A SHRIMP AQUACULTURE INVESTMENT BY GRAPEFRUIT PRODUCERS IN THE INDIAN RIVER PRODUCTION REGION OF FLORIDA: A RISK ASSESSEMENT

By

JENNIFER L. CLARK

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To Christopher C. Ferraro for his friendship, love, and logic.

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> For it matters not how small the beginning may seem to be, what is once well done, is done forever.--Thoreau

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

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Jennifer L. Clark

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Recent risky events including crop diseases, weather events, and non-agricultural development have negatively impacted grapefruit production in Florida. Traditional risk management tools include insurance, contracting, government programs, and crop diversification. Existing culture technologies and high consumer demand for shrimp may make this species a feasible candidate as a crop diversification strategy for Florida farmers.

The primary objective of this research project was to identify potential costs, benefits, and associated risks for Florida grapefruit producers interested in a low-salinity shrimp production investment. The economic success of this investment is determined by the positive probability of net present value (NPV) of net cash income over a 15-year planning horizon. Various management implications are examined via scenario simulation including different stocking densities, a higher local price premium, lower capital construction costs, lower survival rates, and the addition of random kill and hurricane events.

The computer software, Simetar©, used in this analysis operates as an Excel add-in to generate statistical probabilities specific to the production assumptions programmed into a spreadsheet accounting model. Preliminary model output indicates that this hypothetical, low-salinity shrimp investment is capital intensive (relative to grapefruit production) and a low

probability exists for a positive NPV of net cash income. In subsequent scenarios, an analysis of various management implications indicates a higher probability of economic success of the shrimp investment, although the potential for negative NPV values continue to persist when the probabilities of random kill and hurricane events are considered.

CHAPTER 1
INTRODUCTION

Preamble

Agricultural investments are subject to many unforeseeable elements because of their biological nature and market dependency. Many of these elements are beyond the producer's control. While farm profit can be viewed as the reward for accepting risk, the risk to the agricultural producer's future cash income can be significant and may increase over time (Hardaker, 2004). Although in this context risk can be associated with the possibility of greater reward, it is the necessary balance between risk exposure and risk tolerance that management seeks to meet strategic goals (Olsen, 2004).

Production and price risks are traditionally recognized as the greatest sources of agricultural risk (Fumasi, 2005). Economists differentiate between risk and uncertainty with the assumption that the risky events can be approximated via a known probability density function, whereas the probabilities of uncertain events are simply unknown (Roberts et al., 2004). Well-defined probability estimates, specific to the firm's financial performance, can provide a proactive methodology to analyze the risk parameters associated with an agricultural investment.

Traditional risk management tools include crop insurance, government programs, contracting, hedging, options, financial reserves, and choice of production activities (Miller et al., 2004). Additionally, crop diversification is one activity that can reduce the firm's exposure to financial risk. The success of a diversification strategy is highly dependent on the correlation between commodity characteristics, including variety, planting date, input prices, market prices, environmental conditions, and changes in consumer demand (Olsen, 2004). Reducing the dispersion in overall returns by selecting a combination of characteristics with low or negative correlations is the objective of a crop diversification strategy (Hardaker, 2004). Consideration of the variance of net incomes across alternatives, as the dispersion measurement, is one approach to defining the risk reduction achieved through crop diversification (Robinson, 1979).

Crop selection in a diversification strategy is similar in nature to the portfolio selection problem in financial management. Typically, the decision maker relies heavily on the portfolio selection hypothesis, traditionally used to evaluate financial instruments, which suggests that "the investor does (or should) consider that expected return is a desirable thing and variance of return is an undesirable thing" (Markowitz, 1952). This hypothesis was extended to include farmers and assumes that agricultural investors are generally risk averse (Johnson, 1967). The general strategy of portfolio selection in the agricultural production context sets forth to calculate the probability distribution of net returns from farm enterprises, and select the efficient combination of these enterprises that minimize the variance of expected net income. Stochastic simulation models, as a method for risk analysis, continues to be widely used to calculate risk exposure via the probability of an event's occurrence (Fumasi, 2005; Richardson et al., 2000; Zucker & Anderson, 1999; Griffin & Thacker, 1994; Medley et al., 1994; Gempesaw II et al., 1992; Karp et al., 1986; Sadeh et al., 1986; Hanson, et al., 1985; Bailey & Richardson 1985).

Using a stochastic simulation add-in for spreadsheet software such as Simetar© (Richardson et al., 2006) in financial spreadsheet applications represents an approach developed to calculate the probability distribution of net returns to an agricultural investment. This approach can be used as a measure of the risk associated with a crop diversification strategy. The Simetar© add-in module provides stochastic functions not available in the standard Microsoft Excel spreadsheet format. Utilizing this software, any financial spreadsheet model can be operated in a probabilistic mode by assigning user-defined probability distributions to variables that are perceived to introduce risk into the proposed investment (Richardson, 1976).

Examples of risky variables can include prices and yields of the proposed crops being considered for diversification. Through an iterative Latin Hypercube sampling process, random values can be generated from the specified distributions for each stochastic variable and mathematically manipulated throughout an accounting framework of a financial model to forecast enterprise net returns (Hardaker, 2004). By repeating this process multiple times, a probability distribution for the net returns of the proposed investment can be determined. Simple statistics can then be used to calculate the expected value and variance of the probability distribution for the investor to use to evaluate a proposed enterprise or combination of enterprises. It is in this manner that risk is transformed into a single value (Richardson, 1976).

Problematic Situation

Citrus canker (*Xanthomonas axonopodis* pv. *citri*), a bacterial pathogen, has been a periodic management issue for Florida grapefruit producers since its presumed introduction from Japanese rootstock in 1910 (Schubert & Sun, 2003). Symptoms of citrus canker disease include lesions on the fruit, leaves, and stems (Figure 1-1) that immediately restrict producer access to the fresh product market and ultimately reduce harvest yields during the life of the tree due to defoliation, premature fruit drop, die-back of twigs and general debilitation of the tree (Graham et al., 2004). Although citrus canker was officially declared eradicated in the state of Florida in 1994, a re-introduction of the disease emerged through a residential area of Dade County in 1995 and eventually contaminated commercial groves located in the southwest and southeast areas of the state (Schubert & Sun, 2003).

In response to this outbreak, the state quickly implemented a Citrus Canker Eradication Program (CCEP) with remediation protocols that required the destruction and burning of all trees within a 1,900-foot radius of any infected tree (Zansler et al., 2005). Cleared grove acreage was then required to be plowed and left fallow for two years before the acreage could be replanted in citrus (White et al., 2006). Although the CCEP protocols were amended in January 2006, by this date seven million citrus trees on 80,000 acres had been burned (Connor, 2006).

Compounding the financial implications of citrus canker, commercial grapefruit producers in Florida recently experienced unprecedented production risks during the 2004 hurricane season. Commercial citrus production in the state of Florida is divided into four major production regions: the Central Florida region, the Southwest region, the Southern region, and the Indian River region (Figure 1-2). The Indian River production region, located along the southeast Atlantic coastline, refers to Brevard, Indian River, Martin, Palm Beach, and St. Lucie counties (Muraro, 2003) This region is known for producing a high quality grapefruit (Obreza & Collins, 2002) and accounts for 73% of the grapefruit acreage in the state of Florida (FASS, 2004). During the hurricane season of 2004, four hurricanes impacted the Indian River production region during August and September causing widespread tree damage and a loss of 70 % to 80% of projected grapefruit yields (Muraro & Hebb, 2005). Prior to the 2004 hurricane season, Florida produced over 40% of the world's fresh and processed grapefruit products (Spreen et al., 2006), but after the 2004 hurricane season Florida production was reduced by an estimated 68% (Brooks et al., 2005).

In addition to marginalized returns from citrus production, the recent surge in demand for non-agricultural acreage for development has led many producers to receive increasingly competitive price valuations for their land resources in this region. The appraised value of grapefruit groves in the Indian River production region has increased from $3,929 per acre in 2003 (Reynolds, 2003) to over $15,000 per acre in 2007 (Connelly, 2007). Due to the financial losses resulting from citrus canker disease, CCEP efforts, hurricane events, and the opportunity cost of appreciating land values, producers within the Indian River production region are considering whether or not to "either quit farming and sell now or continue farming and sell later." While some in this region have chosen the former option, producers that continue to operate in this industry are seeking potential risk management strategies to mitigate the exposure to future financial loss.

Alternative crops are being considered as a management strategy by citrus producers to utilize acreage left fallow as a result of the CCEP. Crop diversification is one risk management strategy being considered that may have the potential to mitigate production risks regarding disease and weather events associated with grapefruit production. A speculative interest in small-scale shrimp farming as a diversification strategy is being considered as a separate production enterprise in addition to current grapefruit production. Biological protocols have been developed for the production of the shrimp species, *Litopenaeus vannamei*, in inland, freshwater ponds in Florida.

The sub-tropical climate of the Indian River production region supports an extended growing season for *L. vannamei* with best growth rates between 23-30°C and a temperature tolerance down to 15°C and up to 33°C (Wyban & Sweeny, 1991). The extended season represents a potential 10-month growing season utilizing a one-month greenhouse headstart facility that can result in a large (25-gram) fresh product. Additionally, irrigation groundwater from the Floridan aquifer that is high in dissolved minerals, especially chlorides, has the correct mineral balance to support fresh-water acclimation and culture of this species (Wirth et al., 2004). High consumer demand exists for shrimp and well-established production technologies suggest that this species may be a feasible candidate for crop diversification on the fallow acreage in the Indian River production region of Florida.

Researchable Problem

Production protocols for farming shrimp in the United States are vastly different from production protocols employed in other areas of the world where commercial production takes place in outdoor ponds that receive tidal flows of brackish to full-strength sea water (Samocha, 1998). The limited availability of and environmental concern for coastal acreage in the US renders the investment in a typical salt-water, flow-through, shrimp production facility as economically risky (Van Wyk et al., 1999). As a result, this risk has promoted the development of new technologies that utilize highly-mineralized (low-salinity) well-water accessed via deep-water well systems (Larramore et al., 2001; Samocha et al., 1998, 2002; Van Wyk et al., 1999). This technology allows shrimp production to move inland, away from the high cost and environmentally sensitive coastal corridor.

Within the grapefruit producing community of the Indian River production region, there has been considerable interest in shrimp aquaculture as a production enterprise. Permitted well-point access to the Floridan aquifer and available inland acreage for pond development encourages the investigation of a shrimp aquaculture enterprise as a diversified portfolio option. Although grapefruit producers are anxious to explore this diversification option, limited economic data exists specific to the financial feasibility of a small-scale shrimp farming enterprise in this area of south Florida. Despite the continued existence of several private shrimp farms within the United States, the profitability and cash flows of a low-salinity shrimp aquaculture investment still remains indeterminate. While production strategies and technologies continue to be made publicly available, limited risk analyses have been published specific to the financial feasibility of low-salinity pond shrimp operations in this region of South Florida. Analytical tools that exist for the shrimp-farming industry are typically 1) elaborated in discussion during conference proceedings (Browdy, 2007; Duncan, 2007; Zazueta, 2007; Roy et al., 2005; Green, 2004; McMahon & Baca, 2001; Samocha et al., 2001; Van Wyk, 2000), 2) developed as commercially-marketable instruments (AQUAFarmer^{TM}, 2004; Hanson & Posadas, 2004; Ernst et al., 2000; Griffin & Treece, 1996), 3) or are site and facility-specific (Wirth et al., 2004; Van Wyk et al., 2000). A need exists for an analytical risk assessment tool regarding the financial parameters of a site-specific shrimp aquaculture investment using low-salinity aquaculture production protocols for Florida producers.

