that overall costs per unit of production are reduced to a level that they become competitive. One key advantage of RAS is that RAS technology is species-adaptive, allowing operators to follow market trends for seafood preferences (Timmons et. al 2002).

3. 1.1 Fish Growing Tanks

Tank size and design is considered of great importance in a recirculating aquaculture facility. Many RAS operations fail because of inability of the tank to self clean. In other words the tank design should facilitate the easy removal of wastes. Fish tanks can have different sizes and shapes; however the oval or circular shaped tanks are preferred over the others since they facilitate easy cleaning in the corners by the rotating motion of water and they allow a wide range of rotational velocities to optimize fish health and conditions. In addition, circular tanks improve the uniformity of the culture environment (Timmons *et al.* 2002). To facilitate the self-cleaning process, the water column must be in constant rotation within the tank. The rotational

CHAPTER 3

Fish Growing Tanks

velocity in the culture tank should be as uniform as possible from the tank edge to the tank center and from the surface to the bottom. However, it shouldn't be any faster than that required to exercise the fish. Usually velocities of 0.5 - 2.0 times fish body length per second are optimal for maintaining fish health, muscle tone and respiration (Losordo and Westers, 1994). Velocities required to drive wastes and solids to the tank's center for tilapia should be anywhere between 20 – 30 cm/s (Balarin and Haller 1982).

Fish can be kept in the same tank throughout the growing season, or they can be transferred to different tanks in accordance with their growth stage. Size of the tank is also important in determining the density rate, which is the number of fish that will be stocked per unit volume. Density rate in turn will also depend on the fish length and weight. Timmons *et al.* (2002) suggest the following formula to estimate the number of fish that can be carried per unit volume of tank:

$$D_{\text{density}} = \frac{L}{C_{\text{density}}}$$

Where:

L = Fingerling length in cm and $C_{\text{density}} = 1.5$ inches for tilapia

Graphs summarizing stocking density for tilapia as a function of body length and body weight are presented in figures 3.1 and figure 3.2 respectively.

Some of the newer firms are utilizing larger tanks than they were using throughout the 80's and 90's. Then the average tank size was 8 m in diameter and it was considered a large tank; nowadays we are seeing tanks anywhere between 10-15 m in diameter. Substantial savings in

both capital and labor costs can be realized by using larger tanks, however the downside of this is that as tank size increases so does the risk for having catastrophic economic failures. If things start to go wrong in a tank the whole tank will fail and not just part of it.

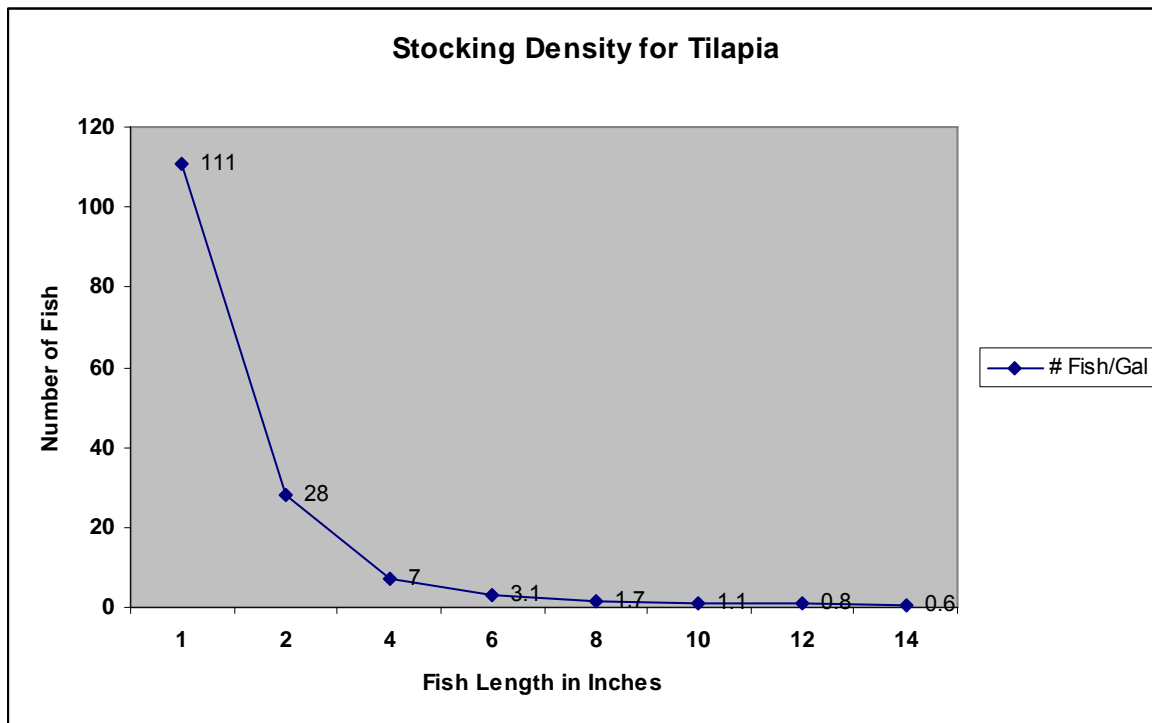


Figure 3.1 Fish per Gallon of Water as a Function of Body Length for Tilapia

Source: Computed based on Timmons *et al.* 2002, pg 122 data

3.1.2 Solids Capture And Removal, The Sedimentation Tank

Since suspended solids adversely impact fish performance, the first consideration when building a RAS is the removal of solids and wastes. Suspended solids and wastes mainly come from feces, biofloc (dead and living bacteria), and uneaten food. The size of the suspended particles will vary greatly ranging from cm size to micron (μm) size. Timmons *et al.* 2002 reports that the majority of these suspended particles will be less than 100 μm in size.

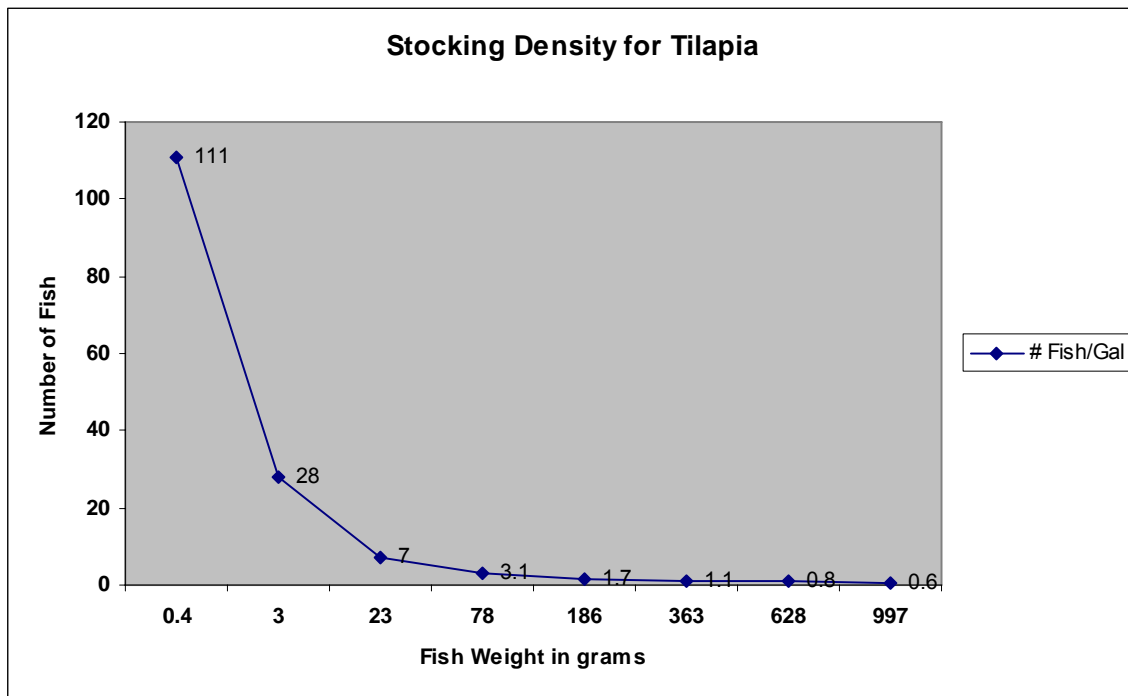


Figure 3.2 Fish per Gallon of Water as a Function of Body Weight for Tilapia

Source: Computed based on Timmons *et al.* 2002 data, pg 122

Literature shows that mechanical filtration fails to clean up particles of this size (Chen *et al.* 1993). So sedimentation and screening is used for removing large particles and foam fractionation, whereas ozone treatment is used to remove fine solids. Granular media filters can control the widest range of solids and for that reason they are the most popular choice for the sedimentation tank. Suspended solids consist of both organic and inorganic components. The organic component consumes oxygen and contributes to biofouling problems, while the inorganic component triggers and helps the formation of sludge deposits. Contradictory literature exists on the acceptable upper limit of total suspended solids (TSS). FIFAC (1980) advises that TSS be maintained at below 15 mg/L, while Muir (1982) recommends a maximum for TSS between 20 – 40mg/L for the same systems. Evidence cited by Chapman *et al.* (1987) states the concentration depends on the particular species and the distribution of particle size. A general rule of thumb provided by Timmons *et al.* (2002) states that the amount of TSS produced will be equal to: 0.25* dry weight of fish feed.

3.1.3 Nitrification And The Bio-filter

In recirculating aquaculture systems nitrogen is of primary concern as a component of the byproducts generated by rearing fish. Nitrogenous wastes come from four main sources: (1) Urea, uric acid and amino acid excreted by the fish; (2) organic debris from dead and dying

organisms; (3) uneaten feed, and feces; and (4) as nitrogen gas from the atmosphere. The decomposition of these nitrogenous wastes, called ammonia, is of great importance due to the high toxicity that ammonia poses to the fish. The process of ammonia removal by a biological filter is called nitrification. There are generally three ways for ammonia removal: air stripping, ion exchange and biological oxidation. Out of the three systems bio-filters are the most commonly used tools in RAS for ammonia removal. There exist a number of different bio-filters used today such as: rotating biological contractors (RBC), fluidized sand reactors, trickling bio-filters, bead/micro-bead filters and dynamic bead bio-filters (Simon 2004.)

3.1.4 Oxygenation And Aeration Of Fish Tanks

In order for the fish to grow normally in a RAS dissolved oxygen in the tank should be maintained at least at about 5mg/L. The availability of dissolved oxygen in the tank is a primary limitation to increasing production capacity in intensive RAS. If only simple aeration is used to provide dissolved oxygen the system will support only about 0.33 lb of fish per gallon of water. But, if pure oxygen and high efficiency gas transfer devices are used to increase the amount of dissolved oxygen the stocking density can easily increase up to 1 lb/gallon of water, which translates into over two hundred percent increase in production capability of the same system.

There are three types of oxygen transfer systems: high pressure oxygen gas, liquid oxygen and on-site oxygen generators.

3.1.5 Carbon Dioxide Stripping Unit

Fish and bacterial respiration are the main sources of carbon dioxide introduced in the system; however, carbon dioxide can also come from decaying organic matter and atmospheric diffusion. As stocking densities increase and water exchange rates decrease, dissolved carbon dioxide will become a limiting factor to production. Carbon dioxide is very toxic to fish as it reduces the capacity of the blood to transport oxygen. As the concentration of the carbon dioxide in the water increases so does blood CO₂ level. The safe operating level of CO₂ for tilapia is around 60mg/L (Timmons *et al.* 2002). Removal of carbon dioxide is easily done through a gas exchange process using air stripping columns. Accurately predicting the exact carbon dioxide removal rate is difficult due to the complexity of the equilibrium system that CO₂ is part of and due to the fact that atmospheric concentration can adversely affect the stripping.

3.2 Production Management

When tilapia is grown in a RAS stocking density typically starts out very high for fry and then it is decreased at regular intervals throughout the production cycle to avoid overcrowding and to ensure adequate water quality and efficient tank space usage. It makes no economic sense to pump water for a tank system which is stocked initially at one tenth of its capacity. As density becomes too high, fish are physically moved to new tanks or given more space by adjusting screen partitions within the rearing tank. Tilapia exhibits a very high mortality rate, as high as twenty percent, during the fry rearing stage. However as fish grow and become hardier the mortality rates drop drastically, such that no more than two percent of the fish are expected to die during final grow out. Usually fry are given a diet containing forty percent protein and they are fed continuously throughout the day. The feeding rate is usually at twenty percent of the body weight and as fish grow bigger it drops down to five-ten percent (McLean 2007). With high quality feeds and proper feeding techniques the feed conversion ratio should average 1.5 pounds of feed for a 1-pound fish weight gain. Total tilapia production levels in a RAS facility can range from 3 to 6 pounds/ft³ (Rakocy, 1989).

CHAPTER 4

Model Development

4.1 Overview Of Risk Analysis

In the generic sense risk analysis is any method, quantitative or qualitative, which aims to develop a comprehensive understanding and awareness of the risk associated with a particular decision making situation. In other words, a forecast is obtained for the situation in the form of a probability distribution. Over the years many techniques have been developed to blend both the quantitative and the qualitative methods of risk analysis. The goal of any of these methods is to present the decision maker with a course of action to help him/her choose that course of action that best fits his/her preferences through a better understanding of the outcomes that could result from each of these courses of action. For a particular situation a decision maker is generally faced with a number of alternative actions rather than a single option due to risk or uncertainty that the situation possesses. The concept of risk comes about due to our recognition of future uncertainty – our inability to know with certainty what the future will bring in response to a given action taken today. Simply stated, risk implies that a given action has more than one set of outcomes each being equally or not equally likely to occur. Risk is present everywhere, ranging

from every day life situations to major business situations, that is almost every action is “risky”. The term “risk” is, however, usually reserved for situations where the range of possible outcomes to a given action is in some way significant. When the possible outcomes become significant, it means that the outcome of an action will affect our or others’ welfare. When such a welfare impact is possible some form of risk analysis may be appropriate.

Businesses have been dealing with risk since the beginning of the history of commerce and without doubt every business in today’s world is characterized or faced with some form of risk and uncertainty, whether it is launching a new product in the market or making a small decision such as to hire/fire an employee. A recirculating aquaculture facility is no exception. Risk in a RAS includes biological and environmental factors as well as market uncertainties in both input and output prices.

4.1.1 Analyzing Risk

In the past, when little was known about risk analysis, most managers had looked at the risk of a particular situation, acknowledged its existence and moved on with whatever action they thought was appropriate. Little quantification of risk and uncertainty was done. In fact, most of the decision makers looked only at single point estimates of a project’s profitability. One of

the few approaches used to deal with risk and uncertainty in the past was the application of scenario analysis. Scenario analysis is a procedure by which the decision maker evaluates three scenarios: the best case, the most likely and the worst case scenario. The scenario analysis method for evaluating risk has a major drawback in that the problem of interdependencies is not addressed. That is, the procedure assumes that the random variables examined do not depend on one another (Hertz and Thomas 1983).

A related approach discussed in Mun (2004) for evaluating risk is that of *What-if* or *sensitivity* analysis. Each uncertain variable of the model is perturbed and varied a pre-specified amount and the resulting change on the target variables is captured. This is an excellent approach for understanding which input variables impact the output/target variables the most; however it is a method that only can look at a *limited number*¹ of cases/scenarios, and thus it is not a very comprehensive method for analyzing risk. Both of the above methods are widely used in the risk analysis literature; however a better and more robust method is required. This is the point where simulation comes in. Simulation can be viewed as an extension of the traditional approach of sensitivity and scenario analysis. The term simulation means an analytical method that is designed to imitate the real-life system. In a simulation model the problem of interdependencies is accounted for by using correlations. The uncertain variables are simulated for thousands of times to emulate all the potential permutations and combinations of outcomes. The most widely used simulation in the literature of risk analysis is the Monte Carlo simulation. Monte Carlo

¹ Performing What-if scenario analysis can be time and resource consuming. Only a limited number of scenarios can be analyzed as time and resources are scarce. Also with a complicated model, possible scenarios can be unlimited in number thus making the task of recalculating the model for each scenario very hard

simulation, named after the famous gambling capital of Monaco, is a very popular and powerful method. Monte Carlo simulation is a method that is stochastic in nature- meaning that it is based on the use of random numbers and probability distributions to investigate problems. Monte Carlo simulation in its essence is just an enhanced form of the sensitivity and scenario analysis but it is automatically performed for thousands of iterations while accounting for all the dynamic interactions between the random variables. That is, during the simulation, values for the uncertain coefficients are randomly selected by a computer software based upon their underlying probability distributions, the results are calculated and then another set of values are again randomly drawn and the new results are calculated and so forth for a large number of times (Mun 2004).

Monte Carlo simulation finds use in the public and private sector, ranging from disease management in endangered species captive breeding programs to managing energy production (Paisley et. al. 1999, Pilipovic 1997, Høgåsen and Brun 2003). There is an ongoing debate between statisticians and mathematicians on the validity of the method. Nevertheless, Monte Carlo simulation remains one of the most widely used methods in risk analysis that simulates difficult and complex stochastic mathematical models with great ease. Monte Carlo simulation as a random number generator works well for estimation, forecasting and risk analysis. A simulation calculates numerous scenarios of a model by repeatedly picking values from a user-predefined probability distribution for the uncertain variables and using those values to recalculate the model. As all those scenarios produce results from the model, each scenario can be a forecast (Mun 2004).

4.1.2 Measuring Risk

Literature in risk analysis provides multiple ways to measure and express risk associated with uncertain situations. This section will try to give a brief list of the major ways to express risk and the advantages and disadvantages that arise with each method of expressing risk.

- *Probability of occurrence*: This is the simplest approach and yet very effective.

Two similar projects might incur the same identical costs and based on single point estimates management might be indifferent between the two. However, if risk analysis such as Monte Carlo simulation is performed and reveals that the first project has a greater probability for losses than the second project then clearly the second project will be preferred. For more on probability and the major probability distributions used in Monte Carlo simulation please refer to the following section (4.1.3).

- *Standard Deviation and Variance*: Standard deviation is a measure of the average of each data point's deviation from the mean. This is, perhaps, the most popular measure of risk, where a higher standard deviation implies a wider spread of the outcomes from the mean, and thus a higher risk. The drawback of this measure is that both upside and downside variations are included in the computation of the standard deviation. Some analysts define risk as the potential losses or downside; thus standard deviation and variance will penalize upswings as well as downsides. Another major problem with this measure is its inability to compare differently scaled distributions (Mun 2004).

- *Coefficient of Variation*: This is a measure of the variation of the standard deviation. Stated differently the coefficient of variation is defined as the ratio of standard deviation to the mean which means that risks are normalized. Thus the problem of scale is fully addressed with this measure of risk. This measure of risk is applicable when the variables' estimates, measures, magnitudes or units differ (Mun 2004).

- *Value at Risk*: is another measure of risk introduced in the mid 1990s. Since its introduction it has been put to use by several bank governing bodies around the world. In short, this method measures the amount of capital reserves at risk given a particular holding period for that capital at a particular probability of loss (Mun 2004).

- *Volatility*: Volatility can be briefly defined as a measure of uncertainty and risk. This measure can be estimated using multiple methods including simulation of the uncertain variables and estimating the standard deviation of the variables over time. This measure is more difficult to employ than the others; however is the most powerful one in that it incorporates all sources of uncertainty in one single value (Mun 2004).

Probability of occurrence and probability distributions are the measures used in this analysis¹. This is because Monte Carlo simulation supports only this measure of risk and yet this measure is the most practical. It is also the most popular measure of risk. The number of probability distributions has been continuously enriched since the early days of statistics. Today there are almost enough probability distributions to describe virtually any probabilistic event that

¹ If the other methods of measuring risk presented in this section use only certain moments of the distribution to express risk, the probability of occurrence uses the entire probability distribution.

CHAPTER 4

Measuring Risk

one can think of. Some of the major probability distributions used in literature are presented in appendix G. A number of these probability distributions will also be used in the simulation analysis in this thesis. For a more complete list of probability distributions available for modeling the reader is advised to consult Mun (2004), Spanos (1999), or Morgan and Henrion (1990)

Modeling Risk

Overview of Risk Modeling

In general, there are four steps that encompass the techniques in performing risk analysis with @Risk simulation:

- *Develop an Excel spreadsheet model* – This is the stage when the problem or situation involving the uncertainty is defined, and this is usually laid out in an Excel worksheet format.
- *Identify sources of uncertainty in the model* – uncertain variables in the spreadsheet model are identified and their possible values are specified using probability distributions, these variables are called risk model input variables. In addition to uncertain input variable identification, the worksheet results that the analyst wants to examine in the risk analysis are identified and selected. These results are called risk model outputs.
- *Analyzing the model with simulation* – the simulation will determine and provide the range and the associated probabilities of all possible outcomes of the analyzed model and its outputs.
- *Make a decision given the results* – based on the results provided and personal risk preferences management decisions are made. This is the point where @Risk results are not clear

cut, that is, each decision maker will view the results differently and make decisions in accordance with his/her risk preferences.

4.2 Develop An Excel Spreadsheet Model

The Excel spreadsheet that was used to conduct the analysis in this project is the Aquaculture Economic Cost model (AECM) developed by Charles Coale, Stephanie Smith and others. The principal work, in preparing the AECM model, conducted by Stephanie Smith and her advisors was to build the model, complete the review, and to test and validate the model by using it to evaluate actual and proposed commercial aquaculture operations. In addition, a user-friendly interface was developed. At present the model is being prepared for public distribution.

The AECM model is an Excel-based model created to help current and potential RAS producers estimate the costs and returns for an existing or proposed re-circulating system. In addition it helps producers make production and marketing decisions. The model also develops financial summary sheets and performs financial analyses which could help the entrepreneur obtain funding for starting a business. For current producers the model is useful in that it can help them isolate inefficient aspects and evaluate potential modifications of their operation. The model isolates the inefficient components by detecting the most inefficient aspects of the operation through sensitivity analysis. Producers can then take steps to adjust or eliminate assets

or procedures inhibiting operation's growth and its ability to generate higher profits. The AECM model consists of three major sections, which include the Data Entry section, the Calculations section and the Analysis section. The first section will require that the modeler conducts careful and detailed background research about the aquaculture operation in order to ensure that accurate data is entered for analysis. The calculations section provides a great deal of information about the operation's finances, while the analysis section examines all of the calculations and provides information about the operation's financial stability.

4.2.1 Data Entry Section:

This is the section where general information and cost information on the business is entered. All the variable costs of the operation are entered in this section. The variable costs consist of six categories of entries which include: feed, chemicals, labor, additional expenses, cash balance and income. Information about the fish such as initial weight, feed conversion, mortality and so forth is also entered in this section. In addition to variable costs mentioned above, Equipment Costs and Electrical Components are also entered in this section. There are two subsections that make up equipment costs: subsection one that has two tables listing specific items that are used in a recirculating aquaculture system and subsection two which consists of one table addressing the depreciation expense calculated for the income statement. The Electrical

Components section collects data about the electrical apparatuses used to run the system to calculate the electricity use.

Heating, water, sewer and electrical costs are entries that are collected in the Heating and Utility Information section of the Data Entry. There are three sources of heat available to choose from or the estimated monthly bill could be entered without specifying the source of heat. Building information, loan information, recirculating system components including tank information and labor information are other entries required in the data entry section in order to calculate the overall system costs. For a detailed explanation of each of the entries mentioned above please refer to the Read Me section of the AECM model or refer to Appendix A (Coale et al. 2003).

4.2.2 Calculations Section

This is the section that performs all the calculations and consists of six subsections including *Cost of Production, Break Even and Unit Cost, Depreciation, Balance Sheet, Income Statement and Cash Flow Sheets*. The cost of production worksheet calculates all of the fixed and variable expenses that occur in a production cycle. The first column lists all the variable expenses, the units for each variable (gallons, lbs, kg. etc), the unit cost for each variable, the quantity, the cost per one tank for one cycle are calculated and then in the final column the total

CHAPTER 4

Calculations Section

cost for the entire system for one cycle is calculated. The second half of the Cost of Production worksheet lists all of the fixed expenses. These are the expenses that will be encountered whether the venture is operating at full, half or at its minimum capacity. For an operation to survive in the long-run these expenses must be covered regardless of whether production occurs or not.