Research Objectives

Almost every production decision made by the farmer involves risk (Jolly, 1983); however, risk management can be processed through a systematic series of steps as outlined by Hardaker, (2004) (Figure 1-3). The first four steps of the risk management process are addressed in a three-essay format comprising Chapters 2, 3, and 4. The objective of the analysis in Chapter 2 is to introduce and establish a strategic business context (Step 1 in Figure 1-3) via macro and micro economic principles of agribusiness within which to analyze the investment risk associated with a shrimp production enterprise. This includes an overview of the

- Frozen-shrimp commodity market
- Implications for a differentiated locally-grown, fresh-shrimp product utilizing a direct-marketing strategy to local restaurants
- Resource availability for aquaculture industry creation
- Potential benefits to be gained from cooperative advertising.

The objective in Chapter 3 is to identify and structure the enterprise investment problem (Steps 2 and 3) via the construction of a stochastic spreadsheet model that captures the building and operating cash flows generated from a shrimp production investment. A database of historical market and feed prices is used to linearly forecast future revenue and cost values for the shrimp production investment. Stochastic simulation software incorporates a probability distribution for each of the forecasted values to capture the variability (risk) of net cash income over a fifteen-year planning horizon. Specific attention is given to the baseline probabilities of receiving a positive net present values (NPV), at various required rates of returns, over the planning horizon and subsequently incorporating various scenario specific probabilities. These scenarios include the addition of a value-added price premium, reduced capital (construction) cost requirements, non-optimal shrimp survival rates, and the impact of hurricane and random kill events on the financial position of the enterprise investment.

The objective in the Chapter 4 (Step 4) is to use the deterministic and stochastic capabilities of the model to compare the expected returns and variability of returns for the grapefruit, shrimp, and combined grapefruit-shrimp enterprises. This step of the risk assessment process analyzes the risk and returns of investing in a shrimp enterprise as a crop diversification option for Florida grapefruit producers. Steps 5, 6, and 7 are not included in this analysis and are assumed to be addressed by the individual producer who would utilize the findings of this study to consider his/her individual risk preferences. Chapter 5 summarizes the results and provides a discussion of the applicability of this model as an extension tool for prospective producers at the firm level to use for their own preliminary risk management process.

Hypotheses

- **Hypothesis 1:** An investment into shrimp aquaculture production in low-salinity ponds is capital intensive and may not be a profitable investment.
- **Hypothesis 2:** Probability of acceptable financial performance (as measured by the net present value of net cash income) is dependent upon premium market prices, lowered capital construction costs, higher survival rates, the discount rate calculation used, and the impact of uncertain variables including weather and random kill events,
- **Hypothesis 3:** A shrimp aquaculture investment may not minimize the variance of returns associated with a diversification strategy for grapefruit producers in the Indian River production region

- **Hypothesis 4:** By using historical data to estimate future probabilities of financial performance, investment risk can be quantified and analyzed via stochastic simulation to reflect the implications of investment returns.

Figure 1-1. Illustration of citrus canker infection. Source: (University of Florida, Interdisciplinary Center for Biotechnology Research, 2007)

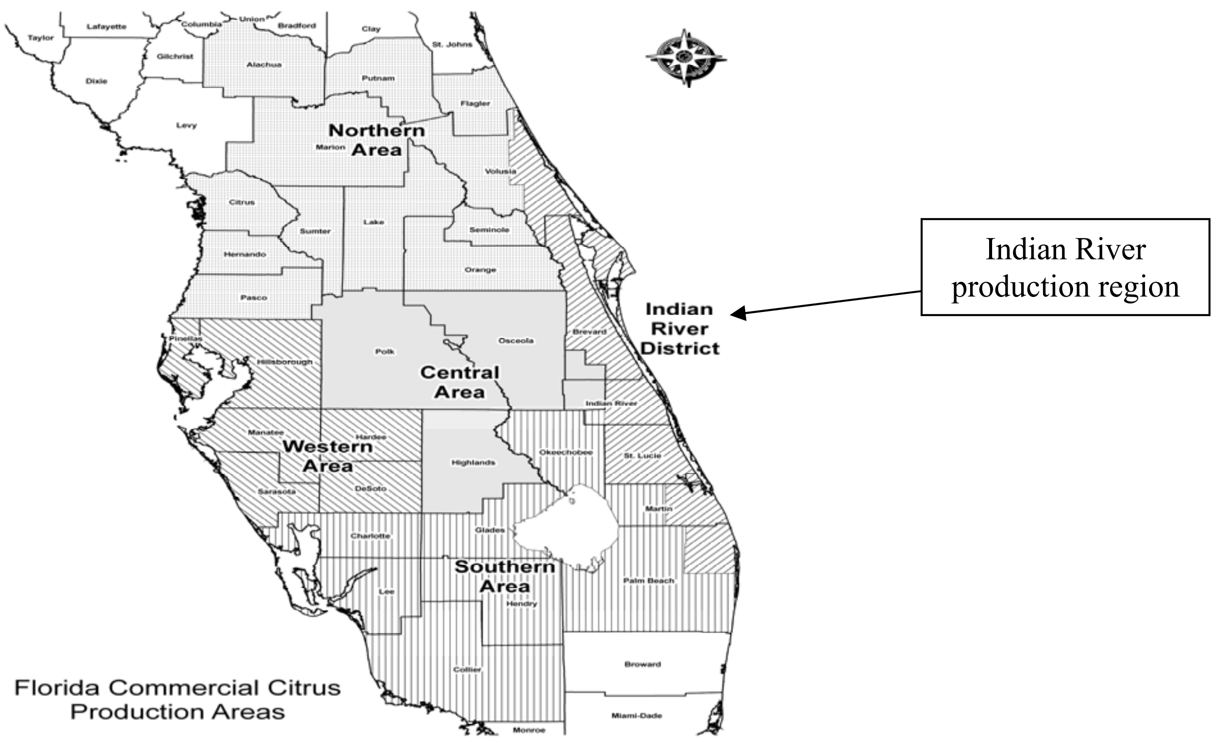

Figure 1-2. Map of the Indian River production region in Florida. Source: (FASS, 2007)

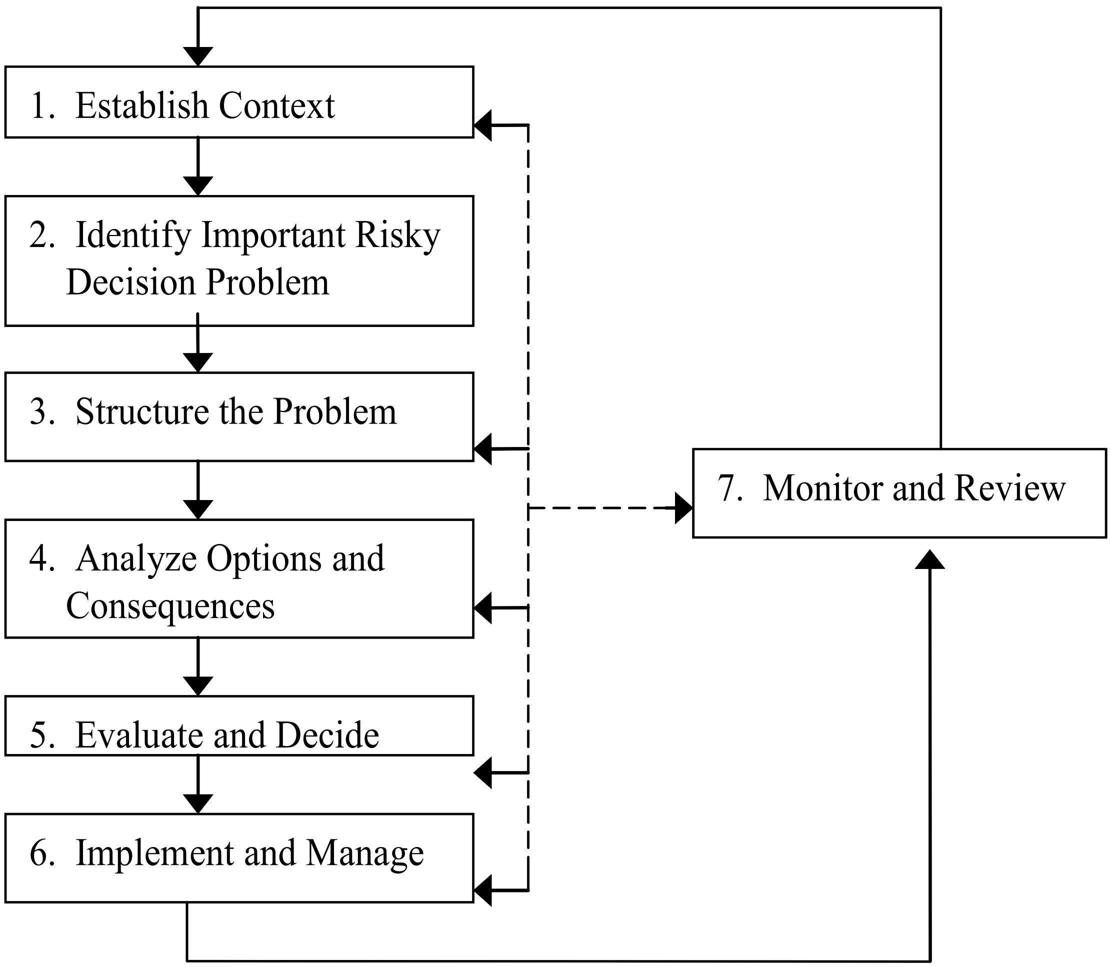

Figure 1-3. Outline of steps in the risk management process. Source: (Hardaker et al., 2004)

CHAPTER 2
SOME ECONOMIC IMPLICATIONS FOR ESTABLISHING A SHRIMP AQUACULTURE INDUSTRY IN FLORIDA

Introduction

Biological growth parameters and production technologies associated with a low-salinity shrimp aquaculture investment have been systematically explored and these results have been widely disseminated. However, determining the financial position of a low-salinity shrimp aquaculture investment is less clear and is highly dependent upon numerous combinations of factor inputs that are site and size specific for each investment decision being considered. Engineering a business strategy for this type of entrepreneurial investment may be facilitated by examining fundamental economic principles associated with creating competitive niche markets.

Two elements originally associated with creating an entrepreneurial business strategy have been defined as the bringing together factors of production (Say, 1803) and the combining of various input factors to carry out a new industry organization (Schumpeter, 1934). These elements of defining a business strategy are applied to the entrepreneurial development of a differentiated, locally-grown, fresh-shrimp industry where the perceived value of a fresh product will be supported by consumer willingness to pay for a value-added product. A potential competitive advantage exists for investors in Florida who are able to define a business strategy by utilizing available consumer information and existing factors of production that include arable land, skilled labor, and state-sponsored advertising resources in the creation of a business development strategy. Prospective shrimp culturists in Florida should strive to utilize a combination of these resources.

The strategic behavior of the firm, in the context of creating a business strategy, clearly defines a firm's operating environment and provides an investor with critical information to navigate the competitive business complex associated with industry creation (Carlton & Perloff, 2005). A business strategy is defined by six elements: 1) the product-market scope in which the business is to compete, 2) the level of investment required, 3) the functional area strategies needed to compete in the selected product market (e.g. product, form, price, distribution, etc.), 4) the strategic assets or competencies that underlie the strategy and provide a sustainable competitive advantage, 5) the allocation of resources over the business units, and 6) the development of synergistic effects and the creation of value by having business units that support and complement each other (Aaker, 2001). The context of each of these elements can be discussed relative to developing a locally-grown, fresh-shrimp aquaculture business strategy in Florida including

- Value-added shrimp versus low-cost commodity shrimp
- Competition and market conduct
- Differentiated product
- Direct-marketing to local restaurants
- Consumer demand for locally-grown, fresh (never-frozen) shrimp
- Factor resources available for new industry creation
- Generic and collective advertising programs

Investors may be able to optimize profits by capitalizing on available consumer research data, restaurants as direct-market outlets, locally-available factors of production and publicly available advertising resources to create a marketing channel for locally-grown, fresh (never-frozen) shrimp produced in Florida. The discussion in this chapter focuses on the elements conducive to creating a potential competitive market advantage within the environment of a differentiation strategy as opposed to relegating market efforts toward a low-cost commodity approach (Porter, 1996).

Economic Context

The creation of a shrimp production industry in Florida is viewed as a risky investment due to undetermined financial parameters and incomplete market information that can be used to generate a successful business strategy. Biological protocols and production technologies for culturing low-salinity shrimp in Florida using the highly-mineralized water of the Floridan aquifer have been elaborated in a collaborative grant-funded commercial scale Penaeid shrimp demonstration project involving the Florida Department of Agriculture and Consumer Services and the University of Florida/ Indian River Research and Education Center in Fort Pierce, Florida (Wirth et al., 2004). Market research data has also been collected on consumer perceptions regarding fresh, locally-grown, shrimp purchasing behaviors (Wirth & Davis, 2001b). This chapter is organized to present some strategic elements that can be used to create value for a differentiation strategy marketing low-salinity shrimp cultured in Florida.

Value-Added Shrimp vs. Low-Cost Commodity Shrimp

World fisheries may have reached their carrying capacity between 1990 and 1997 as estimated by a flat, or in some areas declining, harvest yield (FAO, 1997). As a result, seafood production has been shifting from the traditional "hunting and gathering" aspect of wild-caught seafood to a more agrarian method of producing seafood products for consumption through aquaculture. The United States domestic shrimp industry supplies only 10% of US shrimp demand through wild-caught harvests leaving over 90% of shrimp demand to be supplied by imported shrimp (NMFS, 2007). This trend has accelerated over the past decade as U.S. seafood consumption becomes more reliant upon farmed, rather than wild stocks.

In 1998, 50% of shrimp imported into the U.S. domestic market were farm-raised and the global farmed-shrimp industry exported 305 million pounds of shrimp valued at $1.4 billion to the U.S. (Harvey, 1998). During the first six months of 2006, U.S. consumers demanded 525 million pounds of shrimp valued at $1.6 billion (Harvey, 2006). As a result of increasing consumer demand for shrimp, the number of farmed-shrimp suppliers and total world supply of shrimp increased and the world price of headless, frozen shrimp decreased from $7.00 per pound in 2000 to $2.60 in 2004 (Comtell, 2006). However, after January 2004, price variability has narrowed within the wholesale and Hotel Restaurant Institution (HRI) price spreads, indicative of a maturing industry with production in over fifty countries (Figure 2-1). The HRI prices represent price data for Ecuadorian *L. vannamei* shrimp sized 31-35 tails per pound in a raw, headless, block-frozen form. This HRI price is an "index" price that characterizes the average retail price that a hotel, restaurant, or similar institution would pay a seafood distributor for 31-35 tails per pound count shrimp. HRI price data is collected from a cross-section sample of nationwide representative businesses via a weekly nationwide telephone survey performed by Urner-Barry services.

Competition and Market Conduct

Market power within an industry is defined by the level of competition among participating businesses. The level of competition influences the conduct of firms operating in that industry. The structure–conduct–performance (SCP) paradigm, as first introduced by Mason (1939, 1949), is an analytical approach that uses inferences from microeconomic theory to determine the behavior of firms within an industrial organizational framework (Carlton & Perloff, 2005). The conduct of an industry is generally classified by its pricing behavior and can range from low-bid price competition to highly monopolistic pricing behavior which is in turn dependent upon market conditions, consumer demand, and barriers to enter and exit the industry (Table 2-1). Structure and conduct together determine the performance (i.e. the efficiency and degree of market integration, market price and marketing margins, accuracy and adequacy of information flows, etc.) of the marketing system as a whole (Van Anrooy et al., 2006).

The global shrimp industry has many suppliers producing a relatively homogenous product, with slight differences in species, size, and form. As a result of a lack of market concentration (power), participants in a competitive industry operate within a highly competitive framework where the selling price level is bid down until only the most efficient producers can survive by making a normal profit. At this equilibrium price, supply is sufficient to fill consumer demand which is addressed through a sophisticated network of domestic wholesalers. In this competitive structure, the producer's only option is to become a price-taker for the homogenous good. One problem for small-scale diversified shrimp farming operations in Florida is that higher unit-costs of production, relative to Asian and Latin American producers who dominate the market, render a commodity-pricing structure that is unprofitable for Florida producers.

An alternative to a competitive price-taking market environment is the perceived-value pricing strategy that is associated with monopolistic competition. In this market structure a large number of producers can co-exist, but each sells a product that is differentiated from the competition (Shaffner et al., 1998) such as distinguishing between the frozen commodity-shrimp market structure and a fresh (never-frozen), locally-grown shrimp market. The benefit to the producer from a differentiated product strategy is the marginal increase in selling price associated with an increase in perceived product value by consumers. Rather than competing for world price in a highly competitive commodity market, focused product-differentiation efforts within a monopolistically-competitive environment could create a marginally profitable market position for small-scale shrimp aquaculture producers in Florida.

Differentiated Product

Utility is defined as the satisfaction created by the consumption of goods and services (Drummond & Goodwin, 2004). One approach on this theory of consumer behavior is that rather than the goods or services being the direct objects of utility (satisfaction), it is the product attributes and characteristics from which utility is derived (Lancaster, 1966). Consumer preferences for certain product characteristics that will produce greater utility are then assumed to create value for the consumer. The primary objective of a monopolistically-competitive firm is to provide greater value to consumers via differentiation (Porter, 1996). Market research specific to aquacultured shrimp indicates increased marginal consumer utility associated with market information regarding environmentally-sustainable culture practices of aquacultured shrimp and corresponding country of origin labeling (Kinnucan et al., 2003; Wirth et al., 2007).

Shrimp consumption in the U.S. takes place primarily in restaurants (Wirth & Davis, 2001a), making restaurants a prime outlet for direct-marketing efforts by producers. Additionally, utilizing a direct-marketing approach for a fresh (never-frozen), non-processed product further reduces the need for sophisticated processing facilities, thereby reducing unit costs of production. However, one requirement is that the perceived marginal value associated with this differentiated product be communicated throughout the marketing channel where it must ultimately be demanded by the consumer. This value might be communicated via the Florida Department of Agriculture's marketing program for Florida seafood (FDACS, 2007) as discussed later in this chapter.

Direct Marketing to Local Restaurants

A conjoint analysis conducted by Wirth and Davis (2001a) indicates that product form is the restaurant buyer's primary (60%) source of utility, followed by size (22%), and price (14%). These findings indicate that an unprocessed (whole shrimp), direct-market approach could be a significant disadvantage for Florida farmers if processing activities are not incorporated into the production process. The findings indicate negative utility associated with a whole shrimp form. This could possibly be the result of an unfamiliar product form due to the ubiquitous standardized commodity shrimp inventory which is shipped headless in frozen blocks. Alternatively, the negative utility associated with whole shrimp could be associated with the unintended consequences of shifting the processing function from the producer to the restaurant buyer – who would then be required to employ marginal labor for processing (i.e. head removal).

The latter disutility (due to increased labor) might be negotiated via marketing efforts emphasizing negligible marginal labor employed in de-heading shrimp during the currently employed de-shelling/ de-veining activity by restaurant employees. Marketing efforts could also convey additional product value associated with the shrimp heads (for use in stocks, soups, alternative recipes, etc.) thus allowing the producer to consider reversing the perceived negative utility.

Consumer Demand for Locally-Grown, Fresh (Never-Frozen) Shrimp

Consumer market research from academic institutions in Florida, Kentucky, Indiana, and Tennessee indicate that local seafood consumers are willing to pay a price premium for fresh (never-frozen) locally-grown seafood products (Wirth & Davis, 2001b; WAS, 2007). In 2001, consumer research data was collected within a focus group setting in Florida in which 50% of participants indicated a willingness to pay a price premium of $1 more per pound, over and above the current market price of $7 per pound, for Florida farm-raised shrimp. Additionally, 88% of these participants indicated a willingness to pay a price premium of $1 more per pound, over and above a market price, for fresh, never-frozen shrimp, while 62% were willing to pay a price premium of $2 per pound for this fresh product (Davis & Wirth, 2001). Communicating the end-users' (i.e., consumers') perceived value for fresh shrimp products to the primary (restaurant) buyers could return a portion of the $1 or $2 local price premium to be received by the producer. The total $1 or $2 price premium for locally-grown, fresh (never-frozen) Florida shrimp at the restaurant level is disaggregated as a portion of restaurant food cost and a portion of restaurant revenue. By using a direct-marketing sales strategy to restaurants, the Florida producer is positioned to receive a portion of the marketing margin (the restaurants' food cost percentage), which is typically received by a seafood wholesaler in the vertical food distribution system.

Typically, most full-service restaurants target a pre-determined food cost percentage between 28% to 32% of the menu price (Walker, 2002) as calculated in equation 2-1 (Powers, 1988).

$$\frac{Food\ Cost}{Food\ Cost\ Percentage} = Menu\ price \qquad (2\text{-}2)$$

The "General Rule of Three" is also an adage that applies to food costs and restaurant profits that is simply stated as, "the amount charged for a food item (menu price) must be at least three times the total cost of the ingredient" (Herbert, 1985). Using the Florida focus group consumer willingness to pay a price premium of $1 more per pound for a Florida-raised, fresh (never- frozen) shrimp product, a restaurant manager could charge (and receive) a price premium by offering this differentiated product on the menu. The benefits to the producer are derived through the calculation of the retaurant's food cost in equation 2-2; assuming a 33% food cost percentage and a $1 menu-price premium. The food cost is calculated to be $0.33 and assumed to be part of the marketing margin benefits transferred directly to the Florida producer in a direct-market sales effort of fresh, never-frozen shrimp. Communicating the value of consumers' perception of fresh, Florida shrimp via a product differentiation pricing strategy can effectively place the local farmer outside of the frozen commodity-shrimp pricing structure.