In the Break Even (BE) and Unit Cost worksheet there are four different break even points calculated: Variable Costs BE, Fixed Cost BE, Total Cost BE and Total cost plus a pre-specified salary BE. Each of these four BE points calculates the minimum price/lb that needs to be received in order to cover variable expenses, fixed expenses, total expenses, and total expenses plus a pre-specified salary for the operator respectively. The final listing in this worksheet is the standard price per pound tilapia producers are receiving in the market. This final section is presented for comparative purposes. This comparison will help to determine the correct pricing structure for the operation.

Straight-line asset depreciation is also addressed and calculated in the calculations worksheet. It is organized in a fashion to calculate the straight line depreciation for each item that is considered when determining the depreciation expense on the income statement. The straight-line depreciation method assumes that an item will depreciate at the same rate/amount each year. The literature provides several other methods for calculating depreciation (such as the Reducing Balance method) however the straight-line is the most commonly used method¹. The

¹ While the Straight-Line depreciation method is based on the principle that each accounting period of the asset's life should bear an **equal amount of depreciation**, the Reducing Balance method provides a high annual depreciation charge in the early years of an asset's life but this depreciation charge reduces progressively as the asset ages. To achieve this, a fixed annual depreciation percentage is applied to the **write-down value** of the asset.

CHAPTER 4

Calculations Section

spreadsheet supports a span of depreciation of up to thirty years². In the schedule, the accumulated depreciation, and the total amount that the item has depreciated over a certain number of years is listed in the columns. The accumulated amount can be found on the balance sheet when determining the value of the asset. However, on the income statement the depreciation cost will be of the same amount every year that an item can be depreciated.

In addition to calculating all of the variable, fixed and depreciation costs, the calculation section prepares three of the most used financial statements for a business, starting with the *balance sheet*. The model is capable of producing three years worth of balance sheets. Each of these balance sheets is designed to represent one production year. The Balance sheet presents total assets, total liabilities and owner's equity at the end of the production year. This information is important when organizing a business plan and when operation's financial stability is being evaluated. *Cash Flow and Income Statements* are the other two statements produced in the calculation section. The cash flow sheets are broken down into sections to demonstrate the cash in flows and out flows for each month of the operation. The cash flow sheets also calculate the necessary borrowing needs so that all of the business expenses are being covered. Moreover the operator's ability to repay these loans is calculated in this worksheet. All sources of income and expenses listed on the cash flow sheet are accounted for in the income statement. Lenders want to review income statements to determine the profitability and financial efficiency of an operation before agreeing to lend (Coale et.al. 2003). Appendix B contains the

² The span of depreciation can be adjusted depending on the type of asset being depreciated. However the maximum span over which an asset can be depreciated is thirty years.

section of calculations from the AECM model, the cash flow statements are not presented in appendix B due to their large size.

4.2.3 Analysis Section

The analysis part of the AECM model consists of three main sections: the executive summary, business ratings and the improvement section. The executive summary, as the name suggests, compiles an overall summary of the financial ratio analysis. The executive summary lists the results of the analysis for the first two years of the operation. A three color (red, yellow and green) coded system was developed for all the ratios. The colors correspond to a traffic stoplight. Red means immediate attention, yellow means needs attention and green means the ratio is within the safe range for the business' financial wellbeing¹ (Coale et. al. 2003).

The business rating sheet provides an aggregate rating of the business. Ratings are assigned to the statistics calculated from the ratio analysis. These ratings measure the strength of the ratio. Depending on the value of the ratio the rating ranges from zero to four, with four being the best and zero the worst. The values for all ratio ratings are summed to provide an overall rating of the enterprise. The overall rating ranges from zero to twenty, meaning that if all the five

¹ A full explanation of the color coded system for business financial ratios is given in Appendix D

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Identify And Quantify Sources Of Uncertainty In The Model

ratios were assigned a rating value of four the overall business rating would be twenty and vice-versa for a business rating value of zero. The three color coding system is also used for the overall ratings. An overall rating of 14 and above is assigned green, between 5 and 14 it is assigned yellow and below 5 it is assigned red.

The improvement sheet¹ calculates the sales, price received and the number of pounds needed to be produced for the business to get the ratios back into the green range if they are not there already. This sheet might produce unrealistic numbers; however it is only intended for those operations that are very close to being within the green range for the specific ratios. Its purpose is to give a general idea to the producer as to how easily he/she can put the business back into financial feasibility.

4.3 Identify And Quantify Sources Of Uncertainty In The Model

Recirculating Aquaculture production is a dynamic activity that is characterized by a number of sources of risk and uncertainty. Risk in a RAS can be related to production, marketing and/or technological failures. In this analysis, only the production and marketing components of risk are being considered. By searching the literature and talking to experts in the field, the six predominant sources of uncertainty in a recirculating system that were identified are: feed cost,

¹ Note that the improvement sheet of the AECM model is presented under “What actions are necessary to improve financial ratios” in Appendix C

CHAPTER 4
Identify And Quantify Sources Of Uncertainty In The Model

mortality rate, feed conversion rate, end weight, selling price and capital interest rate. As stated previously, in addition to using the available historical data, personal interviews with experts (an expert is defined as someone with sufficiently long experience) in the field were conducted to elicit values and their associated probabilities for some of the uncertain factors which were used in simulation. Lori Marsh, of Biological Systems Engineering at Virginia Tech facilitated the process of conducting the interviews.

For the Selling Price and Capital Interest Rate variables historical data were obtained. Prices over the 12 month period for each year from 1987 to 2004 were averaged to obtain a single price for each year. The following table lists the tilapia average selling price over the 18 year period.

Table 4.1: Tilapia Retail Price; Southeastern U.S. (\$/lb)²

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995
Price	\$1.62	\$0.85	\$1.10	\$1.94	\$1.74	\$0.95	\$1.01	\$0.98	\$0.84
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
Price	\$0.91	\$1.14	\$1.06	\$0.97	\$0.94	\$1.04	\$0.97	\$0.93	\$0.93

Source: 1988-2004 Annual Summaries: National Marine Fisheries, Statistics Division.

For the purpose of modeling capital interest rate, federal prime rate was considered a good approximation for the variability of interest rate and was used in this analysis. Federal Prime rate was obtained directly from the Federal Reserve website. As in the case of output

² These are nominal prices. It is acknowledged that if prices were to be adjusted to current dollars with 2004 as the base year, the risk would increase. This is because the distribution of output price would die out quicker (as we will see later output price will be characterized by an exponential distribution) making output price even more variable and thus increase Netprofit's variance.

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price, monthly observations were averaged to get a single rate for each year. Prime Rate data exists from year 1967; however systematic monthly observations exist only from 1980³. For this reason, only the period of data from 1980 to 2005 was considered in this study. The following table contains the data on prime rate used in modeling the capital interest rate. In addition to the table, a chart with the same data is presented on the following page, in figure 4.1 just to give a general idea of how volatile the capital interest rate is and what the general trends have been for the past two and a half decades.

Table 4.2: US Federal Prime Rate from 1980-2005

Year	<i>1980</i>	<i>1981</i>	<i>1982</i>	<i>1983</i>	<i>1984</i>	<i>1985</i>	<i>1986</i>	<i>1987</i>	<i>1988</i>	<i>1989</i>
Rate⁴	15.26	18.88	14.87	10.80	12.07	9.95	8.35	8.21	9.31	10.87
Year	<i>1990</i>	<i>1991</i>	<i>1992</i>	<i>1993</i>	<i>1994</i>	<i>1995</i>	<i>1996</i>	<i>1997</i>	<i>1998</i>	<i>1999</i>
Rate	10.02	8.51	6.25	6.00	7.13	8.83	8.27	8.44	8.36	7.99
Year	<i>2000</i>	<i>2001</i>	<i>2002</i>	<i>2003</i>	<i>2004</i>	<i>2005</i>				
Rate	9.23	6.97	4.68	4.12	4.34	6.18				

Source: Federal Reserve

³ Prior to 1980 not all monthly observations were available, thus averaging the information to get a single rate for the year would not produce a representative rate for the year.

⁴ Remember this is the average rate for the year.

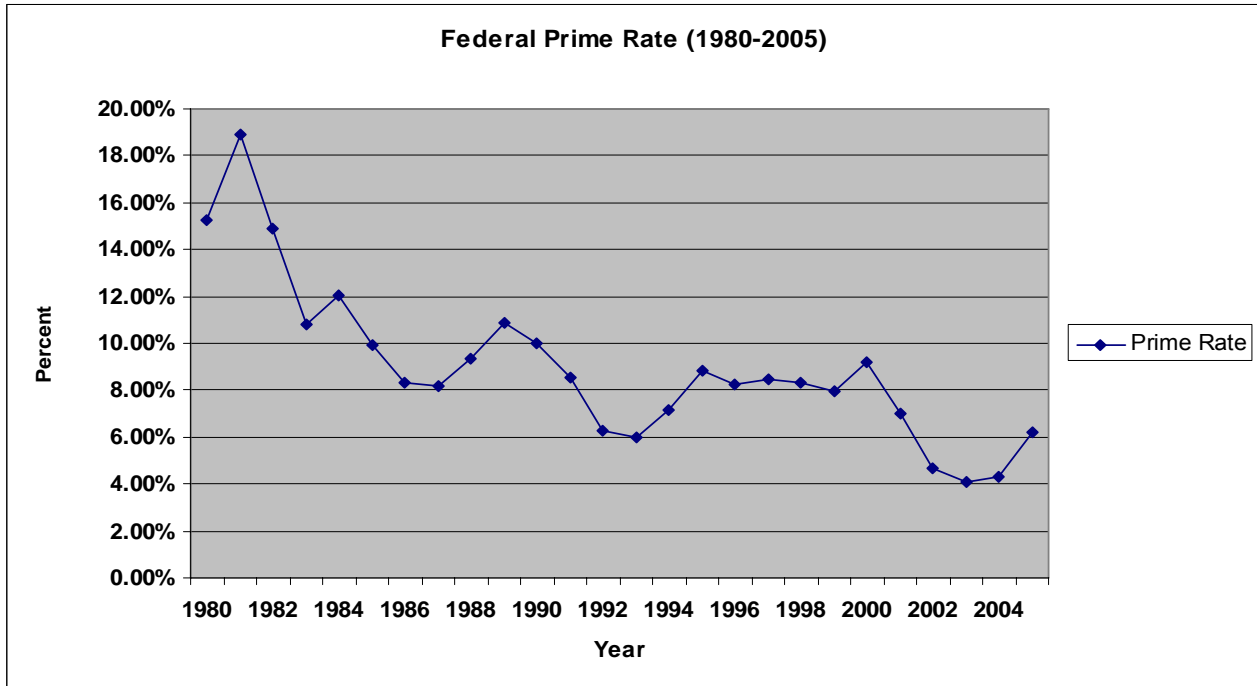


Figure 4.1: US Federal Prime Rate from 1980 to 2005

Source: Compiled based on FED data

In collecting the data for the other four variables; feed cost, conversion rate, mortality rate and final weight, interviews with two experts in the area were conducted and probability distributions were elicited using the conviction weight method (Boehlje and Eidman 1984, pp.452-455) (Personal Communication with Peter Van Wyk, and with Darin Prillaman,). The protocol for expert assessment used in the interview process was The Stanford/SRI Assessment protocol. For a detailed description of the protocol the reader is advised to consult Morgan and Henrion (1990, pp 141-146). The conviction method was pretested on a dairy farm in the

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Rockingham County by Bosch and Johnson (1992) and discussed in their paper “An evaluation of Risk Management Strategies for Dairy Farms”.

At the start of the interview, the purpose of the interview was explained to each of the interviewees, it was then strongly emphasized to them that good and accurate data on the variables being elicited would be very crucial to the validity and credibility of the current study.

Then, the conviction weight method was explained to the experts. Both of the interviewees have a high level of education and had a good familiarity with statistics and probability theory which would suggest that they would have very little difficulty in contemplating the problem and working out the probabilities. Before going into the final stage of eliciting the actual probabilities, the experts were asked one more thing, they were asked to think as far back as they could about the variables under evaluation. Both of the experts have a long experience working in aquaculture. The intention of asking the experts to think as far back as they could was to get them to think about what they have seen in their experiences and how likely they would think those situations were to occur again.

Then we proceeded to the actual probability elicitation. One variable at a time was considered. At first the expert was asked to provide the overall range the variable could take values from, this was of course based on their individual experience, and then to determine the average or most likely value they thought the variable would take. For instance the expert was asked to provide the highest and lowest possible value of mortality rate on his facility. Then, the range given was divided into 10 equally spaced intervals. After that the expert was asked to determine the most likely mortality rate. Next, conviction weight values were assigned to each

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specified value of the variable with 100 being the most likely value. So, if he determined 5 percent as the most likely mortality rate, then the 0.05 point on the range received a conviction score of 100. For all other values below and above the most likely value he was requested to give a score from 0 to 100 indicating how likely he considered those values relative to the most likely point. For example, if he estimated that the likelihood of having 7 percent mortality rate was about 8/10 as likely as the most likely point (the mean or the 5 percent point), a conviction score of 80 was entered for the 7 percent point. For points which the experts estimated a zero probability of occurrence a conviction score of 0 was entered. The conviction scores for the whole variable range were determined in this same fashion. Ranges below the most likely point were considered first until a point was reached for which a zero probability was assigned. Then ranges above the most likely point were considered.

After all the conviction weights for all of the intervals for each random variable were obtained⁵, these weights were summed up into one total conviction score (Table 4.3). Next, each conviction weight was divided by this total to give the probability distribution function (PDF) for that point. The cumulative distribution functions (CDF) were also obtained. CDF's are just the sum of all the PDF's up to the point being evaluated, therefore the name cumulative. So for example, in table 4.3 feed cost has a most likely value of 25 cents/lb, thus the conviction weight for this point is 100. To get the PDF we simply divide the conviction weight of 100 with the total score of 383, and get a PDF point of 0.2611, meaning that there is a 26.11% chance that feed cost will be 25 cents/lb. To get the CDF for this point we simply sum up all the PDF's up to the

⁵ Two experts were interviewed; however each expert was interviewed on only two of the variables. This means that only one data series for each variable was obtained and used in simulation.

25 cents/lb point. This will add up to 0.3734, which means that there is a 37.34% chance that feed costs will take values below 25 cents/lb. The last point (32 cents/lb for feed cost) on the variable range should have a CDF value of 1, meaning that there is a 100% chance that the variable will take on values less than or equal to that point (this is the maximum of the range). Table 4.3 on summarizes the information obtained with the conviction weight method for all four variables elicited. Next, the @Risk program was used to transform these responses into density and cumulative probability graphs. This was done by just entering the PDF's or CDF's into probability fitting window on @Risk. This allows the expert to graphically see his responses. The experts were then allowed to look at the graphs, review them, and make any changes to their answers as they thought it was necessary. Some changes were made after looking at the graphs when the experts thought they gave too much or too little weight on certain interval points.

After the random variables are assigned probability distributions, the natural next step would be is to consider the dependence among these variables. Evaluating the dependency among variables for which historical series exists is relatively easy. Almost any statistical software today is equipped with a function which allows the modeler to obtain a single correlation coefficient from the data. However eliciting subjective correlations among elicited random variables is not as easy, because without historical data correlations cannot be run. It turns out that eliciting these dependencies is the only way to model interdependencies. It was agreed among experts that for the purpose of this study only two of the variables exhibit dependency. It was pointed out that mortality rate is negatively correlated with conversion rate and output price is positively correlated with final weight. The correlations were elicited

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according to the MDC method (Fackler 1991). It turned out that including correlations when running the simulations did not make a big difference in the results, thus for this analysis it was

assumed that correlation coefficient between variables are zero. For comparison a separate simulation results table corrected for correlations is included in appendix H

4.4 Determining Probability Distributions

The random variables are assigned a probability distribution using the best fit feature available in @Risk. Best fit is a built in feature of @Risk that attempts to fit the best probability distribution that underlines the data in hand. Best Fit supports three classes of data for fitting: historical data, density data (PDF'S) and cumulative data (CDF's). Also the data can be either discrete or continuous in its domain. Best fit tries to find the set of distributional parameters that make the closest match between a distribution function and the data sets (historical or elicited) and ranks the ten best matches for the modeler to choose from¹. After the fit is run, @Risk does not produce an absolute answer, but rather identifies a distribution that *most likely* produced the data being analyzed. Comparison graphs and statistics are available for the purpose of evaluating the goodness of fit for each of the potential distributions. When Bestfit is run @Risk returns a graphical representation of the fit and a statistical chart with the major distributional statistics.

¹ Closest mach is defined as how much of the input distribution area the postulated distribution covers. The more it covers the closer the fit.

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Determining Probability Distributions

Table 4.3 Point Estimates Elicited Using the Conviction Weight Method

Probability Elicitations, Probability Density and Cumulative Functions
Used in Probability Distribution Fitting

Feed Cost				Conversion Rate			
Conviction Weight	Cents/lb	PDF	CDF	Conviction Weight	lb fed/1lb gained	PDF	CDF
1	18	0.0026	0.0026	2	1.00	0.0054	0.0054
2	19	0.0052	0.0078	5	1.10	0.0135	0.0189
5	20	0.0131	0.0209	35	1.20	0.0943	0.1132
10	22	0.0261	0.0470	75	1.30	0.2022	0.3154
25	23	0.0653	0.1123	100	1.40	0.2695	0.5849
100	25	0.2611	0.3734	75	1.60	0.2022	0.7871
85	27	0.2219	0.5953	45	1.80	0.1213	0.9084
70	28	0.1828	0.7781	20	2.00	0.0539	0.9623
50	29	0.1305	0.9086	10	2.25	0.0270	0.9892
25	30	0.0653	0.9739	3	2.50	0.0081	0.9973
10	32	0.0261	1.0000	1	3.00	0.0027	1.0000
383	Total Weight			371	Total Weight		
Mortality Rate				Final Weight			
Conviction Weight	Percent	PDF	CDF	Conviction Weight	Grams	PDF	CDF
1	75	0.0014	0.0014	10	650	0.0172	0.0172
4	50	0.0058	0.0072	20	665	0.0345	0.0517
10	25	0.0144	0.0216	30	680	0.0517	0.1034
40	10	0.0576	0.0791	40	695	0.0690	0.1724
60	9	0.0863	0.1655	60	710	0.1034	0.2759
70	8	0.1007	0.2662	80	725	0.1379	0.4138
80	7	0.1151	0.3813	100	750	0.1724	0.5862
90	6	0.1295	0.5108	80	765	0.1379	0.7241
100	5	0.1439	0.6547	60	780	0.1034	0.8276
90	4	0.1295	0.7842	40	795	0.0690	0.8966
75	3	0.1079	0.8921	30	810	0.0517	0.9483
50	2	0.0719	0.9640	20	825	0.0345	0.9828
25	1	0.0360	1	10	850	0.0172	1
695	Total Weight			580	Total Weight		

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Determining Probability Distributions

The following section contains the graphical representation and major distributional statistics for each of the fitted variable distributions. The graphs presented below, called comparison graphs, represent the distribution for the input data (blue area), as mentioned earlier data can be historical or elicited, against the fitted distribution, the red line (this being the postulated or the theoretical distribution). The comparison graph superimposes the fitted data and the fitted distribution on the same graph, allowing the modeler to visually compare them either as density or cumulative curves. This graph allows the modeler to determine if the fitted distribution matches the input data in specific areas. Evaluating the fit with a comparison graph becomes imperative when one wants to have a good match in these specific areas, for example it may be important to have a good match around the mean or in the tails. More on visually evaluating a fit with other visual tools provided by @Risk follows in section 4.4.1, Distributional Goodness of Fit.

The greater of the blue area the red line covers the better the fit. This means that more of the data in hand is captured by the postulated theoretical distribution. The 90% confidence interval is presented at the bottom of the graph. Together with the graph report after a fit is run, a statistical chart is returned by @Risk. This chart contains major statistics for the postulated distribution and the input distribution. α_1 , α_2 , min and max are just the parameters describing the postulated distribution. Left and right X are just the boundaries of the 90% confidence interval (for the fitted distribution), in other words there is a 90% chance that feed cost will fall between 22.09(left X) and 29.55 (right X). These boundaries will always be the same for both

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Determining Probability Distributions

the fitted and input distribution². Left and Right P are the probabilities associated with the 90% confidence interval, left P is 5% and Right P is 95% always for the fit distribution (hence 90% confidence interval), however the left and right P's for the input distribution will be different from the fit distribution, primarily due to differences in location and shape of the two distributions³. The rest of the statistics presented in this chart include the mean, mode, median, variance, standard deviation (which is just the square root of the variance), skewness and the kurtosis coefficient. The closer the fit the closer the statistics of the fitted and input distributions are. If the fit is a *perfect* fit, then all of the statistics for the fitted and input distributions will correspond.

Figure 4.2 below presents the fit results for feed cost. The distribution best describing the data for feed cost is Beta General. As we can see from the figure, Beta General (red line) is reasonably a good fit for the data in hand (blue area). On the right hand side, a table with major fit statistics is presented. Not all of the statistics provided for the fit will be available for the input also⁴. The statistics provided on this chart are useful when the modeler wants to evaluate the fitted vis-à-vis the input distribution.

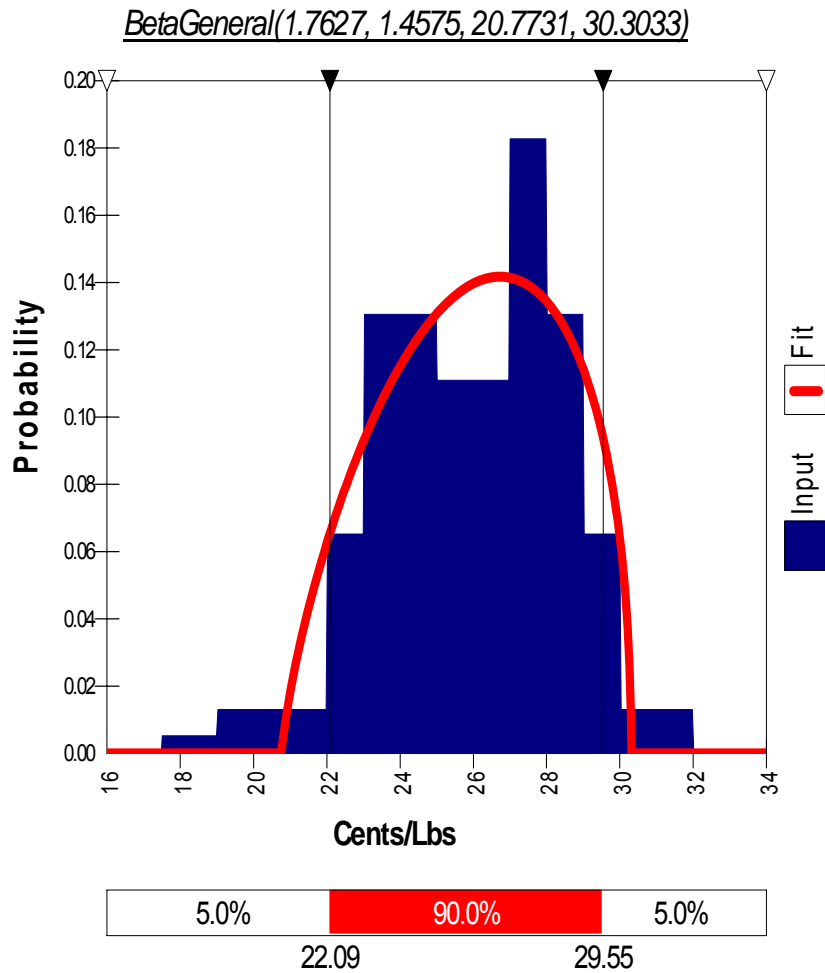
² This is simply because @Risk takes the 90% confidence interval from the fitted distribution and superimposes that on the input distribution, thus the boundaries of the two overlap.

³ The closer the left and the right P's are for the fitted and input distributions the better the fit. This means, in other words, that the fitted and input distributions almost overlap. When the left and the right P's are the same, the fit is a perfect fit, covering exactly the same area as the input distribution.