Factor Resources Available for New Industry Creation

Effective assembly of factor resources in constructing a shrimp production facility, recruiting trained employees, initiating production activities, and establishing a successful marketing channel is required prior to profitably operating a low-salinity shrimp production enterprise. Efficiently managing expenses associated with primary factors of production is especially relevant for the perceived high-capital, high-risk investment associated with shrimp aquaculture. Capital costs can easily become prohibitive in acquiring scarce land resources, while marginal firm profitability can be easily eroded using unskilled labor to manage a complex water quality environment.

Competitive advantages may exist for shrimp aquaculture producers in Florida, specifically regarding primary factors of production that may be available for these producers. For example, Florida citrus producers have access (owned or leased) to scarce production acreage. Additionally, highly skilled labor and management are available through degree and certification programs jointly offered in the area of St. Lucie County, Florida through the Indian River Community College and Harbor Branch Oceanographic Institution. The use of skilled labor has the potential to minimize up-front costs of production typically associated with learning a new technology. A familiar maxim heard within the industry is, “You really aren’t an aquaculturist until you’ve killed a million animals.” Advancing the learning curve through skilled training in a teaching lab can reduce the probability of experiencing an expensive catastrophic crop failure arising from technical inexperience. Skilled and experienced labor reduces potential production risks through optimized feed regimes and efficient labor resources, as well as serving to minimize water quality problems that can lead to disease issues or pond die-offs. Inefficient management can quickly result in sub-optimal financial performance due to reduced survival rates that result in low production yields. The availability of high-value factor resources such as land and a skilled labor force by prospective shrimp growers in Florida has the potential to minimize the probability of a negative net present value of net cash income for the shrimp aquaculture investor.

Generic and Collective Advertising Programs

Generic advertising campaigns are government-sanctioned programs, funded through cooperative producer (supplier) monies and used to promote non-branded, homogeneous products (Ward, 2006). The use of generic promotions is becoming increasingly more important to aquaculture producers as a marketing tool (Kinnucan et al., 2003). The objective of this type of advertising strategy is to increase overall consumer demand for a product by extolling desirable attributes that are common to the product that consumers desire but may not be readily apparent in the product during the search process. Although a low-salinity shrimp aquaculture production facility in Florida selling 25-gram (whole-weight) shrimp is limited to one production harvest per year, a generic advertising program could promote locally-grown shrimp as a specialty (rather than year-round) product thus transferring value-added benefits associated with specialty products to local consumers. Increasing the overall consumer demand for locally-grown Florida-farmed shrimp through a generic advertising program should additionally facilitate a demand for this product by local Florida restaurants that are involved in the supply chain and who directly benefit from the increased consumer demand.

The Florida Department of Agriculture and Consumer Service's (FDACS) Florida Agriculture Promotional Campaign (FAPC) is a state-sponsored identification and promotional program. The program is designed to increase sales of all Florida agriculture products by helping consumers easily identify agricultural products grown in Florida (FDACS, 2007). The use of this state-sponsored membership program by Florida shrimp producers could provide an advertising outlet to increased consumer awareness for fresh, locally-grown shrimp products by using existing promotional material (Figure 2-2).

The FAPC began in 1990 and provides producer benefits through the use of FAPC marketing logos on producer promotional materials. The program generates state-wide advertising exposure from the generic "Fresh from Florida" advertising logo via print, billboard, radio, and television outlets. The rational for a generic marketing strategy specifically designed for Florida farm-raised shrimp may be to highlight the local culture, fresh form, and quality attributes of a fresh, whole-shrimp product. The FDACS implied quality standards represent credence attributes of safety and quality characteristics presented with the approval of a government agency (Wirth et al., 2007) and desired by consumers (Mabiso et al., 2005).

The increase in consumer demand for credence attributes (attributes that are not discernable even after consuming the product) reflects the U.S. government's efforts in the 1990's to provide consumers with additional market information rather than to increase process or performance regulations (Caswell & Mojduszka, 1996). Results from a 2001 University of Florida consumer survey indicated that 62% of respondents agreed that it is important to know the state or country in which shrimp are harvested prior to purchase (Wirth & Davis, 2001b). Consumer research data disseminating from the 2004 University of Florida Aquaculture Demonstration Project in Ft. Pierce, Florida focused on shrimp product attributes, specifically regarding consumer utility associated with purchasing decisions (Wirth et al., 2007).   These findings indicate positive shrimp product utility associated with country-of-origin labels (COOL) and a reduction of shrimp product utility associated with a lack of COOL or COOL associated with another country.

By adopting an informational protocol, Florida shrimp producers could benefit from a state-wide generic promotion effort specific to product attributes of Florida-farmed shrimp. Promoting Florida-farmed shrimp as antibiotic-free could differentiate Florida-farmed shrimp attributes from the imported commodity-shrimp contamination issues regarding banned antibiotics, such as chloramphenicol. Or, an alternative/ additional strategy could promote production protocols of Florida-farmed shrimp as environmentally-responsible culture technologies that are located inland and away from sensitive coastal areas.

Although the worldwide trend for chloramphenicol application is decreasing (Collette, 2006) credence attribute perceptions regarding food safety issues continue to be important to consumers (Erdem & Swait, 1998). Food-safety assurances can communicate product differentiation (Allshouse et al., 2003) and as domestic demand for shrimp continues to be supplied by both domestic and international seafood markets, quality assurances may lead to increased levels of seafood safety being considered a product credence/ search attribute.

Additionally, public opinion has been negatively influenced by large-scale coastal-area shrimp farms that have converted substantial mangrove resource areas into shrimp production ponds. Ponds that may be up to 200 acres in size potentially contribute to salinization of surrounding lands and groundwater sources, as well as to the pollution of coastal waters from pond effluents (Lewis et al., 2002). A survey conducted by Johnston et al., (2001), suggests that environmentally responsible culture practices are important to shrimp consumers who prefer products that do not negatively impact the environment. This research indicates that shrimp consumers are willing to pay a price premium for environmentally responsible products. Ecolabeling is a method used to signal to consumers that efforts have taken place to avoid or reduce the environmental consequences of fish or shrimp production (Kinnucan, 2003) and this labeling has important welfare effects for consumers who are concerned with environmental stewardship related to agricultural products (Wessells et al., 1999). Ecolabeling has been accepted by the General Agreement on Tarrifs and Trade (GATT) as a method of product differentiation (Wessels et al., 2001) which can be relevant for the consumer due to the homogenous nature of fresh and previously frozen shrimp products. If Florida producers can sufficiently promote product differentiation through ecolabeling (i.e., communicating that Florida shrimp are produced in a non-destructive environmental manner), the enhanced marginal utility associated with Florida shrimp products may result in a higher prices in the marketplace (Kinnucan, 2003). Communicating credence attributes to shrimp consumers via a brightly-colored and easily discernable "Fresh from Florida" state-wide marketing label could facilitate desirable harvest information indicated to be a credence attribute desired by consumers.

Summary

A business planning strategy for Florida producers considering shrimp aquaculture production that utilizes local factor inputs and a locally-focused marketing channel may increase the probability of financial success for the firm in the context of new industry creation. By creating a sustainable competitive advantage within a monopolistically competitive, niche-market environment, potential long-term marginal benefits may accrue to the investor. This paper addressed the elements of a differentiation business strategy for Florida-grown shrimp to include direct-marketing efforts to local restaurants, a price premium reflecting the credence attributes of a locally-grown, fresh, never-frozen whole-shrimp product, and a generic advertising campaign to promote quality and environmental standards.

A direct-marketing effort directed toward local Florida restaurants narrows the market development to a population segment where high consumer demand exists for a fresh (never-frozen), locally-grown product. However, one obstacle to overcome in developing a direct-market approach is convincing the first buyer (restaurant manager) that the risk/ reward tradeoff will return positive benefits in the absence of historical precedents or tangible evidence (Aldrich & Fiol, 1994). Although market research identifies a latent demand for the fresh product with consumers, persuading restaurants to subscribe to more than a one-time purchase of fresh product at premium inventory prices may be a limiting factor as consumers establish purchasing behaviors. Restaurant managers may not be initially convinced to pay a premium price for what could be considered as a homogenous product touting perceived-value attributes.

The marginal utility gained from consuming a perceived "superior product" is based on an individual's own tastes and preferences. A differentiated-product market structure may communicate an increased marginal willingness to pay (a price premium) for the consumer's perceived product value (Lancaster, 1966). In a differentiated-product market structure, a large number of producers (both global and local) can co-exist, but each group sells a product that is differentiated from their competition (Shaffner et al., 1998). Creating a niche-market industry with a monopolistically-competitive structure may be possible for Florida producers who have access to scarce resources such as land, water permits, and skilled labor.

Generic advertising in Florida is promoted through the FDACS Florida Agriculture Promotion campaign for agriculture products. This type of commodity advertisement of agricultural products has historically been shown to have significant positive impacts on producer profits (Wolfe, 1944; Nerlove & Waugh, 1961; Comanor & Wilson, 1967; Thompson & Eiler, 1975; Kinnucan & Fearon, 1986; Forker & Ward, 1993; Kaiser & Lui, 1998; Kinnucan & Miao, 1999; Schmit & Kaiser, 2004). Credence attributes, such as those associated with quality and environmental standards can be transferred to the consumer via a promotional advertising strategy (Ward, 2006) to differentiate fresh (never-frozen), Florida-farmed shrimp from frozen, commodity imports. Using generic advertising as a component of the overall business strategy may facilitate the dissemination of consumer information and may increase the probability of repetitive purchase behavior for both consumers and restaurant managers as a fledgling shrimp industry becomes established in Florida.

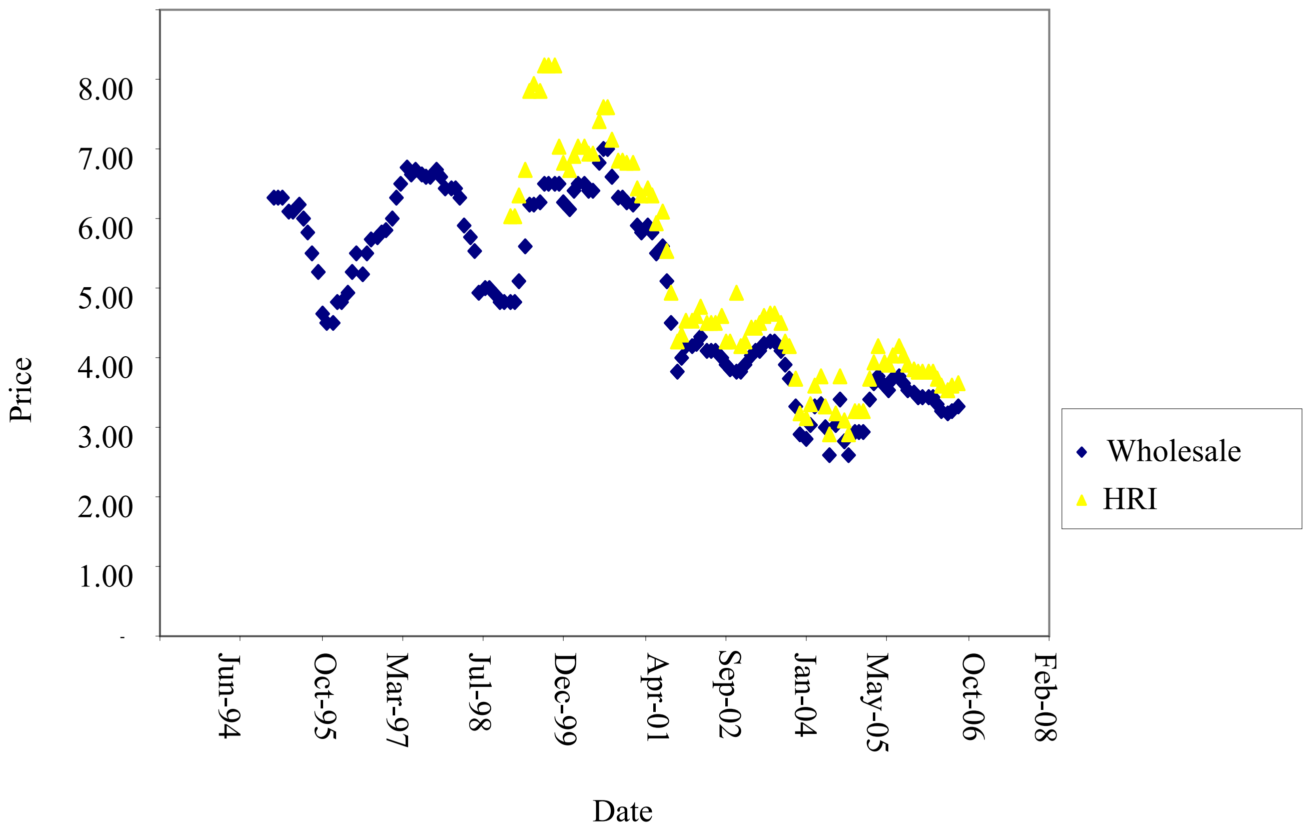

Figure 2-1. Wholesale and HRI shrimp prices 1993- 2006. Source: (Comtell, 2006)

Table 2-1. Factors influencing market conduct within an industry.

Highly competitive	Monopolistic competition	Monopoly
Low price	Low price + value-added premium	High price
Homogenous product	Differentiated product	Unique product
No barriers to entry	Some barriers to entry	Total barrier
Many sellers	Many sellers, each slightly different	One seller

Figure 2-2. Examples of FDACS Florida Agricultural Promotional Campaign material.

CHAPTER 3
DEVELOPING A STOCHASTIC SPREADSHEET MODEL TO ANALYZE THE POTENTIAL OF A SHRIMP AQUACULTURE INVESTMENT

Introduction

The Pacific marine white shrimp, *Litopenaeus vannamei*, is indigenous throughout the eastern Pacific from Sonora, Mexico to Tumbes in northern Peru (Perez-Farfante, 1997) and has historically been the primary species of farmed shrimp cultured in the Western Hemisphere (Lewis et al., 2002). It has recently emerged in Taiwan and China as the leading culture species (Wyban, 2002) due to specific disease resistance, lower overall feed protein requirements, as well as increased tolerance to low temperatures, wide-ranging salinities, and very high stocking densities (Briggs et al., 2004).

The scarcity of available coastal property within the United States for shrimp culture resulted in non-traditional, low-salinity culture protocols being developed for *L. vannamei* shrimp (Larramore et al., 2001; Samocha et al., 1998, 2002; Van Wyk et al., 1999). Private enterprises located within the states of Alabama, Arizona, Florida, Illinois, Indiana, Michigan, Mississippi, South Carolina, and Texas have succeeded in producing shrimp in low-salinity conditions (Davis et al., 2004). Recently, grapefruit farmers in the Indian River production region of southeast Florida have expressed interest in the feasibility of this technology to produce farmed shrimp on part of their fallow acreage. Using permitted well-point access to the Floridan aquifer, farmers have access to highly-mineralized irrigation water which is necessary for shrimp osmoregulation.

Despite the continued existence of several private shrimp farms within the United States, the profitability and cash flows associated with a low-salinity shrimp aquaculture investment still remain, in general, undetermined. Although production strategies and technologies continue to be made publicly available, limited analyses have been published specific to the financial feasibility of low-salinity pond shrimp operations in south Florida. Analytical tools that exist for the shrimp-farming industry are typically 1) elaborated during discussions at conference proceedings (Browdy, 2007; Duncan, 2007; Zazueta, 2007; Roy et al., 2005; Green, 2004; McMahon & Baca, 2001; Samocha et al., 2001; Van Wyk, 2000), 2) developed as commercially-marketable software packages (AQUAFarmer™, 2004; Hanson & Posadas, 2004; Ernst et al., 2000; Griffin & Treece, 1996), or 3) site and facility-specific (Wirth et al., 2004; Van Wyk et al., 2000). A need exists for financial data specific to a shrimp aquaculture investment in south Florida to provide grapefruit farmers with adequate information to consider a shrimp culture diversification option within a risk management context.

Research Objective

The objective of this paper is to present the probabilities of economic success of an investment by a Florida grapefruit grower into shrimp pond aquaculture via a series of eight simulation scenarios. Production is assumed to take place within the Indian River production region of Florida, which includes St. Lucie County. Producer interest in the feasibility of a low-salinity shrimp aquaculture investment is in response to recent production risks, including hurricane events and citrus canker disease, which have adversely affected grapefruit producers in this area. This study estimates the probable costs and returns for a hypothetical shrimp production system operating in St. Lucie County, Florida.

Economic success for this investment is defined by the positive net present value of net cash income over a 15-year planning horizon at specified discount rates. In addition to the baseline parameters employed, the effect of varying a complement of management variables will be examined relative to the economic performance of the investment. These variables will be examined in Scenarios 1 through 7 and include:

- Low stocking density

- High stocking density
- Average survival rate
- Increasing a local price premium
- Reducing capital (construction) costs
- Varying discount rates
- Reducing the survival rate

Following an analysis of these key management variables, the financial implications associated with including hurricane and random kill events are examined in Scenario 8. The probabilistic determination of economic success for this investment, as measured by the positive net present value of net cash income is generated via a stochastic simulation spreadsheet accounting model.

Simulation Model Methodology

Stochastic computer simulation models have been used to analyze capital expenditures and agricultural management scenarios under conditions of uncertainty (Richardson et al., 1976, 2000; Gempesaw II et al., 1992; Crawford & Milligan, 1984; Featherstone et al., 1990; Griffin & Thacker, 1994; Fumasi 2005). This type of agricultural model can be constructed by first programming a financial accounting spreadsheet to reflect deterministic financial accounting equations that calculate investment financial performance. Capital and production budgets primarily drive the cash flow process over each production period throughout the planning horizon. Also programmed into the accounting matrix are estimates for market prices and production yields that ultimately output a formulated calculation for annual net cash income and the net present value of net cash income for the investment planning horizon. A sensitivity analysis of financial results can be examined through user-defined adjustments of prices or inputs, or changes that might influence production yields. The deterministic accounting spreadsheet matrix forms the basic framework for the stochastic simulation model.

The construction of a stochastic accounting spreadsheet incorporates user-defined probability distributions for each input variable that may be considered to introduce risk into the investment scenario (Figure 3-1). These variables may include random or uncertain input costs, market prices, shrimp survival probabilities, random kill incidents, or hurricane events. Each of the spreadsheet-programming formulas, typically estimated via least-squares regression, is modified with an additional estimated probability distribution designation. The values for these random variables are then computed through a representative accounting spreadsheet to result in the financial calculation of key output variables (KOVs) being considered in the investment decision (Richardson, 1976). The KOVs being considered in this study are the discounted net present value of net cash income and annual net cash income levels for a fifteen-year planning horizon.

Stochastic simulation software uses an iterative process to draw a random sample from each stochastic variable distribution and output a KOV result from successive iterations (or states of nature) to a separate worksheet. Statistical analysis on the iterated results discerns the probability of positive NPV of net cash income performance at various rates of return to the investor. The stochastic-spreadsheet model is constructed to be completely dynamic and allows for user-defined changes to be immediately updated throughout the model. The dynamic nature of the spreadsheet model promotes its value as a risk management tool for specific farm-level investment analysis.

Production System Methodology

The framework for modeling a hypothetical low-salinity shrimp production system is based on the University of Florida/ Indian River Research and Education Center (UF/ IRREC) Shrimp Demonstration Project. In 2003, the Florida Department of Agriculture and Consumer Services (FDACS) funded a commercial-scale shrimp demonstration project (SDP) constructed at the UF/IRREC site in Ft. Pierce, Florida. With the assistance of a project manager, researchers were commissioned to build and operate a commercial-scale shrimp demonstration facility utilizing low-salinity groundwater. The findings of this two-year demonstration project chronicled the farm design, cost considerations, production processes, and marketing environment for the production and harvest of market-size *L. vannamei* shrimp in four low-salinity ponds located in South Florida (Wirth et al., 2004). The hypothetical production system design utilizes four 0.29-acre ponds and a head-start greenhouse structure, and calculated shrimp production data assumptions outlined in the following sections:

- Capital Costs
- Product Size
- Growth Function
- Survival Rates
- Feed Costs
- Inflation
- Market Prices
- Revenue Calculation
- Hurricane Probabilities

Based on the information provided in the Final Project Report for the SDP, the revenues and expenses for a hypothetical 5-acre, low-salinity shrimp aquaculture production system were assembled into a series of financial accounting spreadsheets for the purpose of estimating future cash flows for this investment.

Hypothetical Production System Design

To build the stochastic accounting spreadsheet used in this study, a representative farm was modeled after the commercial-scale SDP. The hypothetical production system was originally based on capital and variable cost budgets published in the SDP Final Report (Wirth et al., 2004). Collaboration with South Carolina's Department of Natural Resources - Waddell Mariculture Center (WMC) provided component cost data and management insight to determine variable input requirements for weekly feed and pond aeration. Zeigler feed manufacturers (Zeigler, 2006) provided historical feed costs for forecasting stochastic feed prices. A shrimp-production consulting firm provided *L. vannamei* growth measurements to estimate a growth equation for *L. vannamei* from 1 gram to 25 grams (Manzo, 2006).

Stochastic simulation software was used to estimate the probabilities associated with financial performance of the hypothetical production system incorporating several relevant economic and management scenarios. These data components, organized into a financial spreadsheet framework, complete the stochastic simulation spreadsheet model for a low-salinity shrimp production system. The combination of cost, production, software, and management input components for this research project resulted in a whole-farm financial model for estimating annual net cash income and the net present value of net cash income over a 15-year planning horizon.

Capital Cost

The hypothetical five-acre farm site addressed in this study consists of four 0.29-acre grow-out ponds lined in ethylene propylene diene monomer (EPDM) rubber. The liners prevent water seepage through the sandy-soil environment of southeast Florida. Prior to pond stocking, a 30-foot by 90-foot aluminum framed Quonset-style greenhouse is used for low-salinity acclimation and “head-start” growth of juvenile shrimp from a hatchery-size of 0.1 gram cultured to 1.0 gram. Four EDPM-lined rectangular raceways (45’x14’x 3’) are contained in the greenhouse and schedule 40 poly vinyl chloride plumbing (PVC) pipes are used to recirculate water through a 10-cubic foot bead-filter (Wirth et al., 2004). Supplementary structures include a climate-controlled feed storage area and a retention pond used for water overflow specific to draining the production ponds at harvest or to receive overflow water in the case of flooding during storm events (Figure 3-2).