⁴ Usually higher moments will not be available for the input distribution. This is due to the non-parametric nature of the fitting procedure. We are not assuming any specific distribution of the input, thus higher moments need not be evaluated.

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Determining Probability Distributions

Distribution Fit for Feed Cost

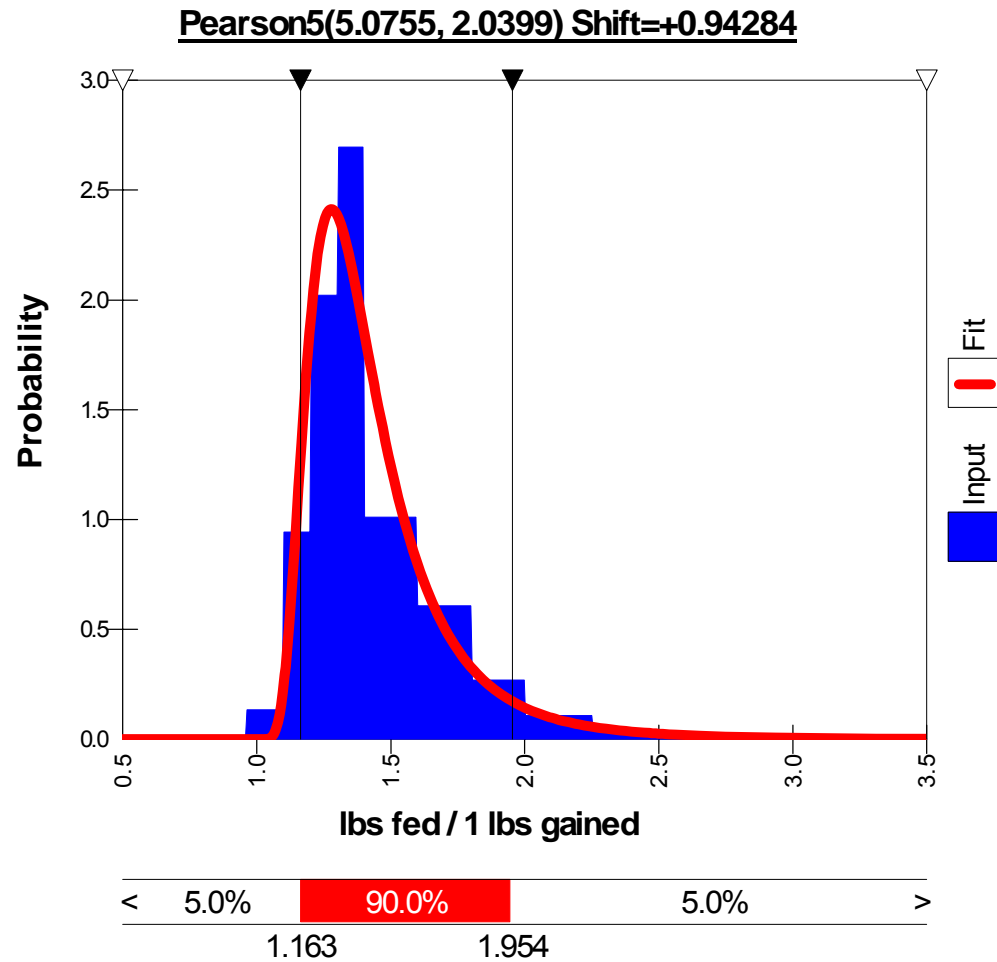


Fit Statistics	Fit	Input
Function	<i>BetaGeneral</i>	N/A
Shift	N/A	N/A
$\alpha 1$	1.76	N/A
$\alpha 2$	1.46	N/A
Min	20.77	N/A
Max	30.30	N/A
Left X	22.09	22.09
Left P	5.00%	5.26%
Right X	29.55	29.55
Right P	95.00%	94.42%
Diff. X	7.4604	7.4604
Diff. P	90.00%	89.17%
Minimum	20.77	17.50
Maximum	30.30	32.00
Mean	25.99	25.93
Mode	26.73	N/A
Median	26.09	26.14
Std. Deviation	2.31	2.53
Variance	5.33	6.41
Skewness	-0.15	-0.36
Kurtosis	2.06	2.90

Figure: 4.2 Comparison Graph for Feed Cost

CHAPTER 4
Determining Probability Distributions

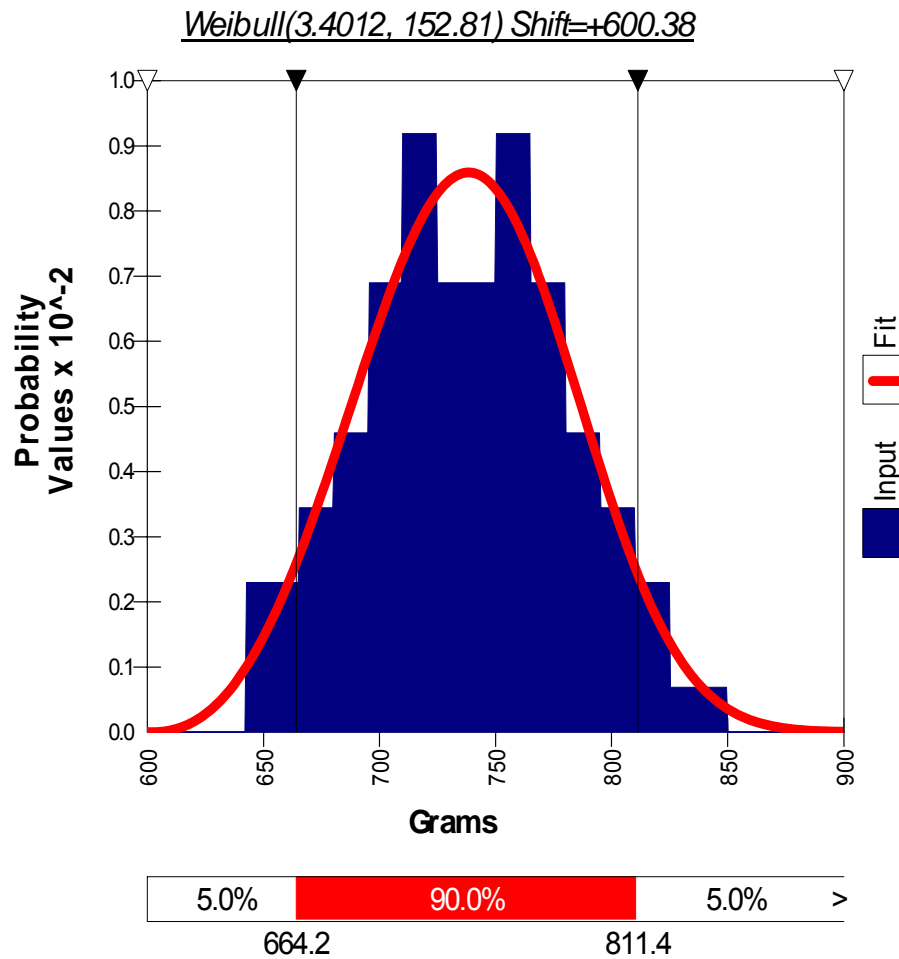
Distribution Fit for Conversion Rate



<i>Fit Statistics</i>	Fit	Input
Function	<i>Pearson5</i>	N/A
Shift	0.94	N/A
A	5.08	N/A
B	2.04	N/A
Left X	1.16	1.16
Left P	5.00%	7.85%
Right X	1.95	1.95
Right P	95.00%	94.98%
Diff. X	0.7907	0.7907
Diff. P	90.00%	87.14%
Minimum	Infinity	0.96
Maximum	Infinity	3
Mean	1.44	1.44
Mode	1.28	N/A
Median	1.37	1.37
Std. Deviation	0.29	0.26
Variance	0.08	0.07
Skewness	3.38	1.41
Kurtosis	41.64	5.79

Figure: 4.3 Comparison Graph for Conversion Rate

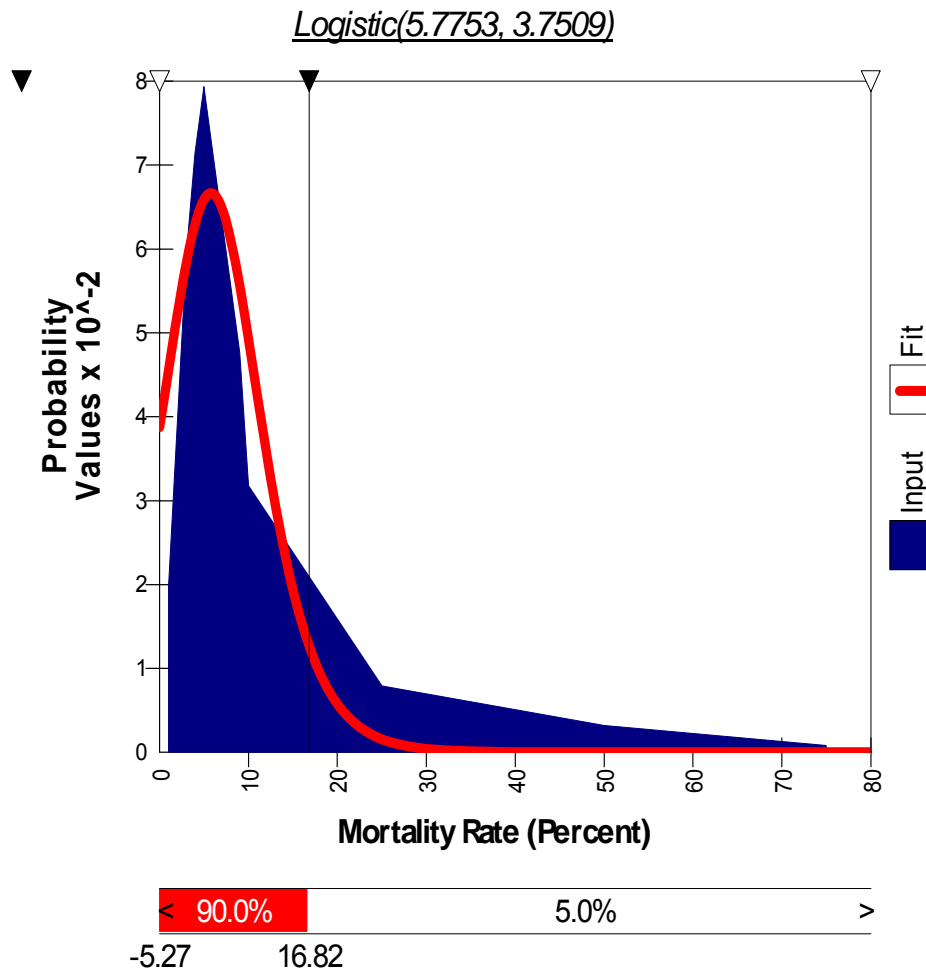
Distribution Fit for Final Weight



Fit Statistics	Fit	Input
Function	Weibull	N/A
Shift	600.38	N/A
A	3.40	N/A
B	152.81	N/A
Left X	664.20	664.20
Left P	5.00%	4.99%
Right X	811.40	811.40
Right P	95.00%	95.14%
Diff. X	147.18	147.18
Diff. P	90.00%	90.16%
Minimum	600.38	642.5
Maximum	Infinity	850
Mean	737.67	737.65
Mode	738.32	N/A
Median	737.58	737.50
Std. Deviation	44.58	43.91
Variance	1987.31	1927.85
Skewness	0.04	0.04
Kurtosis	2.63	2.43

Figure: 4.4 Comparison Graph for Final Weight

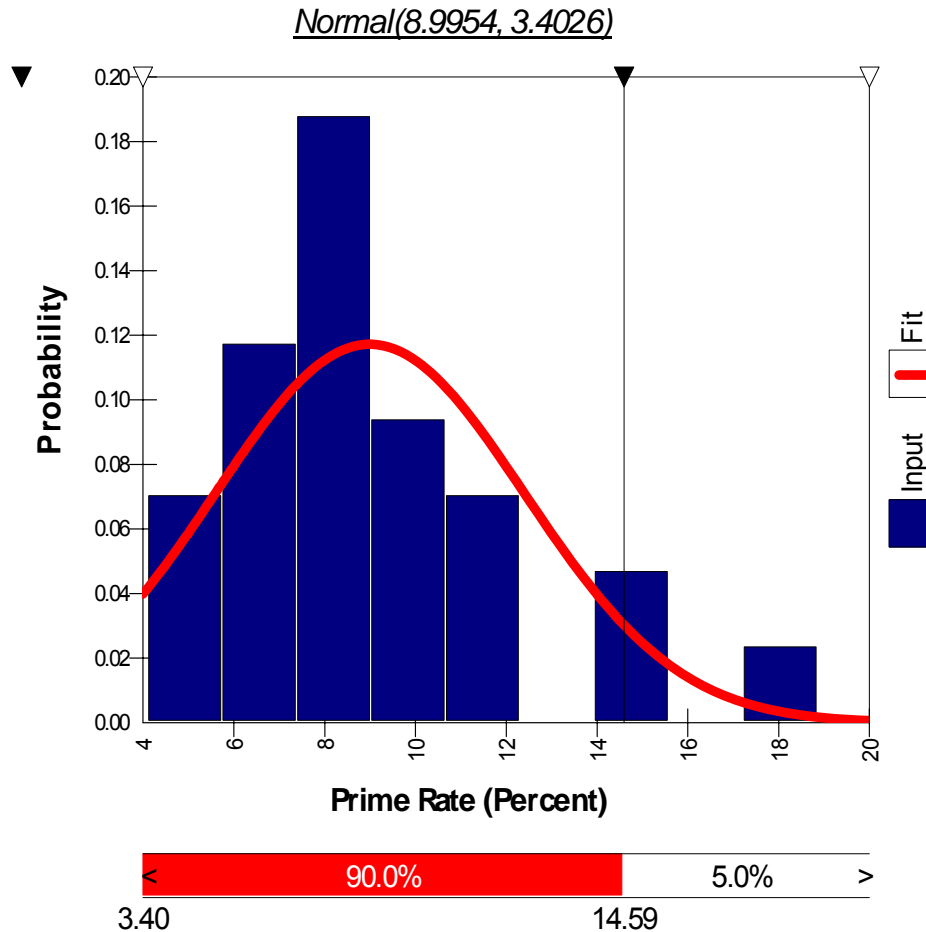
Distribution Fit for Mortality Rate



Fit Statistics	Fit	Input
Function	<i>Logistic</i>	N/A
Shift	N/A	N/A
A	5.78	N/A
B	3.75	N/A
Left X	-5.27	-5.27
Left P	5.00%	0.00%
Right X	16.82	16.82
Right P	95.00%	69.35%
Diff. X	22.09	22.09
Diff. P	90.00%	69.35%
Minimum	Infinity	1
Maximum	Infinity	75
Mean	5.78	15.55
Mode	5.78	5.00
Median	5.78	9.60
Std. Deviation	6.80	14.92
Variance	46.29	222.54
Skewness	0.00	1.70
Kurtosis	4.20	5.45

Figure: 4.5 Comparison Graph for Mortality Rate

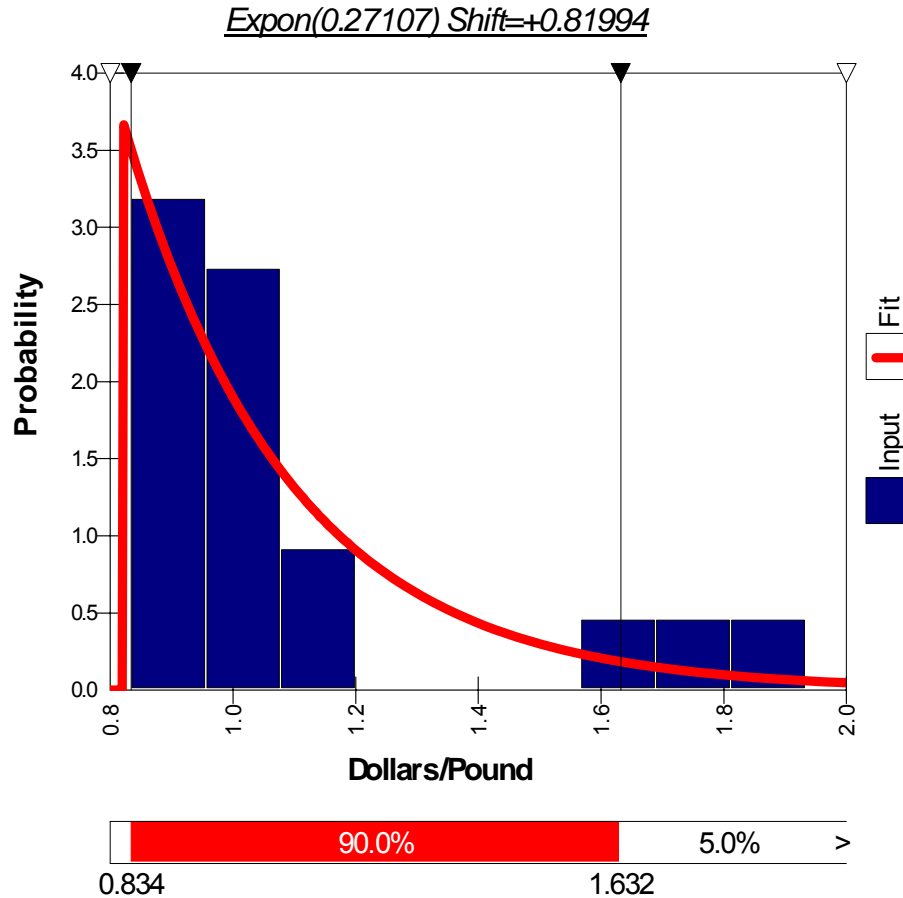
Distribution Fit for Interest Rate



Fit Statistics	Fit	Input
Function	<i>Normal</i>	N/A
Shift	N/A	N/A
M	9.00	N/A
Σ	3.40	N/A
Left X	3.40	3.40
Left P	5.00%	0.00%
Right X	14.59	14.59
Right P	95.00%	88.46%
Diff. X	11.19	11.19
Diff. P	90.00%	88.46%
Minimum	Infinity	4.12
Maximum	Infinity	18.88
Mean	9.00	9.00
Mode	9.00	8.29
Median	9.00	8.40
Std. Deviation	3.40	3.40
Variance	11.58	11.13
Skewness	0.00	1.11
Kurtosis	3.00	4.35

Figure: 4.6 Comparison Graph for Interest Rate

Distribution Fit for Output Price



<i>Fit Statistics</i>	Fit	Input
Function	<i>Expon</i>	N/A
Shift	0.82	N/A
A	N/A	N/A
B	0.27	N/A
Left X	0.83	0.83
Left P	5.00%	0.00%
Right X	1.63	1.63
Right P	95.00%	88.89%
Diff. X	0.80	0.80
Diff. P	90.00%	88.89%
Minimum	0.82	0.84
Maximum	Infinity	1.94
Mean	1.09	1.11
Mode	0.82	0.94
Median	1.01	0.98
Std. Deviation	0.27	0.32
Variance	0.07	0.09
Skewness	2.00	1.68
Kurtosis	9.00	4.41

Figure: 4.7 Comparison Graph for Output Price

Table 4.4 below lists all the six variables (historical and elicited), the probability distribution assigned to them and the method of estimation @Risk used to determine the parameters.

Table 4.4: Probability Distributions and Method of Estimation

Variables	Distribution	Method of Estimation
Feed Cost	Beta General	Least Squares
Conversion Rate	Pearson 5	Least Squares
Final Weight	Weibull	Least Squares
Mortality Rate	Logistic	Least Squares
Interest Rate	Normal	Maximum Likelihood
Output Price	Exponential	Maximum Likelihood

4.4.1 Distributional Goodness Of Fit

After the probability distributions are fit for each of the variables, the next question is whether the fit is a good fit. To answer this question @Risk provides statistical and visual tools. For each fit, @Risk reports one or more fit statistics. These statistics measure how good the distribution fits the input data and how confident one can be that the data was produced by the postulated probability distribution. For each of the statistics provided, the smaller the value, the better the fit (Palisade 2004).

CHAPTER 4
Distributional Goodness Of Fit

The statistics used by @Risk in evaluating a fit include: Chi Square, Anderson-Darling and Kolmogorov-Smirnov statistics. The above three statistics are available only when fitting a distribution to historical data and there is no hard rule to decide which test will give one the “best” result as each test has its strengths and weaknesses. One has to decide which information is most important when deciding which test to use. All of the three statistical tests were used in this analysis.

From the results below, table 4.5, the normal and the exponential distributions for interest rate and output price respectively are not rejected. The null and alternative hypotheses are formulated as follows: H_0 =data are distributed normally versus H_1 =data are not distributed normally. All three tests were carried out at the 95% confidence level and they all fail to reject the null hypothesis for both variables.

Table 4.5: Hypothesis Testing Summary Based on Three Goodness of Fit Tests

Variable	Distribution Tested	Statistical Test	Statistical Test Value	Critical Value	Null Hypothesis
<i>Interest Rate</i>	Normal	Chi Square	3.6150	9.4877	Not Rejected
		A-D ¹	0.7153	0.7286	Not Rejected
		K-S ²	0.1558	0.1703	Not Rejected
<i>Output Price</i>	Exponential	Chi Square	6.4440	7.8147	Not Rejected
		A-D	0.7866	0.7951	Not Rejected
		K-S	0.1766	0.2603	Not Rejected

¹This stands for Anderson-Darling test

² This stands for Kolmogorov-Smirnov test

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Distributional Goodness Of Fit

When fitting a distribution to density or cumulative data (elicited data) the only statistic @Risk provides is the Root Mean Square (RMS) error statistic. This is the same quantity that @Risk minimizes to determine the distribution parameters during its fitting process. The RMS statistic is a measure of the “average” squared error between the input and fitted curve. As a rule: the smaller the RMS error the better the fit. Table 4.6 contains the four elicited variables the distribution fitted and the RMS error coefficient. For all of the variables the RMS is considerably small, thus we conclude that the fit is a good fit.

Table 4.6: RMS Error Statistics

<u>Variable</u>	<u>Distribution Fitted</u>	<u>RMS error Coefficient</u>
Feed Cost	Beta General	0.00024
Conversion Rate	Pearson 5	0.00021
Mortality Rate	Weibull	0.00007
End Weight	Logistic	0.00023

In addition to the statistics provided above, when distributions are fit to data, @Risk produces visual tools to help the modeler visually assess the fit. These visual tools include four types of graphs including: Probability-Probability (P-P), Quantile-Quantile (Q-Q), difference and comparison graphs. The P-P graphs, Q-Q graphs and Difference graphs for Price of tilapia and Interest Rate are presented in Appendix E; comparison graphs for Price of tilapia, interest rate

and the other four variables were presented in the previous section³. The P-P graph plots the distribution of the input data $P_{(i)}$ vs. the distribution of the result $F(x_i)$. If the fit is a “good” fit the plot will be nearly linear. The Q-Q graph plots the percentile values of the input distribution (x_i) vs. percentile values of the result $(F^{-1}(P_i))$. Again if the fit is a good fit the plot will be nearly linear. By looking at the P-P and Q-Q graphs in Appendix E, the linearity in both cases is “acceptable”, which means that the plots are nearly linear and thus null hypothesis is not rejected.

A difference graph displays the absolute error between the fitted distribution and the input data. A “perfect” fit would have an absolute error of zero throughout the variable range. The difference graphs in appendix E for all of the variables confirm a small error between the fit and input, meaning that the fit is a good fit. Usually it is important to have a small absolute error around the mean of the distribution.

When distributions are fit to density or cumulative data (elicited) the P-P and Q-Q graphs are not available. As noted above, the best the modeler can do when dealing with elicited data is to choose, from the list of distributions @Risk provides after distributions are fit to the elicited data, the distribution that has the smallest Root Mean Square error (RMS error). In addition to the RMS error statistic, @Risk provides Comparison and Difference graphs for the modeler to visually evaluate the fit.

³ For a detailed discussion of Comparison graphs for all six variables refer to section 4.4

CHAPTER 5

Results

5.1 Simulating The Aquaculture Economic Cost Model

The final stage in conducting risk analysis with @Risk is the actual model simulation. After the data are collected and the distributions are fit to the data and the probability distributions are applied to cells containing the random or uncertain variables the model is ready for simulation. Also note that in this analysis the distributions applied were truncated to contain only positive values. This will rule out the possibility of @Risk drawing negative values and using those values in performing the simulation. It does not make sense to have a negative output price or conversion rate or capital interest rate. The running time over which @Risk simulates the model is either determined by the modeler or ended as a stopping rule is satisfied. In this analysis the model was simulated for ten thousand iterations. Each iteration consists of one recalculation of the model as @Risk draws random values from the distributions applied.

@Risk draws random values from the underlying distributions with a procedure called sampling process. Sampling in a simulation is done repetitively, with one sample drawn every iteration from each input probability distribution. Statisticians have developed several techniques

for drawing random samples. The important factor to keep in mind when evaluating the sampling method to use in a simulation is the number of iterations required to accurately recreate an input distribution through sampling. Accurate and reliable output distributions depend on a complete sampling of input distributions. If the one sampling method requires more iterations and longer simulation runtimes than another method to approximate the input distributions, it is said to be a less “efficient” method (Palisade 2004).

The two methods of sampling used in @Risk – Monte Carlo¹ sampling and Latin Hypercube sampling – differ in the number of iterations required until sampled values approximate input distributions. A brief discussion of each of the methods follows:

5.1.1 Monte Carlo Sampling

Monte Carlo sampling is the traditional technique for using random or pseudo-random numbers to sample from a probability distribution. Monte Carlo sampling techniques are entirely random – that is, any given sample may fall anywhere within the range of the input distribution. Samples, of course, are more likely to be drawn in areas of the distribution which have higher probability of occurrence. Monte Carlo sampling usually requires a large number of samples to approximate an input distribution, especially if the input distribution is highly skewed or has some outcomes of low probability. With enough iterations, Monte Carlo sampling “recreates” the

¹ Please note the terminology. Monte Carlo here refers to the sampling method not the simulation process itself. Monte Carlo sampling is different from Monte Carlo simulation

input distribution through sampling. A problem of clustering, however, arises when a small number of iterations are performed. Clustering becomes especially pronounced when a distribution includes low probability outcomes which could have a major impact on the results. It is important to include the effects of these low probability outcomes. To do this, these outcomes must be sampled. But, if their probability is low enough, a small number of Monte Carlo iterations may not sample sufficient quantities of these outcomes to accurately represent their probability. This problem has led to the development of stratified sampling techniques such as Latin Hypercube (Palisade 2004).

5.1.2 Latin Hypercube Sampling

Latin Hypercube sampling is a recent development in sampling techniques designed to accurately recreate the distribution. The Latin Hypercube technique forces the samples drawn to correspond more closely with the input distribution and thus, statistical estimates converge faster (in fewer iterations than the Monte Carlo method) on the true statistics of the input distribution. The key to Latin Hypercube sampling is stratification of the input probability distributions. Stratification divides the cumulative curve into equal intervals on the cumulative probability scale (0 to 1.0). A sample is then randomly taken from each interval or “stratification” of the input distribution. Sampling is forced to represent values in each interval, and thus, is forced to recreate the input probability distribution. The technique being used during Latin Hypercube

sampling is “sampling without replacement”. The number of stratifications of the cumulative distribution is equal to the number of iterations performed. A sample is taken from each stratification. However, once a sample is taken from a stratification, this stratification is not sampled from again. As a more efficient sampling method, Latin Hypercube offers great benefits in terms of increased sampling efficiency and faster runtimes (due to fewer iterations). These gains are especially noticeable in a PC-based simulation environment such as @Risk. Latin Hypercube also aids the analysis of situations where low probability outcomes represent input probability distributions. By forcing the sampling of the simulation to include outlying events, Latin Hypercube sampling assures they are accurately represented in the simulation outputs. The Latin Hypercube was the sampling method used in the simulation¹. There are no clear cut criteria for choosing one sampling method over the other; the choice is totally in the modeler’s discretion as affected by the type of analysis being conducted (Palisade 2004).

In order to shed more light on the significance of each random variable influencing the output variables, sensitivity analyses were carried out. @Risk performs sensitivity analysis based on regression or correlation analysis or both. With the regression analysis, sampled input variable values are regressed against output values which lead to a measurement of sensitivity by input variable. With the second technique, correlation coefficients are calculated between output

¹ Some of the input variables used in the model, such as mortality rate, may exhibit low probability outcomes. Sometimes these low probability outcomes have significant effects on the results, thus full consideration of these outcomes becomes important. For example, having a mortality rate of 75% is quite unlikely, however if it happens, the impact on output variables is very significant. Latin Hypercube addresses this issue by stratifying the input probability distributions, therefore allowing samples to be drawn from low probability areas of the input distribution. This does not mean that Latin Hypercube is always superior to Monte Carlo sampling method; in certain situations, (such as when we are dealing with uniformly distributed random variables) it might be more appropriate to use the Monte Carlo sampling method instead.

values and each set of sampled input values. As discussed below, the results of sensitivity analysis can be displayed as a “tornado” type chart.

5.2 Simulation Results

After the simulation is completed @Risk produces the results in a separate pop-up window called the results window. This is an interactive window that is used to display the simulation results. This window includes statistics and data reports for both the inputs and outputs of the model. Statistics generated include: the minimum, mean, maximum, and the standard deviation. Percentiles for the whole range of the input/output variables are also calculated. Percentiles are calculated in increments of five percent.

From the results window the modeler can generate other reports that will help him/her to better evaluate his/her simulation results. @Risk offers the option to generate these reports in Excel for a better representation or modification to the modeler’s preference. Some of the reports generated in this analysis are:

Quick Simulation Summary (table 5.1): this report contains the summary information about the simulation and the main statistics for each output cell and input distribution. The minimum, mean, maximum along with two target values x_1 and x_2 and their respective probabilities p_1 and p_2 (the 5 and 95 percent are the default probabilities displayed in this report). A target value is the upper limit that a certain output variable would take given the respective

CHAPTER 5

Simulation Results

probability for that target value. So the target values calculated for the Year1 output variable were -\$299,607.97 and -\$112,319.52 for the 5 and 95 percentile respectively. This would mean that there is a 5 percent chance that income for year one would fall below -\$299,607.97 and a 95 percent chance that income for year one would fall below -\$112,319.52. The same explanation applies for the two remaining output variables and all nine input variables at 5 and 95 percent for p_1 and p_2 respectively. Target values can be adjusted as desired and @Risk will automatically produce the probabilities associated with the values entered. A useful and often used target value is 'zero'. By entering zero in the target value we answer questions such as: what is the chance of a negative income for the first year? In this analysis, @Risk calculated almost a 99 percent chance of having negative income in the first year. The complete simulation summary is presented in table 5.1 on the following page.

CHAPTER 5
Simulation Results

Table 5.1: Quick Simulation Summary

Summary Information	
Workbook Name	Aqua Econ Cost Model
Number of Simulations	1
Number of Iterations	10,000
Number of Inputs	9
Number of Outputs	3
Sampling Type	Latin Hypercube
Simulation Start Time	5/12/2006 14:22
Simulation Stop Time	5/12/2006 14:22
Simulation Duration	00:00:35
Random Seed	1600609983

Output		Statistics						
Name	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2
Net Profit or (Loss) Year1	G33	(651,013.63)	(216,905.26)	205,019.41	(299,607.97)	5%	(112,319.52)	95%
Net Profit or (Loss) Year2	H33	(518,765.06)	(53,689.28)	807,103.63	(183,329.27)	5%	161,586.14	95%
Net Profit or (Loss) Year3	I33	(516,792.13)	(53,111.33)	809,778.38	(183,947.33)	5%	174,432.44	95%

Input		Statistics						
Name	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2
Building Loan / Interest Rate (%)	AJ8	0.01	9.04	21.85	3.52	0.05	14.60	0.95
Feed Cost (cents/lb)	B9	20.03	25.64	30.30	21.42	0.05	29.48	0.95
Feed Conversion (lb fed/ 1lb. gain)	B10	1.05	1.44	6.52	1.16	0.05	1.95	0.95
System Loan / Interest Rate (%)	AJ10	0.01	9.04	24.35	3.52	0.05	14.60	0.95
Generator Loan / Interest Rate (%)	AJ12	0.01	9.04	22.28	3.52	0.05	14.60	0.95
Land Loan / Interest Rate (%)	AJ14	0.01	9.04	22.13	3.52	0.05	14.60	0.95
Mortality (%)	B16	0.00	7.90	44.47	0.98	0.05	17.58	0.95
End Weight (grams)	B41	607.48	737.66	907.11	664.16	0.05	811.34	0.95
Output Price (\$/lb)	B42	0.82	1.09	3.33	0.83	0.05	1.63	0.95

Output Graphs: A variety of graphs of simulation results can be generated in the results window. Graphs can be generated for both output cells, where the graph displays the distribution values calculated during the simulation, and input cells where the graph displays the distribution values sampled during the simulation from the selected distribution function. Types of graphs produced by @Risk include: Fitted distribution, Histogram, Cumulative ascending and Cumulative descending. The fitted distribution, the histogram, the cumulative ascending and the cumulative descending graphs and their respective 90 percent confidence intervals for all the three output cells (Income Years) are presented in figure 5.1 through figure 5.12. These figures present the same results in different visual ways. So, figure 5.1 represents the fitted distribution for net income for the first year that @Risk calculated. There are a couple features that can be seen more clearly in figure 5.1 than in the other figures (graphs). Those are:

Distributional Variance; distributional variance shows the spread of outcomes relative to the mean. Range and likelihood of occurrence are directly related to the level of risk associated with a particular event. By looking at the spread and likelihood of possible results, figure 4.8, the modeler can make an informed decision based on the level of risk he/she is willing to take. Risk averse¹ decision makers prefer a small spread in possible results, with most of the probability

¹ Definition: Risk averse individuals (investors) are those who, when faced with two alternatives with the same expected returns (same distributional mean) but two different risks (two different spreads), prefer the one with the lower risk (spread). www.economist.com

associated with the desirable results. But if the modeler is a risk taker², often called risk seeking or risk loving, then he/she is willing to accept a greater spread in outcome distribution.

Distributional Skewness, the simulation output distribution can also show skewness. Skewness is – how much the distribution of possible results deviates from being symmetrical about the mean. Skewness is important when it comes to visually assessing your outcome distributions. If your outcome distribution has a large positive tail (positively skewed), and you are basing your results only on the mean of the distribution, you might not realize the possibility of a high positive outcome that could occur in the tail.

Figure 5.1 visually presents the 90% confidence interval for net profit for year1 also. From this we see that for the first year there is a 90% chance that income will fall between -\$299,607.97 and -\$112,319.52.

A cumulative ascending graph such as that displayed in figure 5.2 becomes useful when the modeler wants to visually see the probability associated with cumulative outcomes falling below a certain value. For example, from figure 5.2 we see that there is a 95% (90% + 5% from the 90% confidence interval) chance for net income to fall below \$112,319.52 or that there is almost a 100% chance that net income will be negative(below \$0.00) and almost a 0% chance that income will fall below roughly to say 400,000.00.

The same explanation applies for the histogram, figure 5.3, as for the fitted distribution in figure 5.1. A cumulative descending graph, such as that displayed in figure 5.4, on the other hand

² Definition: A risk taker is someone who cannot get enough risk. Risk taking individuals prefer alternatives with an uncertain outcome to one with the same expected returns (distributional mean) and certainty that it will deliver them. www.Economist.com

is the opposite of the cumulative ascending. So for example, if from cumulative ascending one visually see the maximum value that net income can attain, from the cumulative descending one can visually see the minimum value that net income can attain. So from figure 5.4. we see that there is almost 100% chance that net income will exceed, roughly, \$-400,000.00 and almost a 0% chance that net income will be positive. Put this in a different way, a cumulative ascending displays the probability of certain values falling below a threshold, whereas a cumulative descending displays the probability associated with certain values falling above a threshold.

The same explanation applies to the remaining figures, figure, 5.5 through 5.12 which represent net income for year two and three.