Due to a relatively high water table in the Indian River production region, additional fill dirt is needed to increase pond elevation for the prevention of water intrusion beneath the pond linings (Wirth et al., 2004). The fill requirement adds additional construction expenses and results in a need for more acreage than would otherwise be needed at sites with a higher elevation above mean sea level. The minimum "unit size" for this shrimp pond production model is five acres. The construction costs for the greenhouse (Table 3-1) and ponds (Table 3-2) are estimated to be $90,961, and $403,032 respectively.

Product Size

Assuming a one-crop production period of 35 weeks, the production model corresponds to 4 weeks of greenhouse head start and 31 weeks of pond production for a 25-gram (whole-weight) shrimp. Pond stocking is assumed to occur in April with harvest in November. The non-processed, whole-shrimp product is assumed to be direct marketed to local restaurants in Florida. The product form of harvested shrimp in the production model is assumed to be fresh and non-processed (head-on), however, available time-series price data used in the model reflects a commodity-priced, frozen, headless shrimp form. Therefore, it was necessary to convert the 25-gram (head-on) shrimp yield produced in the production system to a pricing standard common in the shrimp industry.

A 25-gram (head-on) shrimp corresponds to approximately a 31-35 (headless) tail count (tails per pound) shrimp if a 60% product yield is assumed (Pacific Seafood Group, 2002, Briggs et al., 2004). The size-calculation function of shrimp tails per pound is given in equation 3-1

$$y = Whole\ shrimp\ weight\ (grams) * 0.60 \tag{3-1}$$

where, y is the tail-meat weight (grams) of the harvested (head-on) shrimp.

$$y = 15\ grams \tag{3-2}$$

From this equation, a 25-gram (head-on) shrimp harvested from the production system is estimated to yield 15 grams of tail-meat (equation 3-2).

Based on the tail-meat yield, the conversion of whole shrimp necessary to yield one pound (454 grams) of tail meat is given in equation 3-3

$$15x = 454 \ grams \tag{3-3}$$

where, x is shrimp tails per pound.

$$x = 30.27 \ shrimp \ tails \ per \ pound \tag{3-4}$$

From equation 3-4, the number of shrimp tails per pound is assumed to approximately correspond to an industry standard, 31-35 tails per pound size-class pricing strategy. No processing or marketing costs are directly included in the spreadsheet model, although ice is indirectly included as a harvesting procedure cost.

Growth Function

Feeding regimes and their respective costs are a function of estimated pond biomass and survival, which constitute one of the largest expenses for an aquaculture operation (Rosenberry, 2007). The spreadsheet model calculates marginal growth and mortality rates over the production period to determine production period feed costs and molasses application costs based on standard feeding protocols for this species (Wirth, et.al., 2004). Although published data exists for *L. vannamei* weighing less than or equal to 20 grams whole weight (Trimble, 1980, Wyban et.al., 1987, Hochman et.al., 1990), limited published data exists specific to a growth function up to size 25 grams. Typically, *L. vannamei* is cultured to 20 grams (whole-weight) due to a decreasing marginal growth rate for this species (Wyban & Sweeney, 1991). This shrimp species approaches broodstock size at approximately 35 grams (Palacios, 2000). Market research indicates, however, that premium prices may be received by the producer for a direct-marketed 25 gram, whole-weight (31-35 tails per pound) product size class (Wirth, 2003). Premium prices may be obtained from a cultured shrimp product that is differentiated, by product size, from a commodity (20 gram whole-weight) size class. The target size for this analysis is a 25-gram (whole-weight) shrimp.

Head-start nursery shrimp growth rates are estimated linearly from sampled IRREC nursery weight data (Wirth et al., 2004). This growth function used the beginning data point of 0.11 grams and ending data point (pond stocking weight) of 0.72 grams. A simple linear estimation (for Week 1 through Week 4) for a daily nursed-shrimp growth function used in feed calculations is shown in equation 3-5

$$w = 0.11 + 0.021x \qquad (3\text{-}5)$$

where, w is the nursery shrimp weight (grams), x is days, and the marginal growth coefficient is equal to 0.021 grams of nursery weight gain per day.

To estimate the production pond growth curve from 1 gram to 25 grams (Week 5 through Week 35), weekly growth data were obtained from a commercial broodstock-shrimp producer employing recirculating technology during a grow-out period of 36 weeks (Manzo, 2006). Recorded weight data was used to estimate a growth function for *L. vannamei* from 1 gram to 25 grams using a log-reciprocal regression function as recommended by Hochman, et. al., (1990) and shown in equation 3-6.

$$w = e^{\alpha_0 - \alpha_1 (1/x)} \qquad (3\text{-}6)$$

where w is the average weight of the animal in grams, α is a growth coefficient, and x is the animal age in weeks.

From this function, a simple growth equation was estimated using SAS software v.8 (equation 3-7).

$$w = e^{4.16 - 31.36(1/x)}, \quad R^2 = 0.992 \qquad (3\text{-}7)$$

The t-statistic of -59.00 for the independent variable (*x*, age in weeks) allows us to reject the null hypothesis that the slope coefficient equals zero. The correlation coefficient (R^2) indicates that 99.2% of the variance of the weight variable can be explained by the regression equation (Ott & Longnecker, 2004). The estimated growth for pond stocked shrimp closely resembles the SDP data up to 15 grams and is used to forecast the marginal weight gain of *L. vannamei* shrimp from 1 gram to 25 grams (whole-weight) (Figure 3-3).

The marginal weight gain was used to estimate the marginal feed costs for *L. vannamei* shrimp, on a weekly basis, for 35 weeks. The survival rate for calculating the pond feeding regime is pre-estimated by the farm manager at stocking time. Over time, the manager's experience with specific pond conditions should allow for a more accurate estimate of actual survival rates so as to optimize feed costs and avoid overfeeding.

Survival Rates

Survival rates used to calculate yields in the model are based on yields expected to result from production skill and experience or with some initial consultant advice. A consultant was budgeted in the spreadsheet model for initial construction oversight and management training. The expected yield for the deterministic scenarios is constant at 80% survival. Production yield probability distributions for the stochastic scenarios were based on a GRKS distribution using estimates of minimum, mid-point, and maximum expected survival (Richardson et al., 2006). This continuous probability distribution is a substitute for a triangular distribution and can be used to simulate an empirical probability distribution for survival that is based on minimal data inputs. Properties of this distribution are that 50% of the observations are less than the midpoint and 50% of the observations are above the midpoint. Additionally, a second property of this distribution is that 95% of the observations are between minimum and maximum, 2.2% of the observations are below the minimum, and 2.2% of the observations are above the maximum.

Feed Costs

Future feed prices for shrimp nursery feed and growout feed were estimated via least-squares from historical feed pricing data for years 1997-2006. Feeding protocols within the financial spreadsheet model were based on a projected 80% survival rate and a feed conversion of 1.8 kilograms of feed per 1 kilogram of shrimp weight gain (1.8:1). The nursery feed prices represent 40% protein content crumbled feed (PL 40-9 ½) blend and the pond growout feed prices represent 35% protein content pelleted feed (Zeigler Brothers SI-35) at the 400-ton pricing level (Ziegler, 2006). Shipping costs for feed transport were estimated from costs reflected in the IRREC data (Wirth et al., 2004).

Inflation

Inflation rates for base year (2007) costs including fuels (energy), supplies (PL's), and wage rates for years 2006-2015 are from the University of Missouri's Food and Agriculture Policy Research Institute published inflation data (FAPRI, 2006). Inflation rate estimates for years 2016 through 2021 (Table 3-3) were estimated via least squares regression from the 2007-2015 FAPRI data, (SAS v.8). The inflation rates for shrimp nursery feed and growout feed costs were extrapolated from historical feed pricing data for years 1997-2006. The annual inflation rate of agriculture land values in Florida reflects a 5% annual rate per year based on the 2002 estimated value of land and buildings per farm between 1997 and 2002 (USDA, 2002).

Market Prices

Twenty years ago Mexico, Central America, and Northern South America were the predominant suppliers of shrimp to the U.S. Currently, Asia and Indonesia are the predominant domestic shrimp suppliers (Adams et al., 2005). A rapid decline in retail prices during 1999-2004 reflects rapid expansion in the eastern hemisphere (Thailand, Vietnam, Indonesia, India, China, Malaysia, Taiwan, Bangladesh, Sri Lanka and the Philippines) (Figure 3-4) after widespread disease outbreaks reduced long-term production yields in the western hemisphere (Mexico, Belize, Ecuador, Honduras, Brazil, Panama, Columbia, and Guatemala) (Rosenberry, 2007).

Historical market-price data for a 25-gram whole weight shrimp (corresponding to 31-35 tails per pound (headless) product form) were collected from Urner-Barry seafood price subscription service for the period January 1999-August 2006 (Urner-Barry, 2006). These prices represent price data for Ecuadorian *L. vannamei* shrimp sized 31-35 tails per pound in a raw, headless, block-frozen form (Figure 3-5). The database prices reflect the so-called "Hotel Restaurant Institution" price (HRI). This HRI price is an "index" price that characterizes the average price that a hotel, restaurant, or similar institution would pay a seafood distributor for 31-35 tails per pound count shrimp. HRI price data is collected from a cross section sample of nationwide hotels and restaurants via a weekly nationwide telephone survey performed by Urner-Barry services.

The forecasted prices used in the financial spreadsheet model were estimated via least-squares regression on monthly historical prices from January 2004 to August 2006 using SAS v.8 and utilizing the Urner-Barry subscription database. The correlation coefficient (R^2) indicates 25% of the price data can be explained by the regression equation. This period reflects some stabilization in reported retail shrimp prices from January 2004-August 2007, relative to reported prices from January 1999-December 2003. This relative price stabilization may reflect equilibrium supply and demand levels approaching a market-clearing world price in the global shrimp industry (McConnell & Brue, 1993).

Revenue Calculation

The growth rate and total biomass for each pond is conducted on a whole shrimp weight basis. However, yields for the shrimp harvest for each pond reflect headless (tail-weight) yields for spreadsheet model revenue calculations. The tail-weight harvest amount (in pounds) that is used for the investment revenue calculation reflects a 60% meat yield from the total biomass of shrimp produced and harvested annually (Pacific Seafood Group, 2002, Briggs et al., 2004). Although the model assumes a direct-market, whole-shrimp sales approach with no producer processing, the use of a headless-pricing strategy for revenue calculation is employed due to the availability of historical headless market-price data for market-price forecasts. The forecasted pricing data reflects historical HRI prices from the Urner-Barry subscription market price data for shrimp sold in a headless, frozen block product form. By using a 60% body- weight tail yield, the spreadsheet model calculates investment revenue for a 31-35 shrimp tail per pound product form using prices representing a hotel-restaurant pricing strategy, as shown in equation 3-3

$$R = 0.6Q * HRI\ Price \tag{3-3}$$

where, R is producer revenue, Q is whole-shrimp biomass harvested, and HRI Price equals retail price received for headless, (31-35 tails per pound) product form. The actual price received by the producer in a direct marketing strategy selling whole shrimp can be calculated by an algebraic manipulation of equation 3-3 as shown in equation 3-4

$$P = 0.6Q * HRI\ Price \tag{3-4}$$

where, P is producer price received (for a head-on, direct-marketed 31-35 tail count shrimp product). The price received by the producer would be lower than the HRI price due to the total biomass calculated for producer revenue. Therefore, using an approximate meat yield (60% of biomass) for the revenue calculation in the model corresponds to the historical Urner-Barry product form pricing for forecasting future shrimp prices throughout the investment-planning horizon.