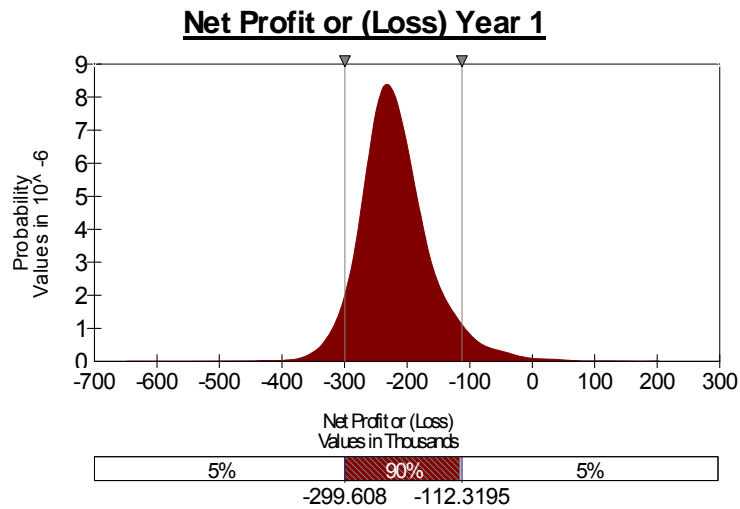


Figure 5.1: Fitted Distribution for Net Profit Year 1

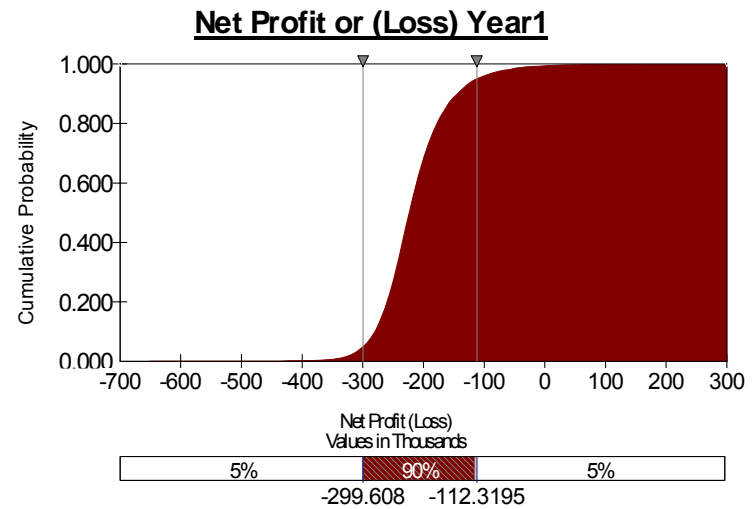


Figure 5.2: Cumulative Ascending Net Profit Year 1

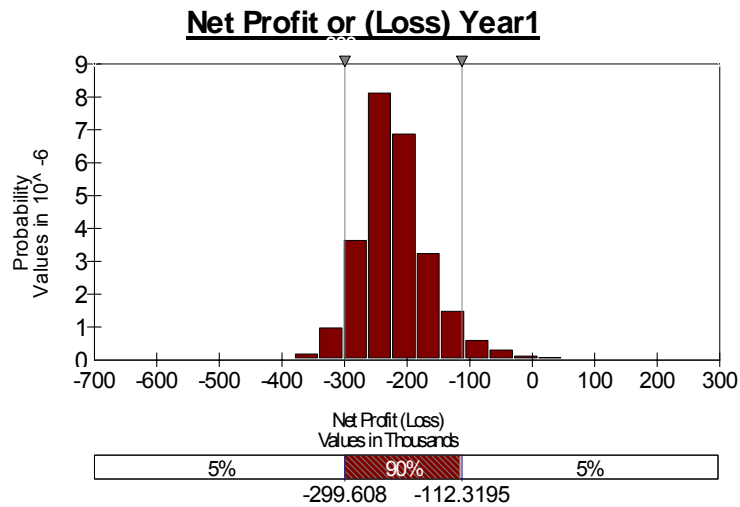


Figure 5.3: Histogram graph for Net Profit Year 1

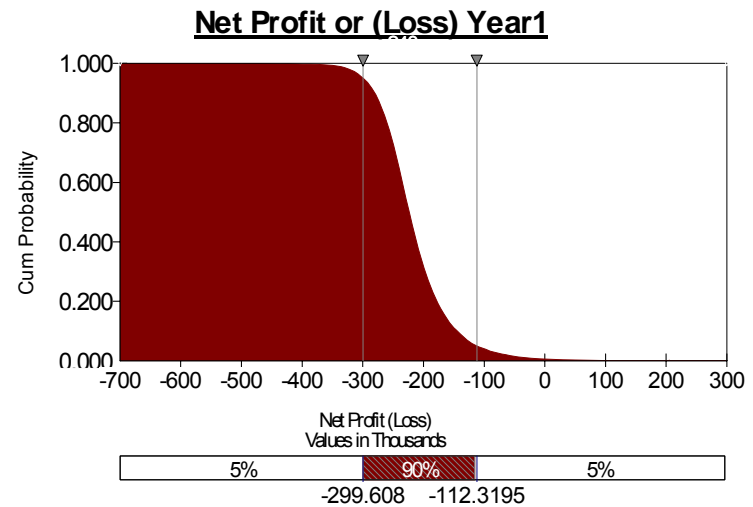


Figure 5.4: Cumulative Descending Net Profit Year 1

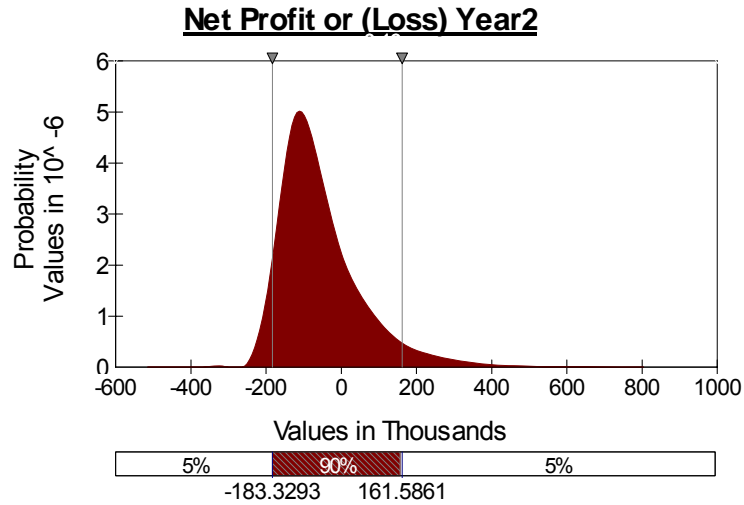


Figure 5.5: Fitted Distribution Net Profit Year 2

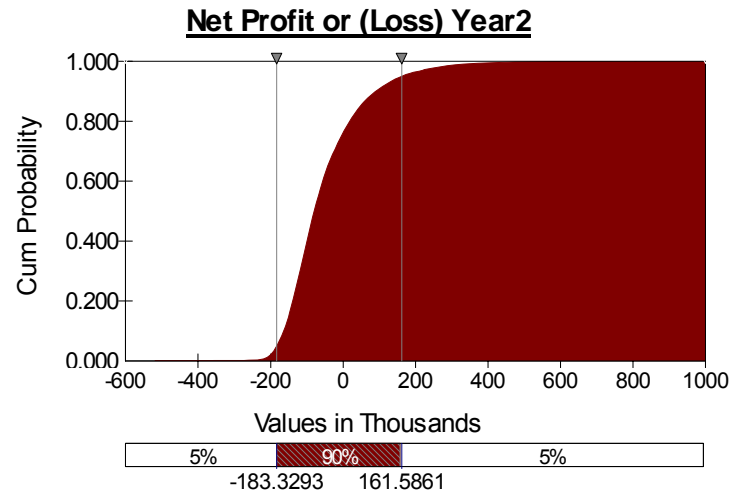


Figure 5.6: Cumulative Ascending Net Profit Year 2

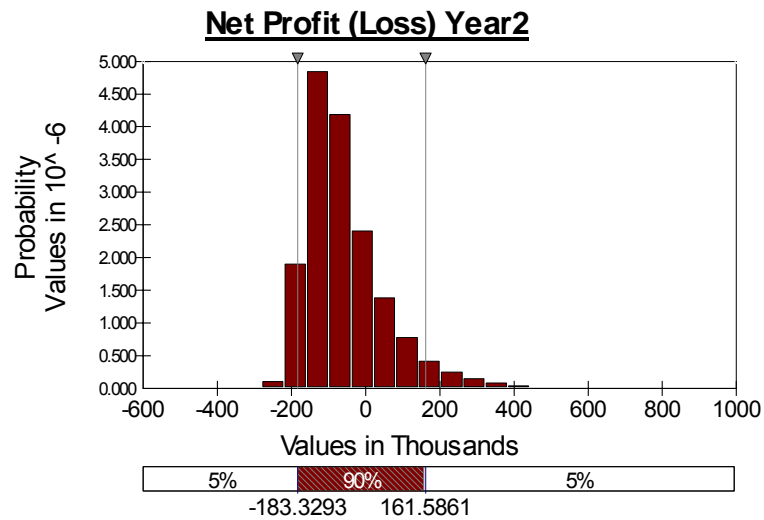


Figure 5.7: Histogram Graph Net Profit Year 2

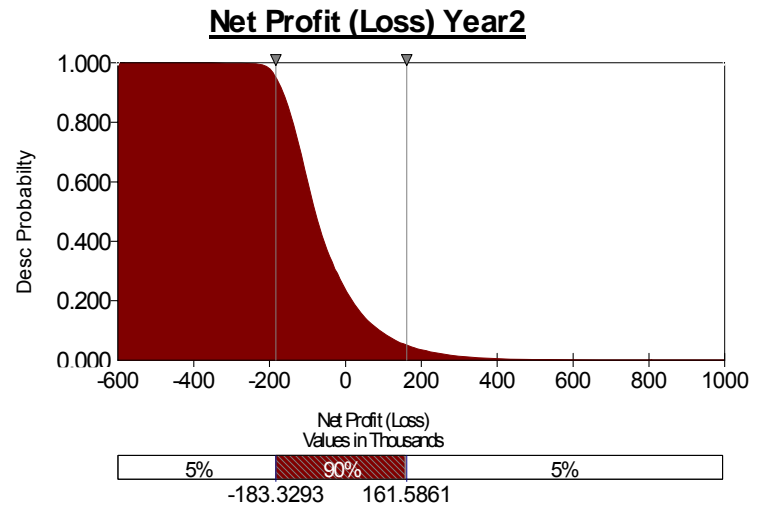


Figure 5.8: Cumulative Descending Net Profit Year 2

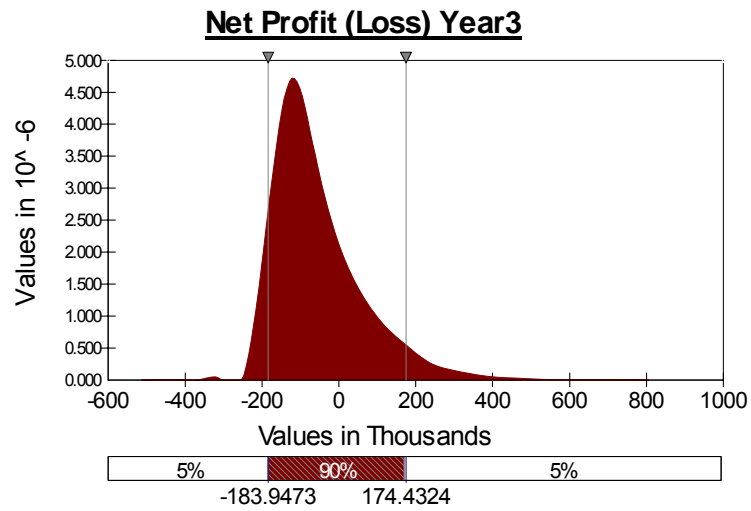


Figure 5.9: Fitted Distribution Net Profit Year 3

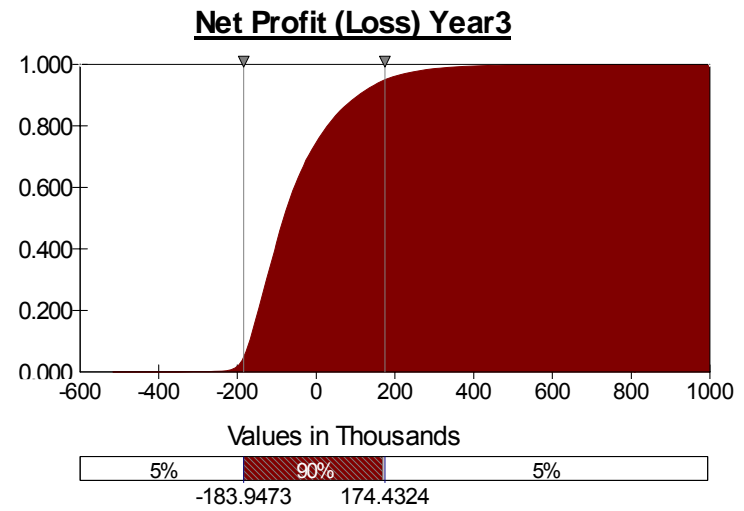


Figure 5.10: Cumulative Ascending Net Profit Year 3

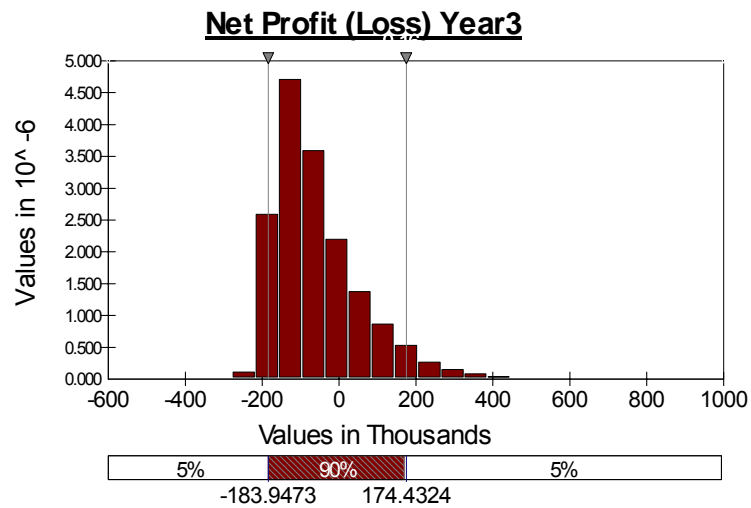


Figure 5.11: Histogram Graph Net Profit Year 3

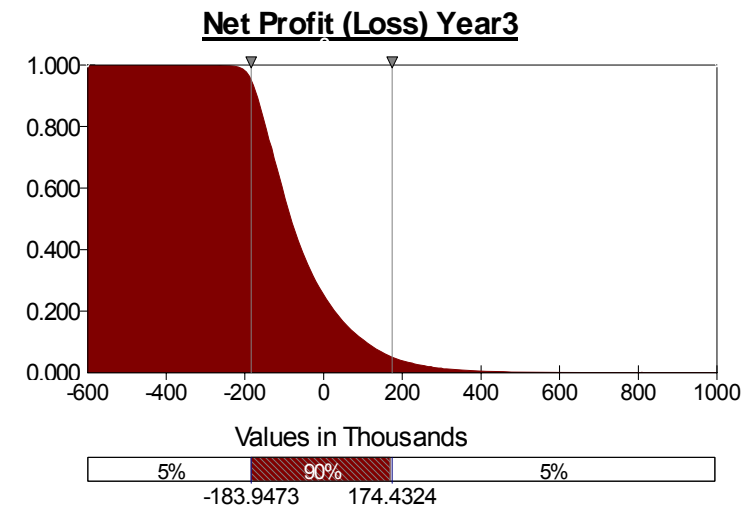


Figure 5.12: Cumulative Descending Net Profit Year 3

Overlay Graphs: Many times when the same variable is simulated over several years it is useful to compare the simulated distributions of that variable for each year on the same graph. This can be done in @Risk by generating overlay graphs. The following figure (figure 5.13) contains the overlay graphs of the simulated distributions for Net Profit Year1 (G33), Net Profit Year2 (H33) and Net Profit Year3 (I33). The notation G33, H33 and I33 represents the cell number where net income is contained in the income statement in the AECM spreadsheet model. As the figure indicates the graphs for the second and third year are pushed to the right. This means that there is a lower probability that lower net income values, than in the first year, will occur in year two and three. Which in turn means that there are better chances to achieve positive profits in the second and third year.

Summary Graph: A similar report to overlay graphs is the summary graph. A summary graph is especially important when displaying trends such as how the mean and variance (risk) associated with the simulated variables change across time. Figure 5.14 shows the summary graph from the simulation of the AECM model. The center line (yellow line) of the graph represents the trend in mean value across time, from Year1 through Year3. The red region represents one standard deviation above and below the mean. The green region above the mean represents the 95th percentile, and the green region below the mean represents the 5th percentile. As years pass there is an upward trend in the mean (expected returns), but there is also an increase in risk (variance), shown by the wider intervals. Furthermore, the rate of increase in the mean returns over time is decreasing, meaning that there is a greater increase in the mean from Year1 to Year2 than from Year2 to Year3 (the mean return is increasing at a decreasing rate).

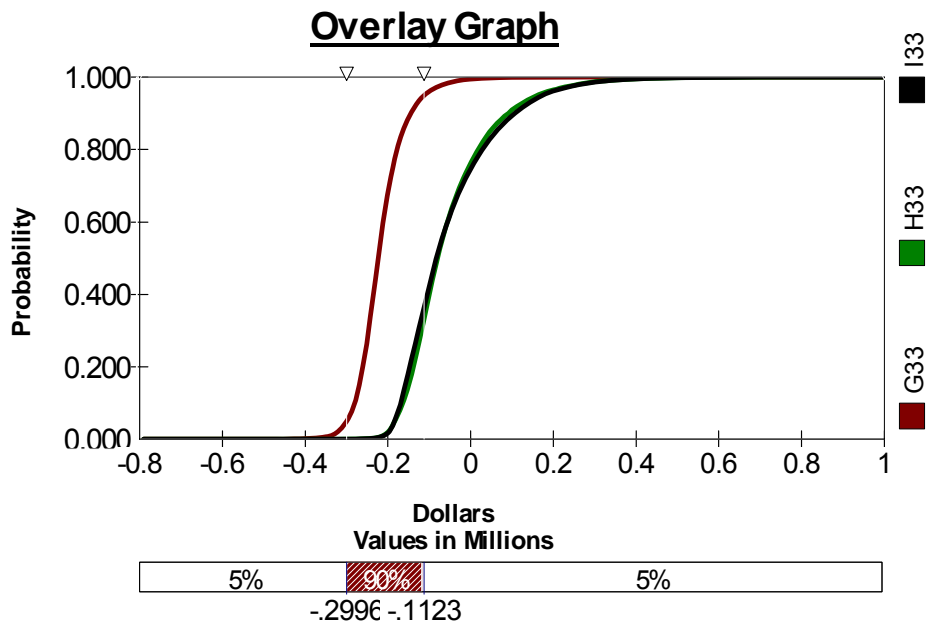


Figure 5.13: Income Distribution Comparison for Year1 (G33) thru Year3 (I33)

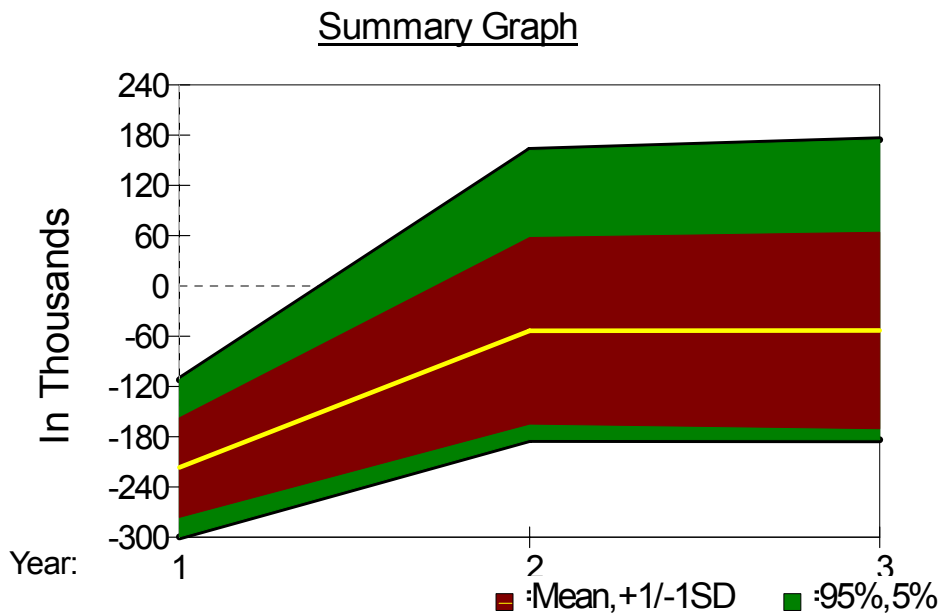


Figure 5.14: Income Distributions Summary Graph; Year1 through Year3

5.3 Sensitivity Analysis

After the simulation results are obtained, it is often of interest to the modeler to see which inputs have affected the outputs the greatest and by how much. Sensitivity analyses were performed on the AECM model in order to see which of the analyzed inputs affect Net Income the most. @Risk produces what it is called a sensitivity report. In this report inputs that significantly affect each output cell are ranked in their respective order of significance, with the first being the one affecting output cells the most. The sensitivity analyses performed on the output variables and their associated inputs use either a multivariate stepwise regression analysis or a rank order correlation. These two methods used for calculating sensitivity analysis are discussed below:

Regression is simply the name of a statistical method that tries to fit data to a predefined theoretical equation. In the case of linear regression input data is fit to a straight line. Multivariate regression is simply an extension to the simple regression. Multivariate regression tries to fit multiple input data sets to a planner (coming from theory) equation that could produce the output data set. The sensitivity values returned by @Risk are normalized variations of the regression coefficients (Palisade 2004). Stepwise regression, the technique used by @Risk to get sensitivity analysis results, is a technique designed to calculate regression values with multiple input values. Other techniques exist for calculating multiple regressions, but the stepwise regression technique is preferable for large numbers of inputs since it removes all variables that provide an insignificant contribution from the model. At the end of each stepwise regression

sensitivity report @Risk lists a goodness of fit value called the R^2 value. This value is simply a measurement of the percentage of variation that is explained by the linear relationship. If this number is less than ~60% then linear regression does not sufficiently explain the relationship between the inputs and output and another method of analysis should be used (Palisade 2004).

The coefficients listed in the @Risk sensitivity report are normalized regression coefficients associated with each input. A regression value of 0 indicates that there is no significant relationship between the input and the output, while a regression value of 1 or -1 indicates a 1 or -1 standard deviation change in the output for a 1 standard deviation change in the input.

The other technique in generating the sensitivity analysis results is the Rank Order Correlation. Correlation is a quantitative measurement of the strength of a relationship between two variables. The most common type of a correlation is linear correlation, which measures the linear relationship between two variables. The rank order correlation calculates the relationship between two data sets by comparing the rank of each value in a data set. To calculate rank, the data are ordered from lowest to highest and assigned numbers (the ranks) that corresponds to their position in the order. This method is preferred to linear correlation when we do not necessarily know the probability distribution functions from which the data were drawn. For example, if data set *A* was normally distributed and data set *B* was lognormally distributed, rank order correlation would produce a better representation of the relationship between the two data sets. The rank order correlation value returned by @Risk can vary between -1 and 1. A value of 0 indicates there is no correlation between variables; they are independent. A value of 1 indicates

a complete positive correlation between the two variables: that is when the value of the input variable is “high” the output value will be “high”. A value of -1 indicates a complete inverse relationship between the two variables; when the input value samples “high” the output value will sample “low”. Other correlation values indicate a partial correlation; the output is affected by changes in the selected input, but may be affected by other variables as well (Palisade 2004).

When comparing the two methods to choose one over the other, the one thing to keep in mind is the R^2 value reported by the Stepwise Regression. If this value is low it could be concluded that the relationship between the input and output variables is not linear. In this case the Rank-Order Correlation analysis to determine the sensitivity in the model might be more appropriate. If the R^2 value reported by the stepwise regression is high, it is easy to conclude that the relationship is linear and the stepwise regression method is very eligible to be used.

In some cases, @Risk produces contradictory sensitivity analysis results. For example, @Risk might report a significant positive relationship between two variables in the regression analysis and a significant negative correlation in the rank-order correlation analysis. This effect might be caused by multicollinearity. Multicollinearity occurs when independent variables in a model are correlated to each other as well as to the output. Reducing the impact of multicollinearity is a complicated problem to deal with. Sometimes removing the variable that causes the multicollinearity from the sensitivity analysis might help (Palisade 2004).

In general, it is of interest to report both Stepwise Regression and Rank-Order Correlation coefficients on one report. Table 5.2 summarizes all model inputs and outputs and their associated regression and correlation sensitivity coefficients. The regression and the

CHAPTER 5
Sensitivity Analysis

Table 5.2: Sensitivity Report: Stepwise Regression and Correlation

Rank	Name	Regression	Correlation	Standard Deviation
31: Net Profit or (Loss) Income Year 1				46,518.72
1	Price / Tilapia	0.8466	0.7419	0.2711
2	Feed Conversion lb. feed/lbs. gain / Cost	-0.3886	-0.6279	0.2854
3	Feed Cost/lb. / Cost	-0.2239	-0.1717	2.3100
4	System Loan / Interest Rate	-0.2215	-0.3957	3.4026
5	Building Loan / Interest Rate	-0.1090	-0.3889	3.4026
6	Mortality / Cost	-0.0621	-0.3587	6.8033
7	Land Loan / Interest Rate	-0.0210	-0.3487	3.4026
8	End Weight (lbs.) / Tilapia	0.0107	0.8047	44.579
9	Generator Loan / Interest Rate	0.0000	-0.3584	3.4026
R-Squared=		0.9968		
Rank	Name	Regression	Correlation	Standard Deviation
31: Net Profit or (Loss) Income Year 2				97,851.21
1	Price / Tilapia	0.9268	0.8774	0.2711
2	Feed Conversion lb. feed/lbs. gain / Cost	-0.2106	-0.5678	0.2854
3	Feed Cost/lb. / Cost	-0.1465	-0.2910	2.3100
4	System Loan / Interest Rate	-0.1199	-0.2359	3.4026
5	Mortality / Cost	-0.1181	-0.2946	3.4026
6	End Weight (lbs.) / Tilapia	0.0872	0.8249	6.8033
7	Building Loan / Interest Rate	-0.0609	-0.2310	3.4026
8	Land Loan / Interest Rate	-0.0117	-0.2118	44.579
9	Generator Loan / Interest Rate	0.0000	-0.2169	3.4026
R-Squared=		0.9943		
Rank	Name	Regression	Correlation	Standard Deviation
31: Net Profit or (Loss) Income Year 3				105,001.27
1	Price / Tilapia	0.9011	0.8772	0.2711
2	Feed Conversion lb. feed/lbs. gain / Cost	-0.1916	-0.5688	0.2854
3	System Loan / Interest Rate	-0.1403	-0.2291	2.3100
4	Feed Cost/lb. / Cost	-0.1283	-0.2904	3.4026
5	Mortality / Cost	-0.1256	-0.2970	3.4026
6	End Weight (lbs.) / Tilapia	0.1234	0.8255	6.8033
7	Building Loan / Interest Rate	-0.0367	-0.2243	3.4026
8	Generator Loan / Interest Rate	-0.0078	-0.2103	44.579
9	Land Loan / Interest Rate	0.0000	-0.2055	3.4026
R-Squared=		0.9901		

correlation coefficient for output price are, 0.8466 and 0.7419 respectively. The regression coefficient can be explained as follows: If output price is increased by one standard deviation, or 27.11 cents, Net Profit or Loss for year one will be increased by 0.8466 standard deviations, or \$39,382.75. The correlation coefficient indicates also that there is a strong positive relationship between Net Income and price of output. The same explanation applies to the rest of the coefficients.

Tornado Graphs: A graphical representation of the sensitivity report is obtained by generating tornado graphs. A tornado graph can be displayed for either the regression or correlation coefficients of the sensitivity analysis result. The graph represents each input variable's coefficient by a bar stretching out either to the right or to the left depending on the sign of the coefficient, positive or negative, respectively. Also, the length of the bar represents the magnitude of the coefficient, the longer the bar the higher the impact of that variable on the output cell. Tornado graphs based on regression analysis for all three output cells analyzed in this study are presented in figures 5.15 through 5.17. Figure 5.15 presents the graphical representation of the regression sensitivity report for Net Income Year1. Price will have a positive impact on net income since the bar stretches out to the right. At the end of the bar the regression coefficient is listed, 0.847 in this case. Conversion rate has a negative impact on Net Income Year1, this is represented by the bar for conversion rate stretching out to the left. The negative impact for a higher conversion rate can be explained as follows: as conversion rate¹ increases this means that more feed needs to be fed for a 1 pound gain, a net increase in total cost

¹ Remember, conversion rate is specified as follows: number of pounds of feed needed per one pound gain in live fish.

and thus a decrease in Net Profit. Again at the end of the bar the regression coefficient is listed, -0.389 in this case. The same explanation applies for the remaining two graphs.

From either the sensitivity report or the tornado graphs it can be clearly seen that output price is by far the most important variable in the model. Output price for all the three years of income maintains an almost one standard deviation to one standard deviation relation with income, an indication that output price plays a crucial role in income fluctuations. Also from the simulation analysis presented above we saw that given the current circumstances the expected Net Income for all the three years will be negative. Given these results the next question of interest might be: What would output price have to be to support a positive expected Net Income for all the three years, or what would happen if the mean for output price were to double? In order to answer this question a second simulation with a modified output price distribution was performed. The modified simulation is addressed in the next section.

Regression Sensitivity for Net Profit (Loss)
Year1

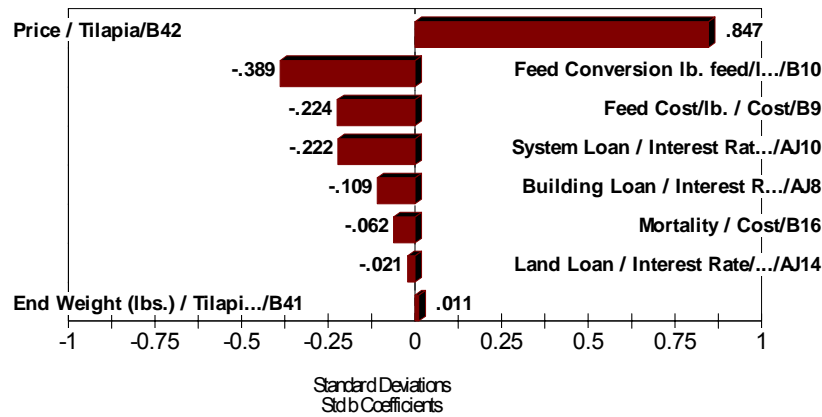


Figure 5.15: Tornado Graph for Net Profit Year1

Regression Sensitivity for Net Profit (Loss)
Year2

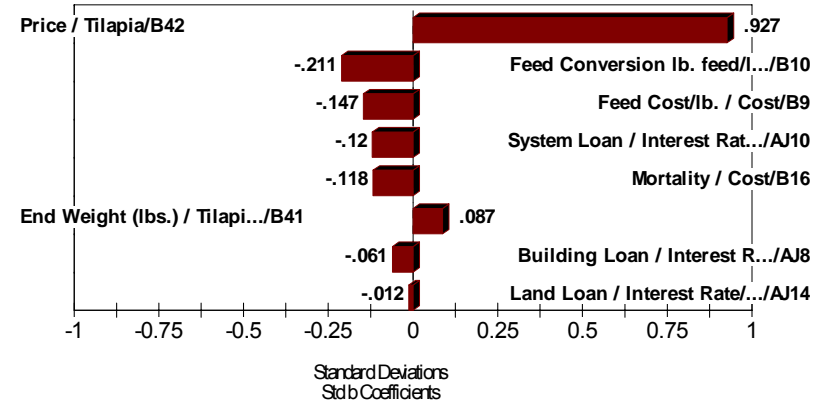


Figure 5.16: Tornado Graph for Net Profit Year2

Regression Sensitivity for Net Profit (Loss)
Year3

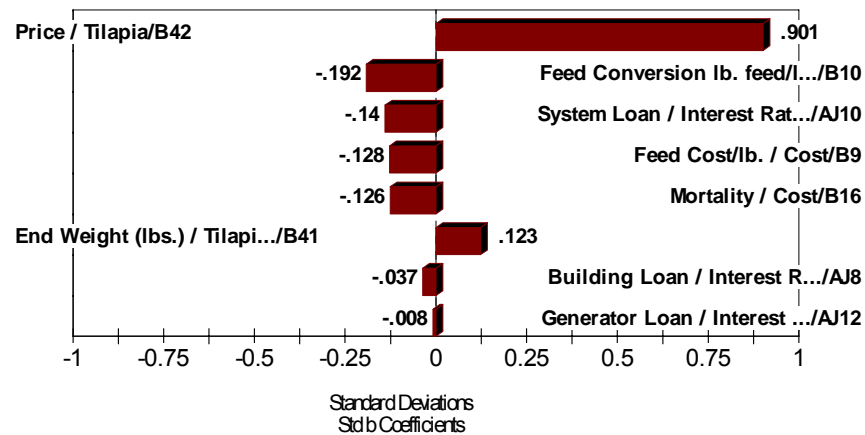


Figure 5.17: Tornado Graph for Net Profit Year3

5.4 Modified Simulation

In order to answer the question posed in section 5.3. and to illustrate how a “what if” type scenario can be used to explore improvements in the profitability of an aquaculture system, the Aquaculture Economic Cost model was simulated for a second time. The risk model was kept at the same settings as the original version. The modified model consists again of six input variables: feed cost, mortality rate, feed conversion rate, end weight, selling price and capital interest rate, and three output variables: Net Income (Loss) for years one through three. All of the input variables’ distributions except for the output price distribution were maintained the same as in the original model (the distributional parameters were not changed). Output price distribution was modified as such to keep the same distribution (exponential) but its location (mean) was shifted by double. The sample observations were kept the same. The reason for this is that if we multiplied each and every sample observation by two it would, of course, double the mean of the distribution, but it would also double its other distributional parameters, such as variance and standard deviation, and thus most likely produce a different distribution. So when applying the exponential distribution to output price in the AECM model the mean of the distribution fit was manually doubled from its original value of \$1.09 to \$2.18. The rest of the distributional parameters such as variance, standard deviation, skewness and kurtosis were kept the same.

5.4.1 Simulating the Modified Model

After modifying the mean of output price variable, the AECM model was simulated for a second time for ten more thousand iterations. In order to keep the simulation environment the same as in the original model, Latin Hypercube was the method of sampling used in the modified simulation also. After the simulation was completed the new simulation results were generated. Table 5.3 summarizes the modified simulation results. Table 5.3 looks very similar to table 5.1, but now the coefficients estimated for output price are different and the expected (mean) Net Income (Loss) for the second two years is positive. For the first year Net Income is negative even after the price increase. One explanation to this result is that in the first year the business incurs a higher cost (start up costs) than in the following years making it difficult to have a positive Net Income in the first year. All the other reports generated in the original simulation could be generated in the same fashion for the modified simulation also, and the same explanation for each of the reports would apply as in the original simulation.

The above modification of the original simulation model is one of the many modification one could apply to explore profitability improvements. Each of the model variable probability distributions could be altered in the same fashion and modified results can be generated. For example if mortality rate was a significant source of Net income variations, a similar model modification could have been applied to evaluate a situation where mortality rate was characterized by the same probability distribution but its mean was to be downshifted (lower mean mortality rate). One could also take a similar approach in modifying feed cost also.

However, caution should be used when applying “what if” scenarios of the above type (modifying underlying probability distributions). First, probability distributions should be altered in such a way as to preserve the original distributional parameters as in the initial model¹; this means that we are looking for a shift in the location of the distribution not a change in the distribution itself. If distributional parameters or the distribution itself are affected when modifying the model then comparing the original simulation results with the modified simulation results for “what if” scenario purposes becomes irrelevant. Second, the simulation environment should be maintained the same. The number of times the model is simulated (iterated), the sampling method and all the other simulation settings should not be altered. Generally even when simulating the exact same model for fewer iterations can and most likely will produce different results. Changing the sampling method when simulating for a second time is certainly not advised. The sampling method is the key to simulation, it is the method that commands the software (@Risk) on how to draw random numbers from the underlying probability distributions and use them to re-calculate (iterate) the model and if that method is altered all of the results will. Thus maintaining the same sampling method becomes very important when the results of two simulations need to be compared

¹ By parameters here is meant shape parameters, such as variance, standard deviation, kurtosis, skewness and other higher moment parameters. Location parameters, such as mean and truncation, are the parameters that can be changed.

CHAPTER 5
Simulating the Modified Model

Table 5.3: Quick Modified Model Simulation Summary

Summary Information	
Workbook Name	Aqua Econ Cost Model
Number of Simulations	1
Number of Iterations	10,000
Number of Inputs	9
Number of Outputs	3
Sampling Type	Latin Hypercube
Simulation Start Time	10/17/2006 14:22
Simulation Stop Time	10/17/2006 14:22
Simulation Duration	00:00:35
Random Seed	1600609983

Output		Statistics						
Name	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2
Net Profit or (Loss) Year1	G33	(551,517.10)	(120,647.10)	1,256,473	(277,678.00)	5%	178,488.30	95%
Net Profit or (Loss) Year2	H33	(427,066.30)	143,546.10	1,941,266	(159,922.90)	5%	745,501.10	95%
Net Profit or (Loss) Year3	I33	(425,521.60)	147,813.10	1,943,658	(165,505.50)	5%	749,615.50	95%

Input		Statistics						
Name	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2
Building Loan / Interest Rate (%)	AJ8	0.01	9.04	21.85	3.52	0.05	14.60	0.95
Feed Cost (cents/lb)	B9	20.03	25.64	30.30	21.42	0.05	29.48	0.95
Feed Conversion (lb fed/ 1lb. gain)	B10	1.05	1.44	6.52	1.16	0.05	1.95	0.95
System Loan / Interest Rate (%)	AJ10	0.01	9.04	24.35	3.52	0.05	14.60	0.95
Generator Loan / Interest Rate (%)	AJ12	0.01	9.04	22.28	3.52	0.05	14.60	0.95
Land Loan / Interest Rate (%)	AJ14	0.01	9.04	22.13	3.52	0.05	14.60	0.95
Mortality (%)	B16	0.00	7.90	44.47	0.98	0.05	17.58	0.95
End Weight (grams)	B41	607.48	737.66	907.11	664.16	0.05	811.34	0.95
Output Price (\$/lb)	B42	0.82	2.18	3.33	0.98	0.05	2.63	0.95

Chapter 6

Summary and Conclusions

6.1 Introduction

This chapter is divided into two main parts; the first part summarizes the whole thesis from the beginning, stating the objectives, presenting the model development, model formulation and interpreting the results. The second part presents the overall conclusions and limitations of this study as well as opportunities for future research.

6.2 Thesis Summary

Chapter One provides an overall perspective of the sea food industry in the United States and around the world, focusing on the economic trends over the past few decades of the fishing industry and aquaculture production in order to give the reader a perspective as to where the aquaculture industry stands in terms of its importance in the overall food supply and where it might be in the coming years. The chapter shows that seafood consumption continues to increase rapidly as scientific evidence continues to show world's fisheries being in crisis. Natural stocks of finfish and shellfish have been declining for years, and evidence shows dramatic decline in

total global catches. Given this background, in order for the world to ensure a stable seafood supply the development of aquaculture becomes important. In fact aquaculture is already supplying more than 30 percent of the total seafood supply. In addition domestic aquaculture has the potential to reduce the national seafood trade deficit, currently the second largest contributor to the national debt after petroleum products. Also domestically produced aquaculture products are important as they can guarantee product safety and quality compared to imports. As such, conducting risk analysis in recirculating aquaculture production systems to evaluate the range and likelihood of positive net income becomes imperative. The purpose of this study is to modify an existing static analytical model developed for a RAS through incorporation of risk considerations to evaluate the economic viability of the system. In addition the objective of this analysis is to provide a well documented risk – based analytical system so that individuals (investors/lenders) can use it to tailor the analysis to their own investment decisions—that is to collect the input data, run the model, and interpret the results. In order to accomplish these objectives, Monte Carlo simulation is employed.

Chapter two presents some general information on tilapia, as it is the species used in this analysis. The first half of this chapter presents a historical perspective of the use of this species and then continues with its life and biology. The second half of this chapter presents some main points on the economics of this species. Total U.S. production of tilapia, whether it is indoor or outdoor, total imports and major tilapia trading partners with the U.S. and their respective amounts exported to the U.S. are some of the parameters presented in this chapter. The main point drawn in this chapter is that despite a steady increase in domestic aquaculture supply of

tilapia, most of the domestic demand is still met by imports. Imports of aquaculture products in the U.S. have risen drastically in the recent years, keeping aquaculture products' prices at relatively low levels. This low price is an indication that price might be a determinant variable in this analysis. This indication was reinforced in the simulation results.

A general overview of re-circulating systems and their main components is presented in chapter three. This is intended to give the reader a general perspective on how re-circulating systems work, how dynamic they are and to give the reader a feeling of what some of the sources of uncertainty in this business are. Then the chapter proceeds with a discussion of how Tilapia is produced in re-circulating systems. Tilapia stocking density, feeding rates, conversion rates and different management techniques and strategies are also presented towards the end of this chapter. The chapter is also intended to familiarize the reader with the biology of tilapia, the chapter shows that numerous biological features (such as, relatively high feed conversion rates, tolerance to water salinity, short maturity period and so forth) make tilapia very adaptable for RAS production. Another major point in this chapter is that RAS are one of the most productive intensive fish rearing systems. One disadvantage is that RAS are capital intensive, however when compared with other intensive rearing systems, such as open sea net pens, RAS capital requirements are similar (McLEAn 2007).

Chapter four and five are the main components of this thesis. Chapter four starts with a general overview of risk analysis from a historical and present perspective. Different risk measuring analytical tools are also presented in this chapter. Then the chapter continues with the theoretical concepts employed in a risk analysis with Monte Carlo simulations.

Next, @Risk model development stages are listed and each of these stages is described in detail. The four stages of model development are as follows, *Develop an Excel spreadsheet model, Identify sources of uncertainty in the model, Analyze the model with simulation, Make a decision given the results*. The primary target of this thesis were stages two, three and four, with a particular interest on two and three. This is because stage one was conducted in a previous research project (Coale 2003), and the fourth is the subjective stage where each model user will make their decisions based on their risk preferences.

The focus of this thesis was to evaluate the role of six major variables: Feed cost, Mortality rate, Feed conversion, Final weight, Output price and interest rate on the expected net return from the system for three years into the future. The data used to quantify the above variables by the means of probability distributions came from two sources: historical data and expert opinion. Historical time series data were obtained for Output price and Interest rate. Expert opinion data were obtained for quantifying the other four variables.

After data were collected distributions were fitted for each of the six variables. The fitting procedure and major statistics are also presented in chapter four. Next hypothesis tests for the fitted distributions were performed and presented towards the end of this chapter. It turned out that the distributions satisfied all of the goodness of fit statistics.

Chapter five deals with simulating the AECM model and presenting the results. The chapter starts with outlining the simulation set up. Latin Hypercube turned out to be the desired sampling method, this is mainly because accounting for events with low probability of occurrence was a major concern. The model was then simulated with @Risk for ten thousand

iterations. After the model was simulated the range of net income for all the three years was obtained. Table 5.1 outlines the details of the results obtained. According to this analysis, there are strong chances that there will be negative expected net income (mean net income) for all the three years. More specifically the simulation shows that net income for all the three years, respectively, will be -\$216,905.26, -\$53,689.28, and -\$53,111.33. The simulation also shows that distribution variance decreases from year 1 to year 3, meaning that risk decreases from year1 to year3.

In addition to the simulation sensitivity analysis were carried out in order to see how each of the six variables evaluated were affecting net income. Both methods available in @Risk, the stepwise regression and correlation, for carrying out sensitivity analysis were used. Both methods reported that output price is a significant variable affecting net income.

Next, after evaluating the above sensitivity results, the following question arose: what would be the impact on net profit for all the three years if output price were to double? That is, what would happen if the same distribution for output price was to be maintained but its mean were to double. To answer this question a second simulation was performed. The second simulation was carried out under the same configurations as the first simulation except that in the second simulation the distributional mean for output price was manually doubled. According to the second simulation, there are better chances to make positive net profits in recirculating aquaculture. The second simulation reports expected net profits for the three years, respectively, as follows: -\$120,647.10, \$143,546.10, and \$147,813.10.

6.3 Overall Conclusions

The major objectives set forth for this study in chapter one have been achieved. A complete illustration of using the AECM model with @Risk simulations to conduct risk analysis in recirculating systems with actual data (being that historical or elicited) was carried out. Current and potential aquaculture producers may extract useful information from this study only with discretion. Even though data from actual aquaculture businesses were used, the results of this analysis will not be representative for a specific aquaculture business and should not be used for specific managerial and policy purposes. Each business is unique in the way it is managed and operated and thus has unique production and technical risks associated with it. The main purpose of this study was to provide an illustration as to how to employ the AECM model and @Risk with Monte Carlo simulation to conduct risk analysis.

Even though the above results reported in this study were obtained solely for illustration purposes, based on this study and previous analyses, some general directions for current and future aquaculture production are evident. The study shows that the early years of production for a re-circulating aquaculture center are costly, and close attention should be given, in these early years, to maintaining business in the profitability range. While conducting the study it was understood that economies of scale is certainly an advantage for big businesses, and also that operating on a large scale can be one way to keep input costs (such as feed) at low levels¹. In

¹ The study does not directly illustrate this, however, economies of scale was pointed out as an advantage for big businesses by one of the interviewees during the probability distribution elicitation process

addition, sensitivity analysis reported that output price is by far the most important determinant of in the profitability of a recirculating system. This means that low cost imports of tilapia and other fish, mainly from Asia, are the main threat for the future of domestic aquaculture producers. Finding ways of lowering cost and becoming more competitive will be the main challenge for domestic producers to overcome in the coming years. Experts agree that currently the only way for domestic producers to compete with cheap foreign imports is to exploit niche markets with live fish. Such niche markets currently consist of ethnic groups, such as Hispanic and Asian communities, who are willing to pay a premium for live fish that imports cannot provide (McLean 2007).

Also based on sensitivity analysis results provided above, some general directions for future policy on protecting the domestic aquaculture producers against foreign imports can be drawn. Protecting domestic producers is important because domestically produced aquaculture products are highly perceived as safer and of better quality as opposed to imports. However, the above sensitivity results must be used with caution because, as stated above, their purpose is for illustration only.

6.4 Future Research Opportunities

The model provided by this analysis is a simulation type model that tries to quantify the risk and uncertainty associated with aquaculture production. The results obtained from the simulation basically quantify this risk and uncertainty in probability terms, such as, saying that

there is a ninety percent chance that Net Income for year1 will fall between certain values. As outlined in chapter one this information is useful for current producers to see how the bottom line of the business will fluctuate in the coming years, and for potential producers who would like to evaluate their chances of making positive profits before committing their resources to such a venture. Risk simulation results may in many cases be useful to loan providers who may use the information obtained from the simulations in making their decisions on whether or not to issue a loan to certain businesses.

In certain instances, however, current and potential aquaculture producers may not be only interested in quantifying risk but also optimizing it¹. That is, business owners might not only be interested in obtaining bottom line probability distributions, but also in optimizing their stochastic production model to achieve desired economic profit levels. An extension to the simulation model presented in this study could be carried out to optimize risk and uncertainty associated with aquaculture production. Risk optimization with simulation is a different procedure of optimizing a model from conventional model optimizations. Conventional methods only optimize models that are deterministic in nature. By including simulation in the optimization procedure we account for uncertainty in model variables. While simple simulation provides the range and the probability distribution for output variables, optimizing with simulation will try to minimize certain distributional parameters obtained in the simple simulation. One way of optimizing the AECM model with simulation could be to minimize Net profit's variance, standard deviation or other distributional parameters as desired. @Risk, the

¹ The model can be setup to maximize or minimize risk depending on the nature of the problem.

software used in the current analysis, offers an extension to include Risk optimization with Monte Carlo simulation and might be a good starting point for such a study.

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Appendix A
AECM Model Data Entry Section

User Interface Page 1

Variable Costs

Item		Cost
Feed		
Feed Cost/lb.	\$	0.26
Feed Conversion lb. feed/lbs. gain		1.44
Tank Size		14,000.00
Fingerlings Cost/each	\$	0.22
Number of fingerlings purchased for one tank		9,000
Initial Weight of fingerlings (grams)		100
Initial Stocking density (lb./gal)		0.1575
Mortality		7.886%
Chemicals		
Sodium Bicarbonate	\$	0.06
Sodium Bicarb kg/tank/week		105.8382
Salt Prophylactic Treatment		0.043
Calcium Chloride	\$	-
50 lbs of Salt	\$	10.00
Labor		
Wage / hr	\$	8.25
Labor Dead Time		5%
Maintenance		1%
Cash		
Monthly Phone Expense	\$	102.00
Interest Rate		4.00%
Startup Legal Services	\$	-
Accounting Sercies	\$	500.00
Liability Insurance	\$	4,000.00
Flood Insurance	\$	-
beginning cash balance	\$	40,000.00
Minimum Cash Balance	\$	5,000.00
Operator's Desired Income	\$	24,000.00
Percentage of total income to come from aquaculture operation		100%

Appendix A
AECM Model Data Entry Section

Fish

Type of Fish		Tilapia
Days		180
End Weight (lbs.)		1.622861374
Price	\$	1.09
Months in a Cycle		6
Number of Months in the Cycle that Harvesting Occurs		3
Month in which production will begin		January

Appendix A
AECM Model Data Entry Section

User Interface Page 2

Equipment Costs

Item	Quantity	Price	Total Price	Useful Life
Scale	2	\$ 800.00	\$ 1,600.00	10
Tool Kit	1	\$ 450.00	\$ 450.00	20
Oxygen Meter	4	\$ 580.00	\$ 2,320.00	10
pH meter	2	\$ 360.00	\$ 720.00	0.49
Nets	0	\$ -	\$ -	0.49
Total Equipment Costs			\$ 5,090.00	

Item	Quantity	Price	Total Price	Useful Life
Computer	1	\$ 2,500.00	\$ 2,500.00	8
Generator	1	\$ 20,000.00	\$ 20,000.00	12
Land Costs	2	\$ 2,000.00	\$ 4,000.00	
System Costs (range \$2-\$5 per gallon)	168000	\$ 2.68	\$ 450,000.00	

Depreciation Calculations

Item	Salvage Value (Indicate a dollar value)	Depreciation Useful Life
Comuter	\$ 100.00	2
Generator	\$ 4,500.00	10
System	\$ -	12
Oxygen Meter	\$ -	2

Appendix A
AECM Model Data Entry Section

User Interface Page 3

Electrical Component

Items	Number of Components	Hours Used / Day	Days of Use	Horsepower
Lightbulbs	14.00	16.00	365.00	
Propane Heaters	0.00	0.00	0.00	0.00
Fan	6.00	8.00	74.00	0.75
Water Heaters	4.00	4.00	74.00	1.50
Regenerative Blowers	2.00	24.00	180.00	6.00
Well Pump	2.00	24.00	180.00	5.00
Pumps	12.00	24.00	180.00	3.00
Drum Filters	4.00	24.00	180.00	0.25
Surface Agitators	0.00	24.00	180.00	0.25
Other Electrical devices:	0.00	0.00	0.00	0.00
Pumps	4.00	24.00	180.00	0.75
Drum Filter booster pump	4.00	24.00	180.00	1.50
Sump Pump	1.00	0.50	95.00	0.50
Heater and AC	1.00	8.00	99.00	

Appendix A
AECM Model Data Entry Section

User Interface Page 4

Heating and Utility Information

Heating Information

Heating Values	Btu	Unit of Fuel	Cost
Natural Gas	1,000,000	1000ft^3	\$ -
Liquid Propane	92000	gallon	\$ -
Fuel Oil (#2)	138000	gallon	\$ -
If you do not have the information above please indicate to the right the average monthly expense for heating the facility			\$ 542.06

Water and Sewer Information

Utility Water	Option	Description of Billing	Unit	Cost per Unit	Description
Well	0			\$ -	
Water System	1		thousand gal	\$ 2.820000	inside corporate limits
Water System	2		thousand gal	\$ 4.940000	outside Corp limits
Water System	3		per bill	\$ 2.060000	inside Corp. limits
Water System	4		per bill	\$ 3.610000	outside Corp. limits
1. Do you have a well or are you on the town or city water sytem?					
If you have answered Well to the previous question skip to question C.					
A. What is your water price per one thousand gallons?	0	0			
B. What is your Water Billing Fee?	0	0			
Please note the comment that is attached to this cell.					
C. What is the cost of digging the well per foot?	\$	10.00			
D. What is the cost of casing per foot for the well?	\$	5.17			
E. What is the cost for grouting for the well?	\$	300.00			
F. What is the cost of pump and accessories plus installation for the well?	\$	1,350.00			
G. What is the depth of the well in feet?	190				
H. What is the useful life in years of the well?	10				
I. How many wells do you have?	2				
Sewer					
Lagoon	0			\$ -	
Water System	1		thousand gal	\$ 3.220000	inside corporate limits
Water System	2		thousand gal	\$ 5.640000	outside Corp limits
Water System	3		per bill	\$ 2.090000	inside Corp. limits
Water System	4		per bill	\$ 3.660000	outside Corp. limits
Do you have a lagoon or do you use a water system to dipose of wastes?					
If you have answered Lagoon to the previous question skip to question C.					
A. What is your sewer price per one thousand gallons?	0	0			
B. What is your sewer billing fee?	0	0			
C. What is the cost of installation for your operation's lagoon?	\$	5,700.00			
D. What is the useful life in years of the lagoon?	12.00				
E. What is the salvage value of the lagoon?	\$	-			

Appendix A
AECM Model Data Entry Section

Electricity Information

Electricity

	1	Small Size Facility	kilowatt-hr	\$	0.047000	VT charge
	2	Small Size Facility		\$	0.050000	Normal Charge
		Small Billing Charge		\$	10.000000	
	3	Medium Size		\$	0.059000	Normal Charge
		Med. Billing Charge		\$	18.000000	
		Med. Price per kw demanded		\$	4.000000	
	4	Large Size		\$	0.019000	Normal Charge
		Large Billing Charge		\$	50.000000	
		Large Price per kw demanded		\$	8.960000	
		State Tax Rate Electricity	first 2500 kw-hr	\$	0.001550	tax per kw-hr
			2500-50000	\$	0.000990	tax per kw-hr
			>50000	\$	0.000750	tax per kw-hr
		Town Tax Rate (applies to most)		\$	2.500000	one charge applied to bill
What is your electricity charge for kW-hr?	3	\$	0.05900			
		\$	4.00			
		\$	18.00			

Appendix A
AECM Model Data Entry Section

User Interface Page 5

Building Information

Size of Your Building	Walls	Ceiling
Length (Sides)	204	204
Width (Ends)	60	60
Insulation of Your Building	25	25
Height	14	
Area of Building	12240	

Option	Description of Building	Building Cost / ft ²					
		10 ft height	12 ft height	14 ft height	16 ft height	18 ft height	20ft Height
1	Input #1 below if you have an actual estimate from a contractor	44.44	0	9.81	0	0	0
2	basic with 25 R value walls, 30 R value ceiling and 30 psf roof with 4"	\$21.250	\$21.550	\$21.850	\$22.250	\$22.750	\$23.250
3	basic with 25 R value walls, 30 R value ceiling and 30 psf roof with 5" concrete flooring	\$21.500	\$21.800	\$22.100	\$22.500	\$23.000	\$23.500
4	basic with 25 R value walls, 30 R value ceiling and 30 psf roof with 6" concrete flooring	\$21.800	\$22.100	\$22.400	\$22.800	\$23.300	\$23.800

From the above list which discription best descr	1
Price of Your Building / ft ²	\$9.81
Building yrs of use	20
Years paying for building or for the Turn Key Op	25
Salvage Value	0
Relative Humidity	80.00%
Temperature Inside facilities	80
Temparature of water entering facility	57
Building Costs	\$120,074
Estimated Building Loan from Loan officer or contractor	\$0

The Following list options for Building and their corosponding costs for each option at a specific height.
In the spot marked Price of Your Building please input the costs per ft² of your desired height and option

User Interface Page 6

Loan Information				
Business Loans	Principal	Interest Rate	Number of Years	Number of Payments per Year
Building Loan	\$120,074.40	9.03%	20	12
System Loan	\$450,000.00	9.03%	15	12
Generator Loan	\$20,000.00	9.03%	5	12
Land Loan	\$4,000.00	9.03%	4	12
Turn Key Operation Loan		0.00%	0	12
Additional Loan (1)	\$0.00	0.00%	0	12
Additional Loan (2)	\$0.00	0.00%	0.00	12

User Interface Page 7

System and Water Information

# of Tanks	12
gals per tank	14000
usable gals per tank (90%)	12600
Water replacement per day	7.50%
Other Water Uses	2.50%
Number of tanks harvested per month	4

Dimensions of Tanks

Area (ft ²)	452.389
Area (ft ²) of all the tanks	5428.668

Appendix A
AECM Model Data Entry Section

User Interface Page 8

Labor Information

Below, enter the task in the first column if it is not already listed. Next indicate the amount of time necessary to accomplish the task in the second column. There are codes to the right that must be entered into the third column to indicate the number of times a task is completed each month

1	Daily	30
2	Weekly	4
3	Twice per week	8
4	Monthly	1
5	Twice per month	2
6	Every other month	0.5
7	Does not apply	0

Task	Minutes for each task	Number of Times the Task is Completed per Month	Number of Laborers Completing Task	Times Completed per Month	Hourly Wage Rate
Dissolved Oxygen	2	1	1	30	\$ 8.25
Temperature	1	1	1	30	\$ 8.25
pH	10	1	1	30	\$ 8.25
TAN	0	7	1	0	\$ 8.25
Feed	1	1	1	30	\$ 8.25
Mortality	5	1	1	30	\$ 8.25
NO2	1	7	1	0	\$ 8.25
NO3	1	7	1	0	\$ 8.25
ALK	1	7	1	0	\$ 8.25
Chloride	1	7	1	0	\$ 8.25
Salinity	8	1	1	30	\$ 8.25
Hardness	4	7	1	0	\$ 8.25
Visual Inspection	20	1	1	30	\$ 8.25
Clean and Adj.	3	1	1	30	\$ 8.25
Stocking One Tank	15	5	1	2	\$ 8.25
Harvesting One Tank	60	5	2	2	\$ 7.88
Read computer screen	2	1	1	30	\$ 8.25
Check succi depth	5	1	1	30	\$ 8.25
Water samples	2	1	1	30	\$ 8.25
Test samples	30	1	1	30	\$ 8.25
Record exchange water (meter)	2	1	1	30	\$ 8.25
Insert data in computer	4	1	1	30	\$ 8.25
Empty fines buckets	10	1	1	30	\$ 8.25
Check drum fileters	4	1	1	30	\$ 8.25
Pump septic tank	240	4	1	1	\$ 8.25