Hurricane Probabilities

In the stochastic spreadsheet model, the probability of a future storm event impacting and causing damage in St. Lucie County was estimated from storm event data available from the National Oceanographic and Atmospheric Administration Satellite and Information Service database and Unisys Weather System database (NOAA, 2007; Unisys, 2006). The storm event data collected included storm dates, longitude/ latitude values, and reported wind speeds per county. Windspeed data was recorded for counties directly within the storm path as well as wind speeds from adjacent counties that were impacted (NOAA, 2006). Damage cost estimates to the shrimp production system were derived from actual events surrounding the 2003-04 hurricane season at the IRREC site in St. Lucie County. Structural damage is correlated to the Saffir-Simpson scale (Table 3-4) which uses wind speed as the determining factor for estimating the severity of potential property damages (NOAA, 2006).

For the purpose of forecasting future hurricane probabilities, wind-engineering researchers at the University of Florida consider historical hurricane event data that captures a period of time long enough to include the cyclical pattern of storm events attributed to the Atlantic Multidecadal Oscillation (AMO). The AMO is a series of long-duration changes in temperature of the North Atlantic Ocean that may last for 20-40 years at a time (NOAA, 2007). These temperature changes may impact the frequency and severity of tropical storms during the annual June – November hurricane season, which may influence the calculation of hurricane event probabilities.

A fifty-year period extending from 1956 to 2005 produced 25 hurricane landfalls that impacted the State of Florida. Historical wind speed data from the storm track and surrounding areas were recorded on a map of Florida demarcated by county. Individually categorized storm windspeed data were input into a spreadsheet and resulted in a count of ten tropical storms, three Category 1 hurricanes, and one Category 2 hurricane for St. Lucie County.

The probability of each of these storms impacting St. Lucie County in the future is calculated by dividing the number of class storms by the total number of storms that have hit Florida over the 50-year period. No hurricane force winds of Category 3, 4, or 5 impacted St. Lucie County during the prescribed period. Although the probability exists for a higher intensity storm to impact the model area, these probabilities are not reflected in the spreadsheet model. Future probabilities and respective damage estimates to the farm resulting from a tropical storm, Category 1, or Category 2 hurricane are given in Table 3-5.

Additional consideration was given specifically to the damage inflicted on a standing shrimp crop from the highest intensity wind event that might occur during the one-year production period. If one or more storms impacted Florida during a single year within the 1956 – 2005 period, only the highest intensity storm was considered for that year (regardless if more than one storm event impacted the area). From the aquaculturist's perspective, this methodology considers the real impact producers face during the production period regarding damages and lost production time over the course of a single hurricane season. Property damage estimates reflect actual damages sustained at the IRREC facility during the 2003-2004 hurricane seasons. Crop loss during this same period was minimal, at less than 1.6%, and is not included as a financial damage estimate.

Key Output Variables (KOVs) of Financial Performance

The economic model operates as a spreadsheet in Microsoft Excel and utilizes Simetar©, an Excel-based add-in developed at Texas A&M University (Richardson et al., 2006). This software operates in a dual capacity to calculate both deterministic variable output as well as stochastic variable output. While the software is operating in the deterministic mode, all stochastic variables default to expected value. The key output variables (KOVs), (e.g. annual net cash income and net present value (NPV) of net cash income for the 15-year planning horizon) are calculated as a measurement of the investment financial performance. Conversely, when the software operates in the stochastic mode, all stochastic variables utilize a probability distribution that incorporates variability, or "risk", into the calculation of KOVs. These variables include market prices, feed costs, hurricane events, random kill events, and survival rates (yields). The KOVs measure the financial performance for multiple scenarios in this study. In this study, 8 scenarios (2 deterministic scenarios and 6 stochastic scenarios) are analyzed. While all price, cost, and yield variables operate in the stochastic mode for Scenario 3 through Scenario 8 the influence of hurricane and random kill events are only analyzed in Scenario 8.

The KOVs for the deterministic scenarios measure the annual net cash income and net present value (NPV) of net cash income over a 15-year planning horizon for the shrimp aquaculture investment. The calculation of these financial performance measurements are given in equations 3-5 and 3-6 (Higgins, 2004).

$$NI = TR - (FC + VC) \tag{3-5}$$

where, NI is net cash income, FC are fixed costs, and VC are variable (operating) costs.

$$NPV = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0 \tag{3-6}$$

where, NPV is net present value of cash flow, C is cash flow, t is the investment horizon of fifteen years, and r is the discount rate. A baseline discount rate of 8% is assumed in the calculations corresponding to a 5% interest rate that is comparable to a 30-day U.S. Treasury Bill (USDT, 2007) plus a 3% inflation premium assumption.

Scenario Overview

Eight scenarios were examined in the model to determine the impact of managerial changes to the NPV calculation of net cash income. A suite of 2 deterministic and 6 stochastic scenarios examined changes regarding increased stocking density, an increased price premium, decreased capital construction costs, and decreased survival rate. Hurricane and random kill events are included in the final scenario analysis.

Scenarios 1 and 2- Deterministic Analysis of Two Stocking Densities

Scenarios 1 and 2 incorporate two different stocking densities assumed during the production period; 80 shrimp per meter squared (m^2) and 100 shrimp per m^2, respectively. These two deterministic analyses include a discussion of the NPV values and annual net cash income and expenses associated with the shrimp enterprise using baseline assumptions (Table 3-6). All stochastic variables default to the expected value for KOV calculations. Hurricane and random kill events are not included in Scenarios 1 or 2.

Scenario 3 – Probability of Positive NPV at a Higher Stocking Density

Stochastic Scenario 3 utilizes the 100 shrimp per m^2 assumption used in Scenario 2 to incorporate the variability of stochastic variables in KOV output. Scenario Three incorporates all stochastic variables (except hurricane and random kill events) to calculate the probability of economic success given by positive NPV of net cash income values. The results are presented as a cumulative density function (CDF) indicating the NPV range of values calculated via the iterative stochastic process in the spreadsheet model. The vertical axis of the CDF represents the NPV corresponding probability of occurrence. In Scenario 3, the discount rate is calculated at 8% and hurricane and random kill events are not included.

Scenario 4 – Higher Price Premium

The analyses for Scenarios 1 through Scenario 3 assume a price premium of $1 per pound of shrimp based on consumer willingness-to-pay data (corresponding to $0.33 received by the producer) for locally-grown shrimp (Wirth & Davis, 2001b). Stochastic Scenario 4 considers consumer willingness-to-pay a higher price premium of $2 per pound for a direct-market emphasis on the fresh, never-frozen shrimp product attribute for Florida aquacultured shrimp (Davis & Wirth, 2001). The direct-market assumption utilizes the food cost principle of the "General Rule of Three" to calculate premium benefits received by the producer. This principle is simply stated as, "the amount charged for a food item must be at least three times the total cost of the ingredient" (Herbert, 1985). Based on this information, benefits to the producer are derived by using a 33% food cost percentage of the $2 consumer price premium received by the restaurant operator. The direct benefit received by the producer is calculated as a $0.66 price premium for locally-grown, fresh (never-frozen) shrimp. The results of Scenario 4 are presented as a CDF indicating the NPV range of values calculated via the iterative process in the spreadsheet model. The probability results assume the 100 shrimp per m^2 stocking density. In Scenario 4, the discount rate is calculated at 8% and hurricane and random kill events are not included.

Scenario 5 – Reducing Initial Capital Costs

Scenario 5 considers the potential of reducing the capital costs associated with constructing the hypothetical shrimp greenhouse and four-pond production system. The original capital costs were derived from the FDACS-sponsored commercial-scale shrimp demonstration project (SDP) at UF/IRREC in Ft. Pierce, Florida. The capital costs for the greenhouse ($90,961) and four-pond ($403,032) production system totaled $493,993. Assuming that an agriculture investor has access to idle factor inputs (such as labor and equipment), the access to these resources may lead to cost efficiencies during the construction process. Considering that the $493,993 capital outlay for the SDP in Ft. Pierce was the result of a state-sponsored allocative process via contract basis, a privately-sponsored construction effort would likely incur a capital cost less than this amount. Scenario 5 assumes that the construction costs to build the shrimp production system are reduced by 50% to $246,997. The results of Scenario 5 are presented as a CDF indicating the NPV range of values calculated via the iterative process in the spreadsheet model. The probability results assume the 100 shrimp per m^2 stocking density and the higher price premium of $0.66 per pound of shrimp. In Scenario 5, the discount rate is calculated at 8% and hurricane and random kill events are not included.

Scenario 6 – Reducing the Discount Rate

The NPV calculation has used a baseline discount rate of 8% for Scenario 1 through Scenario 5. In reality each investor's required rate of return (as measured by the discount rate) is independently subjective. Scenario 6 considers a range of discount rates used as the investor's required rate of return on the shrimp enterprise investment. The results as are presented as a CDF indicating the NPV range of values calculated via the iterative process in the spreadsheet model. The probability results assume the 100 shrimp per m^2 stocking density, the higher price premium of $0.66 per pound of shrimp, and the reduced capital cost assumption of $246,997 in this scenario. In Scenario 6, hurricane and random kill events are not included.

Scenario 7 – Below Average Survival Rates

Management experience contributes to the optimization of healthy water quality parameters (e.g. feeding and aeration). Maintaining healthy water quality parameters will improve survival rates of shrimp grown in ponds, which in turn will lead to higher production yields at harvest (Griffin & Thacker, 1994). Anecdotal evidence indicates that the average expected survival rate at harvest time for shrimp producers is 80% with management experience being a major contributor to production yields at harvest time. Scenario 7 examines the impact of reducing average survival rates over various discount rates to determine the probability of economic success of the shrimp investment.

As outlined previously, survival rates at harvest for the stochastic scenarios are based on a GRKS (minimum-median-maximum) probability distribution. Scenario 1 through Scenario 6 assumes approximately average survival rates (70-80-90). Scenario 7 represents a reduction in the survival rate expectations (50-70-90). The results are presented as a CDF indicating the NPV range of values calculated via the iterative process in the spreadsheet model. The probability results assume the 100 shrimp per m^2 stocking density, the higher price premium assumption of $0.66, and the reduced capital cost assumption of $246,997 in this scenario. In Scenario 7, hurricane and random kill events are not included.

Scenario 8 – Random Kill and Hurricane Events

Stochastic Scenario 8 is an extension of Scenario 6 with the addition of hurricane and random kill events included in the stochastic simulation output. The overall survival at the time of shrimp harvest does not contain any contingency for random kill events which can strongly affect firm profitability due to random large-scale mortality (Griffin & Thacker, 1994). Random kill events differ from expected mortality although both are influenced by severe water quality or disease issues (Thacker & Griffin, 1994). The random kill event probability in the spreadsheet model is assumed to be 6% during the production period of 1 year, based on estimates by Thacker and Griffin (1994). When a random kill event occurs, it is assumed that 50% -75% of the pond population is lost. The probability of each random kill event is calculated independently, via the formulated equations, for each of the four ponds within the 5-acre production unit.