Total Number of Laborers		3		
Hourly Wage paid to Laborer #1	\$	8.25	Weighted Average Hourly Wage	\$ 8.25
Hourly Wage paid to Laborer #2	\$	7.50	Weighted Average Hourly Wage	\$ 7.88
Hourly Wage paid to Laborer #3	\$	7.00	Weighted Average Hourly Wage	\$ 7.58
Hourly Wage paid to Laborer #4			Weighted Average Hourly Wage	\$ -
Hourly Wage paid to Laborer #5			Weighted Average Hourly Wage	\$ -
Hourly Wage paid to Laborer #6			Weighted Average Hourly Wage	\$ -
Hourly Wage paid to Laborer #7			Weighted Average Hourly Wage	\$ -
Hourly Wage paid to Laborer #8			Weighted Average Hourly Wage	\$ -
Hourly Wage paid to Laborer #9			Weighted Average Hourly Wage	\$ -
Hourly Wage paid to Laborer #10			Weighted Average Hourly Wage	\$ -

User Interface Page 9

Additional Information

Additional Sources of Income	Source		Total Annual Income
List up to 4 sources	-	\$	-
	-	\$	-
	-	\$	-
	-	\$	-

Additional Expenses	Expense		Total Annual Expense
List up to 10 additional expenses	Marketing Expense	\$	36,000.00
	Rent Oxyen Tank	\$	7,584.00
	Oxygen	\$	24,232.00
	-	\$	-
	-	\$	-
	-	\$	-
	-	\$	-
	-	\$	-
	-	\$	-
	-	\$	-

Appendix B
AECM Model: Calculations Section

Projected Income Statement

Aquaculture Model

Year 1

Part 1 - Income			
		1: Sales	\$ 176,140.88
		2: Returns/Allowances	
		3: Line 1 - Line 2	\$ 176,140.88
		4: Cost of Goods Sold	\$ 47,520.00
		5: Gross Profit (3-4)	\$ 128,620.88
		6: Other Income	
		7: Gross Income (5+6)	\$ 128,620.88
Part 2 - Expenses			
8: Advertising	\$ -	19: Pension/Profit-Sharing	\$ -
9: Bad Debts from Sales/Services	\$ -	20a: Rent/Lease - Vehicles, Equipment, etc.	\$ -
10: Car and Truck Expenses	\$ -	b: Rent/Lease - Other Business Property	\$ -
11: Commissions and Fees	\$ -	21: Repairs/Maintenance	\$ 9,000.00
12: Depletion (Fingerling Loss)	\$ 156.14	22: Supplies	\$ 121,551.88
13: Depreciation	\$ 32,635.18	23: Taxes/Licenses	\$ -
14: Employee Benefit Programs	\$ -	24a: Travel	\$ -
15: Insurance (other than Health)	\$ 4,000.00	b: Meals/Entertainment	\$ -
16a: Interest (Mortgage/Capital Loans)	\$ 74,234.19	c: Nondeductible amount from line 24b	\$ -
b: Interest (Other)	\$ -	d: 24b-24c	\$ -
17: Legal and Professional Services	\$ 4,000.00	25: Utilities	\$ 29,373.26
18: Office Expenses (Computer)	\$ 2,500.00	26: Wages (less employment credits)	\$ 1,472.63
		27: Other Expenses	\$ 67,816.00
		28: Total Expenses	\$ 346,739.27
		29: Tentative Profit (Loss)	\$ (218,118.39)
		30: Expenses for Business Use of Home	\$ -
		31: Net Profit or (Loss)	\$ (218,118.39)

Appendix B
AECM Model: Calculations Section

Projected Income Statement	
Aquaculture Model	
Year 2	

Part 1 - Income	
	1: Sales \$ 352,281.76
	2: Returns/Allowances
	3: Line 1 - Line 2 \$ 352,281.76
	4: Cost of Good Sold \$ 47,520.00
	5: Gross Profit (3-4) \$ 304,761.76
	6: Other Income
	7: Gross Income (5+6) \$ 304,761.76

Part 2 - Expenses	
	19: Pension/Profit-Sharing \$ -
8: Advertising \$ -	20a: Rent/Lease - Vehicles, Equipment, etc. \$ -
9: Bad Debts from Sales/Services \$ -	b: Rent/Lease - Other Business Property \$ -
10: Car and Truck Expenses \$ -	21: Repairs/Maintenance \$ 9,000.00
11: Commissions and Fees \$ -	22: Supplies \$ 132,470.70
12: Depletion (Fingerling Loss) \$ 156.14	23: Taxes/Licenses \$ -
13: Depreciation \$ 32,635.18	24a: Travel \$ -
14: Employee Benefit Programs \$ -	b: Meals/Entertainment \$ -
15: Insurance (other than Health) \$ 4,000.00	c: Nondeductible amount from line 24b \$ -
16a: Interest (Mortgage/Capital Loans) \$ 80,307.64	d: 24b-24c \$ -
b: Interest (Other) \$ -	25: Utilities \$ 29,373.26
17: Legal and Professional Services \$ 4,000.00	26: Wages (less employment credits) \$ 1,606.50
18: Office Expenses (Computer)	27: Other Expenses \$ 67,816.00
	28: Total Expenses \$ 361,365.42

29: Tentative Profit (Loss)	\$ (56,603.66)
30: Expenses for Business Use of Home	\$ -
31: Net Profit or (Loss)	\$ (56,603.66)

Appendix B
AECM Model: Calculations Section

Projected Income Statement
Aquaculture Model
Year 3

Part 1 - Income			
		1: Sales	\$ 352,281.76
		2: Returns/Allowances	
		3: Line 1 - Line 2	\$ 352,281.76
		4: Cost of Good Sold	\$ 47,520.00
		5: Gross Profit (3-4)	\$ 304,761.76
		6: Other Income	
		7: Gross Income (5+6)	\$ 304,761.76
Part 2 - Expenses			
8: Advertising	\$ -	19: Pension/Profit-Sharing	\$ -
9: Bad Debts from Sales/Services	\$ -	20a: Rent/Lease - Vehicles, Equipment, etc.	\$ -
10: Car and Truck Expenses	\$ -	b: Rent/Lease - Other Business Property	\$ -
11: Commissions and Fees	\$ -	21: Repairs/Maintenance	\$ 9,000.00
12: Depletion (Fingerling Loss)	\$ 156.14	22: Supplies	\$ 132,470.70
13: Depreciation	\$ 31,435.18	23: Taxes/Licenses	\$ -
14: Employee Benefit Programs	\$ -	24a: Travel	\$ -
15: Insurance (other than Health)	\$ 4,000.00	b: Meals/Entertainment	\$ -
16a: Interest (Mortgage/Capital Loans)	\$ 80,736.33	c: Nondeductible amount from line 24b	\$ -
b: Interest (Other)	\$ -	d: 24b-24c	\$ -
17: Legal and Professional Services	\$ 4,000.00	25: Utilities	\$ 29,373.26
18: Office Expenses (Computer)		26: Wages (less employment credits)	\$ 1,606.50
		27: Other Expenses	\$ 67,816.00
		28: Total Expenses	\$ 360,594.11
		29: Tentative Profit (Loss)	\$ (55,832.35)
		30: Expenses for Business Use of Home	\$ -
		31: Net Profit or (Loss)	\$ (55,832.35)

Appendix B
AECM Model: Calculations Section

Balance Sheet
Aquaculture Model
December 31, Year 1

Assets		Liabilities	
Current Assets		Current Liabilities	
Cash Balance	\$ 29,700.00	Generator Loan Payment	\$ 287.71
Fingerlings	\$ 7,920.00	Interest on Generator Loan	\$ 127.79
Fingerlings in growth	\$ 30,988.60	Systems Loan Payment	\$ 1,287.49
Feed	\$ 9,958.03	Interest on Systems Loan	\$ 3,285.88
Chemicals	\$ 721.20	Building Loan Payment	\$ 194.40
Equipment	\$ -	Interest on Building Loan	\$ 888.59
Computer	\$ 2,500.00	Land Loan Payment	\$ 75.47
(Accumulated Depreciation)	\$ 1,200.00	Interest on Land Loan	\$ 24.14
Current Value	\$ 1,300.00	Turn Key Operating Loan Payment	\$ -
Insurance	\$ 333.33	Interest on Turn Key Operating Loan	\$ -
		Additional Loan (1) Payment	\$ -
		Interest on Additional Loan (1)	\$ -
		Additional Loan (2) Payment	\$ -
		Interest Additional Loan (2)	\$ -
		Start up Fingerlings	\$ -
		Refill Fingerlings after harvest	\$ -
		Feed	\$ 9,958.03
		Salt	\$ 722.40
		Chemicals (sodium bicarbonate)	\$ 719.99
		Electricity	\$ 2,345.77
		Heating (Natural Gas)	\$ -
		Heating (Liquid Propane)	\$ -
		Heating (Oil #2)	\$ -
		Phone	\$ 102.00
		Water	\$ -
		Well	\$ -
		Sewage	\$ -
		Lagoon	\$ -
		Labor	\$ 133.88
		Maintenance (% of system cost)	\$ 750.00
		Startup Legal Services	\$ -
		Accounting Services	\$ 41.67
		Liability Insurance	\$ 333.33
		Flood Insurance	\$ -
		-	\$ -
		-	\$ -
Total Current Assets	\$ 80,921.16		

Appendix B
AECM Model: Calculations Section

Non-Current Assets

Building	\$	120,074.40
(Accumulated Depreciation)	\$	6,003.72
Current Value	\$	114,070.68
System	\$	450,000.00
(Accumulated Depreciation)	\$	22,500.00
Current Value	\$	427,500.00
Generator	\$	20,000.00
(Accumulated Depreciation)	\$	1,550.00
Current Value	\$	18,450.00
Oxygen Meter	\$	-
(Accumulated Depreciation)	\$	-
Current Value	\$	-
Land	\$	4,000.00
Well	\$	9,064.60
(Accumulated Depreciation)	\$	906.46
Current Value	\$	8,158.14
Lagoon	\$	5,700.00
(Accumulated Depreciation)	\$	475.00
Current Value	\$	5,225.00
Total Non-Current Assets	\$	577,403.82

-	\$	-
-	\$	-
-	\$	-
-	\$	-
-	\$	-
-	\$	-
-	\$	-
-	\$	-
-	\$	-
-	\$	-
Total Current Liabilities	\$	21,278.54

Non-Current Liabilities

Principal Remaining (Building)	\$	117,835.09
Principal Remaining (System)	\$	435,169.50
Principal Remaining (Land)	\$	3,130.64
Principal Remaining (Generator)	\$	16,685.87
Principal Remaining (Turn Key)	\$	-
Principal Remaining (Add'l Loan 1)	\$	-
Principal Remaining (Add'l Loan 2)	\$	-
Total Non-Current Liabilities	\$	572,821.10

Total Liabilities \$ 594,099.64

Net Worth (Owner's Equity)

Contributed Capital \$ -
Retained Earnings \$ 64,225.34

Total Assets	\$	658,324.98	=	Total Liabilities & Net Worth	\$	658,324.98
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Appendix B
AECM Model: Calculations Section

Balance Sheet
Aquaculture Model
December 31, Year 2

Assets		Liabilities	
Current Assets		Current Liabilities	
Cash Balance	\$ 24,000.00	Generator Loan Payment	\$ 314.81
Fingerlings	\$ 7,920.00	Interest on Generator Loan	\$ 100.69
Fingerlings in growth	\$ 30,988.60	Systems Loan Payment	\$ 1,408.75
Feed	\$ 9,958.03	Interest on Systems Loan	\$ 3,164.62
Chemicals	\$ 721.20	Building Loan Payment	\$ 212.71
Equipment	\$ -	Interest on Building Loan	\$ 870.28
Computer	\$ 2,500.00	Land Loan Payment	\$ 82.58
(Accumulated Depreciation)	\$ 2,400.00	Interest on Land Loan	\$ 17.03
Current Value	\$ 100.00	Turn Key Operation Loan Payment	\$ -
Insurance	\$ 333.33	Interest on Turn Key Operation Loan	\$ -
		Additional Loan (1) Payment	\$ -
		Interest on Additional Loan (1)	\$ -
		Additional Loan (2) Payment	\$ -
		Interest on Additional Loan (2)	\$ -
		Fingerlings	\$ -
		Refill Fingerlings after Harvest	\$ -
		Feed	\$ 9,958.03
		Salt	\$ 722.40
		Chemicals (sodium bicarbonate)	\$ 719.99
		Electricity	\$ 2,345.77
		Heating (Natural Gas)	\$ -
		Heating (Liquid Propane)	\$ -
		Heating (Oil #2)	\$ -
		Phone	\$ 102.00
		Water	\$ -
		Sewage	\$ -
		Labor	\$ 133.88
		Maintenance (% of system cost)	\$ 750.00
		Startup Legal Services	\$ -
		Accounting Services	\$ 41.67
		Liability Insurance	\$ 333.33
		Flood Insurance	\$ -
			\$ -
			\$ -
			\$ -
Total Current Assets	\$ 74,021.16		\$ -

Appendix B
AECM Model: Calculations Section

Non-Current Assets

Building	\$	120,074.40
(Accumulated Depreciation)	\$	12,007.44
Current Value	\$	108,066.96
System	\$	450,000.00
(Accumulated Depreciation)	\$	45,000.00
Current Value	\$	405,000.00
Generator	\$	20,000.00
(Accumulated Depreciation)	\$	3,100.00
Current Value	\$	16,900.00
Oxygen Meter	\$	-
(Accumulated Depreciation)	\$	-
Current Value	\$	-
Land	\$	4,000.00
Well	\$	9,064.60
(Accumulated Depreciation)	\$	1,812.92
Current Value	\$	7,251.68
Lagoon	\$	5,700.00
(Accumulated Depreciation)	\$	950.00
Current Value	\$	4,750.00
Total Non-Current Assets	\$	545,968.64

-	\$	-
-	\$	-
-	\$	-
-	\$	-
-	\$	-
Total Current Liabilities	\$	21,278.54

Non-Current Liabilities

Principal Remaining (Building)	\$	115,384.90
Principal Remaining (System)	\$	418,942.26
Principal Remaining (Land)	\$	2,179.41
Principal Remaining (Generator)	\$	-
Principal Remaining (Turn Key)	\$	-
Principal Remaining (Add'l Loan 1)	\$	-
Principal Remaining (Add'l Loan 2)	\$	-
Total Non-Current Liabilities	\$	536,506.57

Total Liabilities \$ **557,785.11**

Net Worth (Owner's Equity)

Contributed Capital \$ -
Retained Earnings \$ 62,204.69

Total Assets	\$	619,989.80	=	Total Liabilities & Net Worth	\$	619,989.80
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Appendix B
AECM Model: Calculations Section

Balance Sheet
Aquaculture Model
December 31, Year 3

Assets

Liabilities

Current Assets

Cash Balance	\$	24,000.00
Fingerlings	\$	7,920.00
Fingerlings in growth	\$	30,988.60
Feed	\$	9,958.03
Chemicals	\$	721.20
Equipment	\$	-
Computer	\$	2,500.00
(Accumulated Depreciation)	\$	2,400.00
Current Value	\$	100.00
Insurance	\$	333.33
Total Current Assets	\$	74,021.16

Current Liabilities

Generator Loan Payment	\$	344.46
Interest on Generator Loan	\$	71.04
Systems Loan Payment	\$	1,541.42
Interest on Systems Loan	\$	3,031.95
Building Loan Payment	\$	232.74
Interest on Building Loan	\$	850.25
Land Loan Payment	\$	90.36
Interest on Land Loan	\$	90.36
Turn Key Operation Loan Payment	\$	-
Interest on Turn Key Loan	\$	-
Additional Loan (1) Payment	\$	-
Interest on Add'l Loan 1	\$	-
Additional Loan (2) Payment	\$	-
Interest on Add'l Loan 2	\$	-
Fingerlings	\$	-
Refill Fingerlings after Harvest	\$	-
Feed	\$	9,958.03
Salt	\$	722.40
Chemicals (sodium bicarbonate)	\$	719.99
Electricity	\$	2,345.77
Heating (Natural Gas)	\$	-
Heating (Liquid Propane)	\$	-
Heating (Oil #2)	\$	-
Phone	\$	102.00
Water	\$	-
Sewage	\$	-
Labor	\$	133.88
Maintenance (% of system cost)	\$	750.00
Startup Legal Services	\$	-
Accounting Services	\$	41.67
Liability Insurance	\$	333.33
Flood Insurance	\$	-
	-	-
	-	-
	-	-

Appendix B
AECM Model: Calculations Section

Non-Current Assets

Building	\$	120,074.40
(Accumulated Depreciation)	\$	18,011.16
Current Value	\$	102,063.24
System	\$	450,000.00
(Accumulated Depreciation)	\$	67,500.00
Current Value	\$	382,500.00
Generator	\$	20,000.00
(Accumulated Depreciation)	\$	4,650.00
Current Value	\$	15,350.00
Oxygen Meter	\$	-
(Accumulated Depreciation)	\$	-
Current Value	\$	-
Land	\$	4,000.00
Well	\$	9,064.60
(Accumulated Depreciation)	\$	2,719.38
Current Value	\$	6,345.22
Lagoon	\$	5,700.00
(Accumulated Depreciation)	\$	1,425.00
Current Value	\$	4,275.00
Total Non-Current Assets	\$	514,533.46

-	\$	-
-	\$	-
-	\$	-
-	\$	-
-	\$	-
-	\$	-
Total Current Liabilities	\$	21,359.65

Non-Current Liabilities

Principal Remaining (Building)	\$	112,703.95
Principal Remaining (System)	\$	401,186.77
Principal Remaining (Land)	\$	1,138.58
Principal Remaining (Generator)	\$	-
Principal Remaining (Turn Key)	\$	-
Principal Remaining (Add'l Loan 1)	\$	-
Principal Remaining (Add'l Loan 2)	\$	-
Total Non-Current Liabilities	\$	515,029.30

Total Liabilities \$ 536,388.95

Net Worth (Owner's Equity)

Contributed Capital	\$	-
Retained Earnings	\$	52,165.67

Total Assets	\$	588,554.62	=	Total Liabilities & Net Worth	\$	588,554.62
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Appendix C
AECM Model: Analysis Section

Financial Ratio Summary (240)

Aquaculture Model

Repayment Ability	Year 1	Year 2	What does the ratio indicate	How to Improve the Ratio
Term Debt & Lease Coverage Ratio	-116.39%	38.92%	This ratio indicates whether the business has enough capital to cover its payments.	<ul style="list-style-type: none"> ● Cut business expenses ● Increase income → Sell capital assets → Defer taxes → Increase production → Increase price ● Restructure Debt → Increase term → Pay interest only → Defer principal or interest
Capital Replacement & Term Debt Repayment Margin	\$ (206,833.83)	\$ 3,440.84		
10-10-6 Sensitivity Analysis				
% Drop in Revenue	-117%	1%	This ratio indicates whether the business will be able to handle a 10% drop in business revenue.	
% Increase in Expenses	-60%	1%	This tells whether the business can handle a 10% increase in business expense.	
% Increase in Variable Interest Rates	-35%	1%	This tells whether the business can handle a 6% increase in interest rates.	
Liquidity				
Current Ratio	3.80	3.48	The liquidity ratios indicates the business's ability to develop cash without disrupting business.	<ul style="list-style-type: none"> ● Restructure Debt → Do not try to pay off debt too quickly ● Recreate marketing plan → Match timing of cash inflows and outflows → Increase operating profits ● Cut business expenses ● Sell assets
Sales/Working Capital	2.95	6.68		

Appendix C AECM Model: Analysis Section

Solvency					
Debt/Equity		9.25	8.97	<p>The solvency ratio tells how much the owner and the lenders have invested in the business.</p>	<ul style="list-style-type: none"> ● Increase Operating Profits <ul style="list-style-type: none"> → Increase prices, quality, volume or added value of product → Improve production efficiencies ● Make additional principal payments ● Avoid unnecessary capital expenditures
Profitability					
Return on Assets (ROA)		-21.9%	13.0%	<p>The ROA ratio is used to compare the profits to the resources used to generate them.</p>	<p>costs</p> <ul style="list-style-type: none"> ● Increase efficiencies of production investments ● Eliminate unproductive capital or labor ● Reduce costs ● Increase production and quality of products to raise profits
Operating Profit Margin		-81.7%	22.8%	<p>The Operating Profit Margin relates profits realized to income generated.</p>	<ul style="list-style-type: none"> ● Reorganize interest expense ● Reduce management draws
Return on Equity (ROE)		-224.03%	129.10%	<p>The ROE ratio measures how well the investments in the operation are generating income.</p>	
Financial Efficiency					
Sales/Total Assets		0.27	0.57	<p>The capital turnover ratio is indicative of capital and manager's performance and measures efficiency of the assets to produce a profit for the operation.</p>	<ul style="list-style-type: none"> ● Increase income ● Decrease capital requirements

Appendix C
AECM Model: Analysis Section

Overall Business Rating

Repayment Ability	Ratios		Rating	
	Year 1	Year 2	Year 1	Year 2
Term Debt and Lease Coverage Ratio	-116.39%	38.92%	0	0
Liquidity				
Current Ratio	3.80	3.48	4	4
Solvency				
Debt-to-Equity Ratio	9.25	8.97	0	0
Collateral				
Return on Assets Ratio	-0.22	0.13	0	2
Financial Efficiency				
Sales/ Total Assets	0.27	0.57	0	0
Overall Rating			4	6

Appendix C
AECM Model: Analysis Section

What Actions are Necessary to Improve Financial Ratios

Repayment Ability

Term Debt & Lease Coverage Ratio		
Sales needed per year	\$	814,108.47
Price needed per lb	\$	2.52
# of lbs need to be produced in a year		746,197.07

10-10-6 Sensitivity Analysis

Based on the above changes in the Repayment Analysis the Sensitivity Ratios will change in the manner indicated below.

% Drop in Revenue	6.73%
% Increase in Expenses	15.15%
% Increase in Variable Interest Rates	9.82%

Liquidity

Sales/Working Capital		
Sales needed per year	\$	263,713.11 0
Price needed per pound sold	\$	0.82
# of pounds needed to be sold in a year		241,714.66
Working Capital		NA

Profitability

Return on Assets (ROA)		
Profit before interest and taxes needed	\$	123,997.96
Price needed per pound sold	\$	1.65
# of pounds needed to be sold in a year		489,362.81
Return on Equity (ROE)		
Profit before interest and taxes needed	\$	31,102.35
Price needed per pound sold	\$	1.34
# of pounds needed to be sold in a year		395,701.73

Financial Efficiency

Sales/Total Assets		
Sales need per year	\$	1,239,979.61
Price needed per pound sold	\$	3.84
# of pounds needed to be sold in a year		1,136,542.84

Appendix D

The Three Color Coded System for Major Financial Ratios

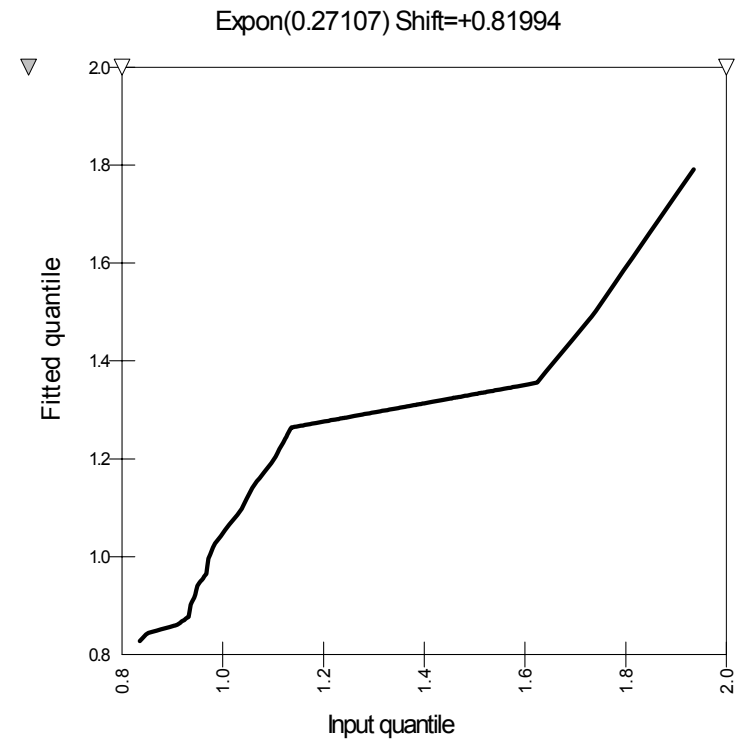
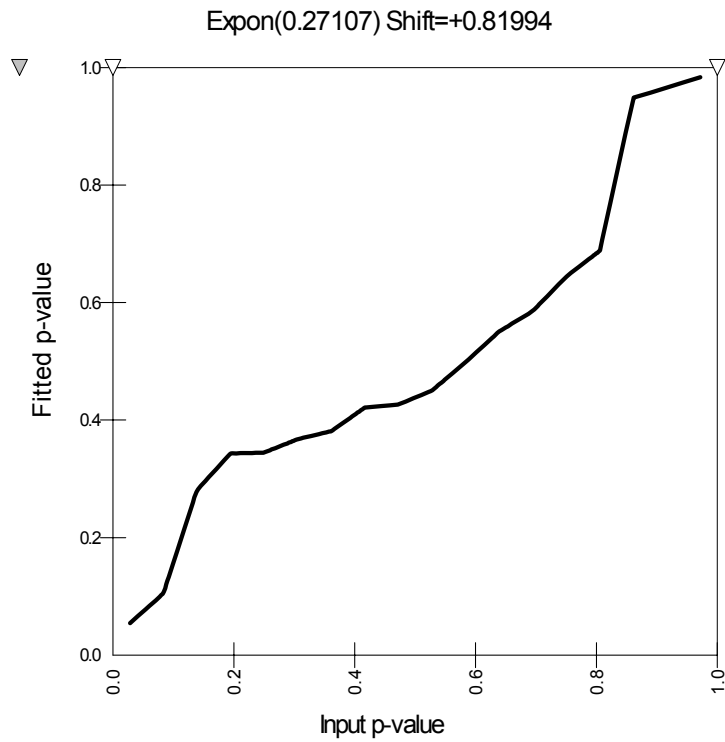
The executive summary section of the AECM model is the overall summary of the financial ratio analysis. This summary lists the results of the analysis for the first two years of production. Each ratio is highlighted in one of three colors - - red, yellow, and green. These colors indicate the level of the ratio, and correspond with a traffic light. A **RED** highlighted ratio needs to be closely examined because immediate action may be required to prevent financial instability. A **YELLOW** highlighted ratio is in the caution zone. Ratios highlighted in yellow should be explored to determine whether any actions are necessary. Depending on the previous year's color a yellow highlighted ratio could be an improvement. The ratio that is highlighted by a **GREEN** is what every producer hopes to see. The green color indicates that the ratio is at a stable level. However, this does not mean that values of the ratios highlighted with green can or should be ignored – they too should be closely monitored in order to prevent the value from declining.

Below is a table that gives the values for each level of the ratios that are used in the analysis and displayed in the executive summary. In the analysis section, appendix C, under Summary of Financial Ratios, there is an explanation of what each of the ratio measures and suggested guidelines to improve each of the ratios. This will help users better understand what actions need to be taken to improve the ratio. These suggestions are very general, allowing creative action to improve the ratio.

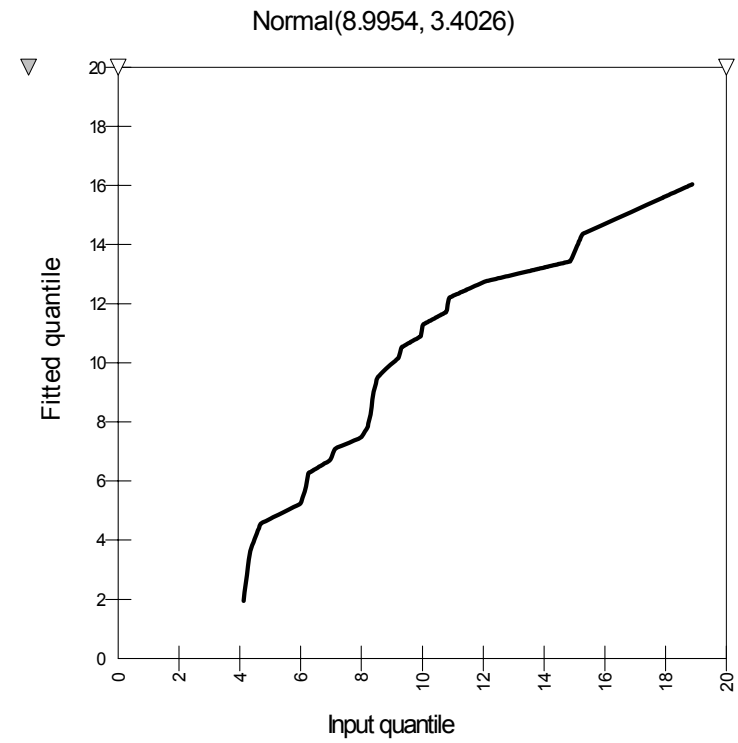
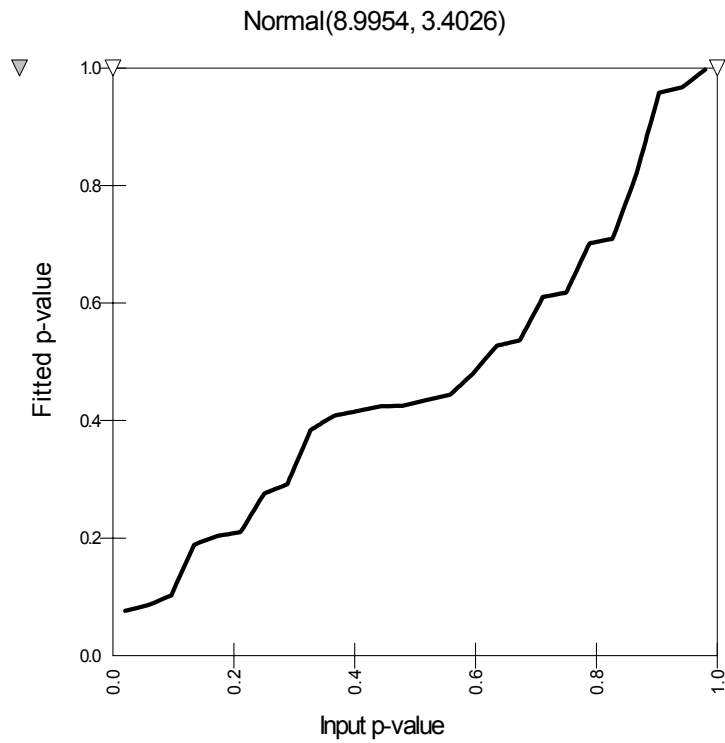
Furthermore, the ratios introduced in the Executive Summary hold a great deal of meaning to a lender and they will help the lender determine if the operation is a sound investment. If desired, these ratios could be simulated in the same way as net profit was in the current analysis to obtain ranges and confidence intervals, which in turn will provide the lender with more information as to how these ratios might fluctuate and help him make a more informed decision.

Ratio	RED	YELLOW	GREEN
Coverage Ratio	Less than 1.1	1.1 to 1.5	Greater than 1.5
% Drop in Revenue	Less than 5%	5% to 10%	Greater than 10%
% Increase in Expenses	Less than 5%	5% to 10%	Greater than 10%
% Increase in Variable Interest Rate	Less than 3%.	3% to 6%	Greater than 6%
Current Ratio	Less than 0.5	0.5 to 1.5	Greater than 1.5
Debt to Equity	Greater than 3.5	1.5 to 3.5	0 to 1.5
Return to Assets	Less than 5%	5% to 20%	Greater than 20%
Operating Profit Margin	Less than 10%	10% to 25%	Greater than 25%
Return to Equity	Less than 20%	20% to 50%	Greater than 50%
Sales to Total Assets	Less than 1	1 to 2	Greater than 2

P-P Graph (left) and Q-Q Graph (right) for Price of Tilapia

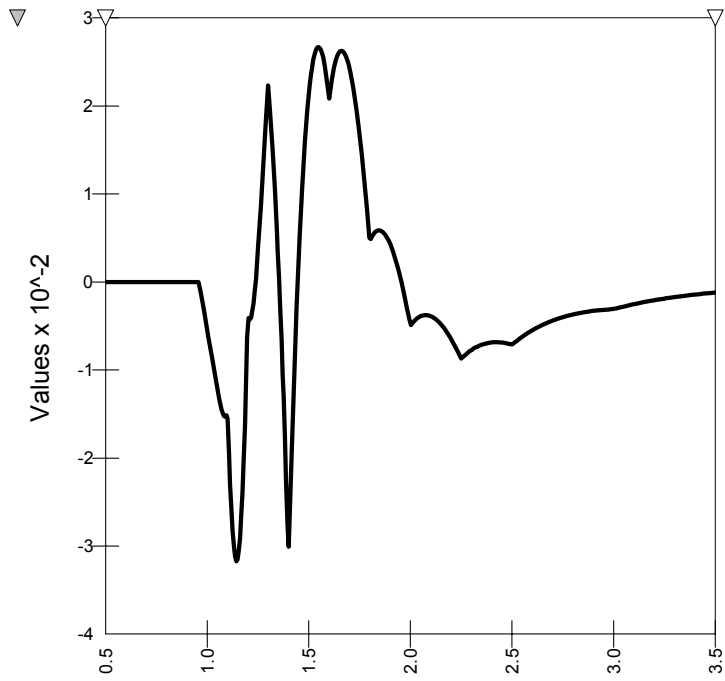


P-P Graph (left) and Q-Q Graph (right) for Interest Rate

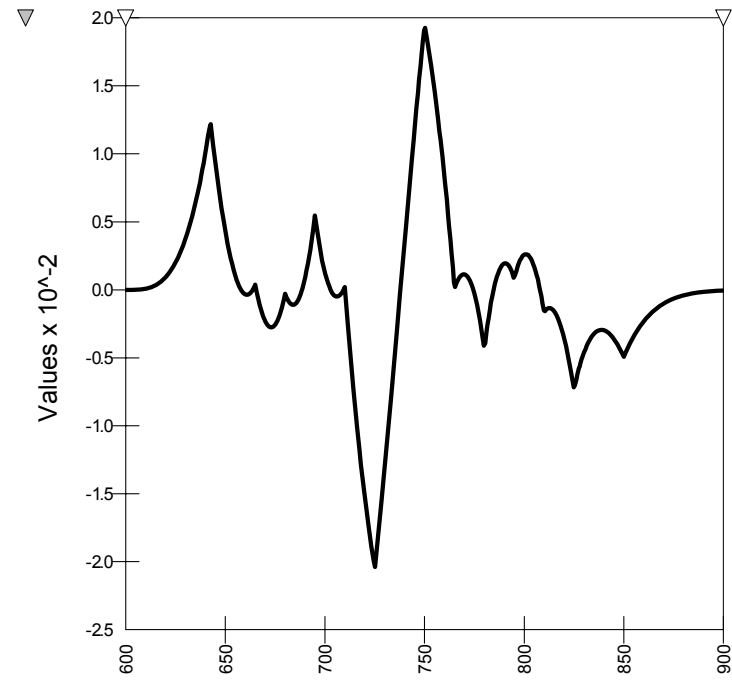


Appendix F
Comparison Graphs

Conversion Rate Difference Graph

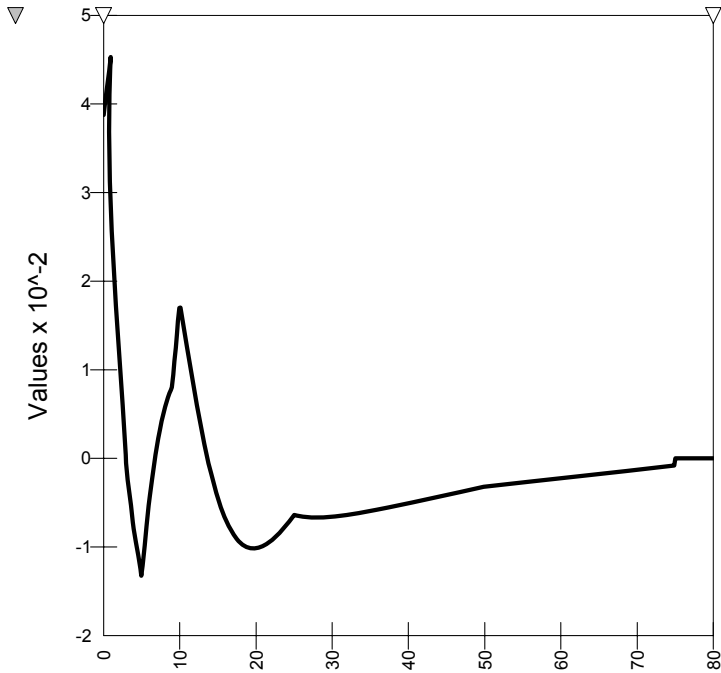


Final Weight Difference Graph

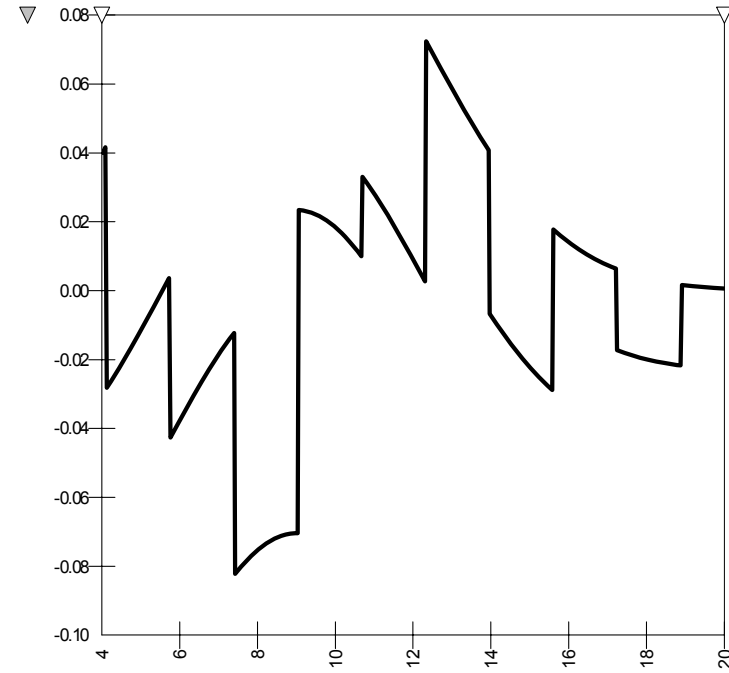


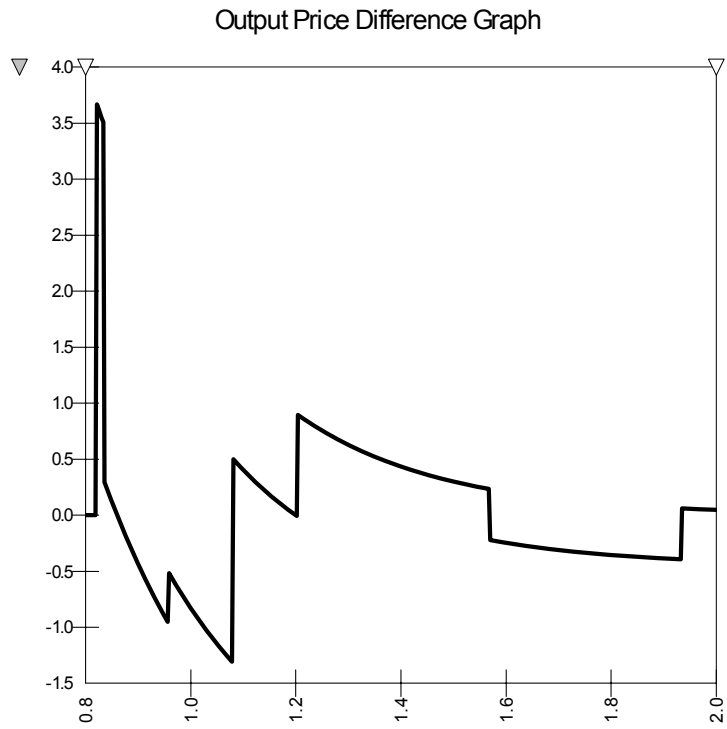
Appendix F
Comparison Graphs

Mortality Rate Difference Graph



Interest Rate Difference Graph





Probability Distributions Used in Monte Carlo Simulation

The list of probability distributions has been growing ever since statistics was born. Some of the major probability distributions and their use include:

Normal Distribution: The normal distribution is perhaps the most important distribution in probability theory because it describes a wide variety of natural phenomena. It is otherwise known as the Gaussian distribution and is widely applied in part because of the central limit theorem and in part because of its well studied and frequent use in classical statistics. The two parameters needed to describe the normal distribution are the distribution mean and its standard deviation. Both of the parameters are estimated from the sample mean and standard deviation. Usually the random variable described by the normal distribution takes on values over the entire range of real numbers, if the random variable only takes on positive or negative values then the distribution is truncated at the desired value (Hertz and Thomas 1983, Morgan and Henrion 1990).

Lognormal Distribution: the lognormal distribution is a variation of the normal distribution and results when the logarithm of the random variable is described by a normal distribution. It is often found to provide a good representation of situations where values for the random variable are constrained to being non-negative and positively skewed. Mun (2004) outlines three conditions underlying the lognormal distribution. The conditions are: the random variable can increase without limits but cannot fall below zero, it is positively skewed with most of the values near the lower limit and the natural logarithm of the random variable yields a

normal distribution. It is suggested that if the coefficient of variation is greater than 30 percent (Mun 2004) the lognormal will be more appropriate than the normal distribution in quantifying the random variable otherwise the normal distribution will be a better approximation. Mean and the standard deviation are the distributional parameters.

Exponential Distribution: when events occur in nature in a purely random fashion the time between successive events is best described by the exponential distribution. The only distributional parameter λ is equal to one divided by the average time between events, and is thus equivalent to the occurrence rate of the process. Then it is said that events occur randomly at the rate of λ event per unit of time. The condition underlying the exponential distribution is that the exponential distribution describes the amount of time between occurrences. Morgan and Henrion (1990) suggest the use of the exponential distribution for events like storm event durations, spill sizes, technical failures and so forth. One key characteristic of this distribution is the “memoryless” property, which says that the future lifetime of a given object has the same distribution, regardless of the time it has existed; this is saying that future outcomes are not affected by time (Mun 2004).

Poisson Distribution: This is somewhat similar to the exponential distribution described in the previous section. The Poisson distribution describes the number of times an event, assuming that event is described by the Poisson process, occurs in a given time period of fixed length T. The three conditions underlying the Poisson distribution are: the number of possible occurrences in any interval is unlimited, the occurrences are totally independent and the average number of occurrences must remain the same from interval to interval. The distributional

parameter α is equal to the average number of events expected over the interval, which is λT . The Poisson distribution is well suited for discrete random variables (Morgan and Henrion 1990).

Gamma Distribution: Given a random Poisson process, the Gamma distribution describes the time required for the occurrence of k events. This distribution applies to a wide range of physical phenomena and is similar to the lognormal, exponential, Pascal and Poisson distributions. The gamma distribution is also used to measure the time between the occurrence of events when the event process is not Poisson (not completely random). This distribution is described by two parameters the mean and the standard deviation where: $\mu = \frac{k}{\lambda}$ and $\sigma^2 = \frac{k}{\lambda^2}$, where k is also known as the shape parameter and λ is still the rate of the Poisson process. When k is equal to one the Gamma distribution collapses to an exponential distribution (Mun 2004)

Weibull (Rayleigh) Distribution: Weibull is another applicable distribution to non-negative physical quantities that describes data resulting from life and fatigue tests. It is commonly used to represent distributions of failure time in reliability models as well as the breaking strengths of materials in reliability and quality control tests. Another physical quantity that is best described by the Weibull distribution is the wind speed (Mun 2004).

Uniform Distribution: The uniform distribution is one of the simplest means of representing uncertainty associated with a model input. With the uniform distribution, values of the random variable fall between two values being the minimum and the maximum and each of the values for the random variable occurs with equal likelihood (all the points are associated with

the same probability of occurrence). Its use is appropriate when the modeler is able and willing to identify a range of possible values for the random variable but is unable to decide which values within this range are more or less likely to occur than others. All that is needed to apply this type of distribution is a minimum and a maximum value for the random variable (Palisade Corporation 2004).

Triangular Distribution: When values in the middle of the range of the possible values of a random variable are considered more likely to occur than values near either extreme, the triangular distribution provides a convenient means of representing uncertainty on that random variable. The triangular distribution is characterized by three parameters, being: the minimum, the most likely and the maximum value that the random variable takes on. These are the only three parameters that the modeler needs when applying a triangular distribution. In addition to being simple to be applied, when uncertainties are large and asymmetric the triangular distribution can be modified to yield log-triangular distributions (Palisade Corporation 2004).

Binomial Distribution: this type of probability distribution describes the number of times a particular event occurs in a fixed number of trials. The conditions necessary for using a binomial distribution include: for each trial, only two outcomes are possible, the trials are independent, that is, what happens in the first trial does not affect the next trial and the probability of an event occurring remains the same for all trials, or the trials are identically distributed. The probability of success p and the number of total trials n are the distributional parameters (Mun 2004).

Beta Distribution: this probability distribution provides a very flexible means of representing variability and is commonly used to represent variability over a fixed range. A distinguishing feature of this distribution is that it can be used as a conjugate distribution for the parameter of a Bernoulli distribution. The Beta distribution is described by four of its parameters, α and β , which are, respectively the minimum and maximum values that a beta random variable can assume and g and h , which are the shape parameters. This distribution is used to describe empirical data as well as predict random behavior of percentages and fractions. The two conditions underlying the beta distribution are: the uncertain variable is a random value between zero and a positive value, and the shape of the distribution can be specified using two positive values (Palisade Corporation 2004 and Mun 2004).

Probability of an event: The Bernoulli distribution: The determination of the probability of an event occurring or not is one of the fundamental issues in risk assessment analysis. The Bernoulli distribution is a convenient way of expressing uncertainty on events for which historical data is sparse. The random variable for this distribution is a discrete one, being of the nature zero-one random variable. The Bernoulli random variable is fully characterized by its parameter, p , and has an expected value of p and a variance of $p(1-p)$ (Mun 2004).

Appendix H
Correlation Corrected Results

Correlated Simulation Results

Summary Information	
Workbook Name	Aqua Econ Cost Model
Number of Simulations	1
Number of Iterations	10,000
Number of Inputs	9
Number of Outputs	3
Sampling Type	Latin Hypercube
Simulation Start Time	6/12/2006 17:28
Simulation Stop Time	6/12/2006 17:28
Simulation Duration	00:00:35
Random Seed	1600609983

Output		Statistics						
Name	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2
Net Profit or (Loss) Year1	G33	(611,013.03)	(186,945.56)	225,109.41	(259,807.57)	5%	(112,319.52)	95%
Net Profit or (Loss) Year2	H33	(478,765.36)	(43,690.28)	817,653.53	(183,329.27)	5%	161,586.14	95%
Net Profit or (Loss) Year3	I33	(466,792.93)	(42,156.33)	819,568.48	(183,947.33)	5%	174,432.44	95%

Input		Statistics						
Name	Cell	Minimum	Mean	Maximum	x1	p1	x2	p2
Building Loan / Interest Rate (%)	AJ8	0.01	9.04	21.85	3.52	0.05	14.60	0.95
Feed Cost (cents/lb)	B9	20.03	25.64	30.30	21.42	0.05	29.48	0.95
Feed Conversion (lb fed/ 1lb. gain)	B10	1.05	1.44	6.52	1.16	0.05	1.95	0.95
System Loan / Interest Rate (%)	AJ10	0.01	9.04	24.35	3.52	0.05	14.60	0.95
Generator Loan / Interest Rate (%)	AJ12	0.01	9.04	22.28	3.52	0.05	14.60	0.95
Land Loan / Interest Rate (%)	AJ14	0.01	9.04	22.13	3.52	0.05	14.60	0.95
Mortality (%)	B16	0.00	7.90	44.47	0.98	0.05	17.58	0.95
End Weight (grams)	B41	607.48	737.66	907.11	664.16	0.05	811.34	0.95
Output Price (\$/lb)	B42	0.82	1.09	3.33	0.83	0.05	1.63	0.95