Inclement weather events occur in Florida regularly and with varying levels of severity from tropical storm strength to hurricane status. Depending on the severity of the storm event, damages to a shrimp culture facility might range from negligible damage to total structural failure. The probability of tropical storm and hurricane events are included in the stochastic model, with damages reflecting actual property damages sustained by the commercial shrimp demonstration facility in Ft. Pierce, Florida during the 2004 hurricane season (Table 3-5).

Deterministic Analysis Results

Baseline Operating Variables

The deterministic investment model (5 acres) estimates the expected values of all input variables including market prices for 31-35 count size class shrimp, shrimp growout feed prices, and shrimp yields and baseline operating variables (Table 3-6). The planning horizon under consideration is fifteen years for a 100% equity-financed farm, which assumes that all cash shortfalls are covered through an operating loan at a 9.25% annual interest rate (Farm Credit, 2007). The two scenarios in the following deterministic analysis include two different stocking densities while keeping all other baseline parameters constant. Decreased survival probabilities, random kill events, and the impacts from forecasted hurricane events are not reflected in the deterministic scenarios. The impact of these parameters will be discussed in the stochastic portion of the analysis.

Scenario 1 – Stocking Density 80 Shrimp per m^2

In the first scenario, the stocking density is assumed to be 80 shrimp per m^2 of pond area. That stocking density is expected to yield at total 13,300 pounds (lbs) of shrimp tail meat annually from the four production ponds. Based on this stocking density the Scenario 1 investment generates a negative net present value of -$462,401. The NPV is calculated considering the discounted net cash incomes from Year 1 through Year 15 and the initial capital investment of -$493,993 in construction Year 0. The income statements over the 15-year planning horizon (Table 3-7) shows crop value of $60,383 and expenses of $68,172, resulting in a farm loss of -$7,789 in Year 1 (construction takes place in Year 0). Operating loans are required for all production years. Variability in the annual net cash income values for Year 2 through Year 15 reflects variation in the replacement of required production and harvest equipment and supplies. The estimated useful life and replacement schedule for greenhouse and pond components that are replaced over the investment horizon are included in Appendix C. Inflation was built into the model and applied to feed, labor, fuel, and supplies costs.

Scenario 2 – Stocking Density 100 Shrimp per m^2

Scenario 2 increases the stocking density in the spreadsheet model to 100 shrimp per m^2 while holding all of the other baseline variables constant (Table 3-6). This increased stocking density in Scenario 2 results in a negative NPV of net cash income over the 15-year planning horizon of -$343,120. The NPV is calculated considering the discounted net cash income flow over Year 1 through Year 15 and the initial capital investment of -$493,993 in construction Year 0. The annual production from this scenario yields 16,667 lbs of shrimp tail meat from four production ponds. The income statement for the planning horizon for Year 1 reflects increased revenue (Table 3-8), relative to Scenario 1 (Table 3-7), as a result of a higher stocking density. Production Year 1 produces a crop valued at $75, 479 and incurs expenses of $76,846 resulting in a negative net cash income in Year 1 of -$1,367. Operating loans are required for Year 1 through Year 8 due to an operating cash shortfall at the beginning of the production period in these years. However, expected values as a result of the increased stocking density in this scenario return positive values of net cash income for Year 2 through Year 15.

Interest charges (9.25%) for operating and loans in Year 1 through Year 8 increase the total expenses of the enterprise for the first 8 years. In Year 9 through Year 15, the annual beginning cash balance covers all operating costs; therefore, operating loans are not required for the remainder of the production horizon. Although the higher stocking density does not result in a positive NPV, the results of the deterministic analysis in Scenarios 1 and 2 provide the investor with preliminary costs and benefit information that may assist in initial consideration of a shrimp aquaculture investment.

Scenarios 3 through 8 consider stochastic (risky) elements that may impact the shrimp aquaculture investment. In these scenarios, the chance of economic success of the shrimp aquaculture investment is illustrated via probabilities of positive NPV of net cash income. Scenario results are output as cumulative density functions with the domain of the NPV of net cash income on the horizontal axis and the probability of the NPV is equal to or less than that value on the vertical axis.

Stochastic Scenario Framework

The stochastic model is developed in a Microsoft® Excel® (Microsoft Corp., Washington, USA) spreadsheet, with the purpose being to forecast the financial parameters associated with a shrimp aquaculture investment over a 15-year planning horizon. The Excel add-in, Simetar©, allows variables within the spreadsheet to be stochastic (probabilistic). The stochastic variables include input prices, market prices, survival rate, random kill events, and hurricanes events. By creating a historical database of the proposed variables, least-squares linear regression can be used to forecast the future values. A linear equation using historical variables (independent variables) to forecast future variables (dependent variables) may not correspond to an exact linear function of the sample observations. The variability of the predicted estimate of the dependent variable is indicated by a random error term in the regression model (Equation 3- 8).

$$y = \beta_0 + \beta_1 x + \varepsilon \qquad (3\text{-}8)$$

where, y is the dependent variable, β_0 is the intercept, β_1 is the slope, x is the independent variable, and ε is the error term. The error term can be used as the source of future variability for the forecasted values. The error term associated with each of the linear estimates has an underlying probability distribution estimated empirically from the observed historical values (Richardson, 1976). The combination of the linear estimation equation and the probability estimation of the error term are what produce the stochastic variables in the spreadsheet model.

The Simetar© software utilizes a stratified sampling technique known as a Latin-hypercube sampling procedure (Inman, et al., 1981) that is efficient in selecting random variables from the probability distribution of a stochastic variable. During repeated sampling, this procedure avoids clustering and ensures that all areas of the probability distribution are considered (Richardson, 2006). Through an iterative procedure, the accounting formulas are calculated by means of random sampling of the probability distributions (Anderson, 1974). Using a random number generator via the Simetar© software, this iterative process (n=500) solves for the key output variable measures of financial performance. A statistical analysis of the output results delivers a probability estimate of financial performance of the investment. These results allow an investor to evaluate the risk associated with this particular investment. In essence, the risk associated with this procedure is reduced to a single variable (Richardson, 1976).

In Scenarios 3 through 8, the resulting probabilities represent the chance of economic success, as measured by positive values of the discounted net present value (NPV) of net cash income. Each of these scenario simulations incorporates all of the risk parameters for market prices, costs, and yields defined as stochastic in the previous discussion. Only Scenario 8 includes the probable impact on economic success of the investment as a result of hurricane and random kill events. The stochastic simulation process assumes the following:

1) Historical price and production variability (risk) are included in the forecasted values over the planning horizon
2) Impact of random kills, decreased survival rates, a local price premium, and various discount rates can be analyzed with respect to their influence over the estimated profitability of this investment.
3) Inclusion of hurricane and random kill event probabilities in Scenario 8 adds a realistic dimension to the probabilities of positive NPV estimates at various discount rates.

Stochastic Analysis Results

Deterministic Scenarios 1 and 2 may be considered as an investor's "first pass" at determining the financial viability of a shrimp aquaculture investment under the assumptions defined in the model. However, the deterministic (expected value) method does not take any of the stochastic price "risk" into consideration relative to the probability of economic success. Random variability of prices and yields based on historic variability are calculated within the spreadsheet equation matrix for each of the 500 stochastic iterations. In addition to price and yield risk, two other key components of production risk have not been considered in the deterministic scenarios. The addition of the risk associated with reduced shrimp survival rates and the addition of random kill and hurricane event probabilities provide the investor with beneficial information and therefore contribute to greater insight into the long-term profitability, and risk, of a shrimp farm investment in Florida.

Scenario 3 – Probability of Economic Success at a Higher Stocking Density

Scenario 3 results are represented by a Cumulative Probability Density Function (CDF) of the discounted net present value of cash flows for the proposed investment with average (70-80-90) expected survival rates and 100 shrimp per m^2 stocking density. This scenario illustrates that there is a 0% probability that the investment will yield a positive net present value at these average survival rates at harvest time, holding all other management variables constant (Figure 3-6). Additional information presented in the CDF indicates that there is also a 100% probability of a negative NPV of net cash flows value of -$281,215 as indicated by the vertical height of the CDF function corresponding to this NPV value on the horizontal axis. The CDF also indicates that there is also a 50% probability of a NPV of net cash flows calculation of -$347,000 as indicated by the 50% level at the vertical height of the CDF function that is corresponding to the -$347,000 NPV value on the horizontal axis

Scenario 4 – Higher Price Premium

In Scenario 4, a $0.66 price premium is added to the forecasted stochastic prices in the spreadsheet model. The stocking density is assumed to be 100 shrimp per m^2, with an average survival rate, and assumes original baseline values previously discussed (Table 3-6). This scenario indicates that there is a 0% probability that the investment will yield a positive net present value of net cash income (Figure 3-7). Additional information presented in the CDF indicates that there is also a 50% probability of a negative NPV of net cash flows value of -$292,000 as indicated by the height of the CDF function corresponding to this NPV value on the horizontal axis

Scenario 5 – Reducing initial capital costs

In Scenario 5, it was assumed the possibility that the initial capital costs necessary to construct the shrimp production facility could be reduced by 50% based on the assumption that the investor has access to idle factor inputs and is able to attain cost efficiencies relative to the SDP budgeted costs. In this scenario, the stocking density is calculated at 100 shrimp per m^2 with average survival rates, a $0.66 price premium is included, and baseline assumptions are assumed (Table 3-6). Scenario 5 results indicate that there is a 2% probability that the investment will yield a positive net present value of net cash income (Figure 3-8). Additional information presented in the CDF indicates that there is also a 50% probability of a negative NPV of net cash flows value of -$46,000 as indicated by the height of the CDF function corresponding to this NPV value on the horizontal axis

Scenario 6 – Reducing the Discount Rate

The NPV calculation has used a baseline discount rate of 8% for Scenarios 1 through 5, however, in reality each investor's required rate of return (as measured by the discount rate) is independently subjective. In this scenario analysis, the probability of positive net present value is calculated using lower discount rates, ranging from 3% to 7%, required by the investor. Model assumptions include a stocking density of 100 shrimp per m^2 with average survival, a $0.66 price premium, baseline variables (Table 3-6) and 50% reduced capital costs. The specific probability values for each of the discount rates are indicated by the height of the CDF function corresponding to the NPV value on the horizontal axis.

Scenario 6 output reflects a shift toward positive values of NPV of net cash income as the discount rate is lowered (Figure 3-9). As expected, with lower required rates of return (discount rate) the investor's probability of economic success increases. Increasing positive probabilities exist, ranging from a 9% probability at a 7% discount rate to a 94% probability at a 3% discount rate. Scenario output of NPV of net cash income that is estimated to have a 50% probability of occurring (Table 3-9) ranges from $66,198 to a negative NPV of -$39,502. This quantitative data output indicating a 50% probability of occurrence may be helpful for risk neutral investors willing to take a 50-50 chance on the shrimp aquaculture investment.

Scenario 7 – Below Average Survival Rates

Scenario 7 represents a reduction in the survival rate expectations (50-70-90) that may result from poor water quality conditions due to overfeeding or heterotrophic/ autotrophic imbalances. Assumptions in this scenario include: a stocking density calculated at 100 shrimp per m^2, capital costs reduced by 50% to $246,997, and a higher price premium of $0.66. Results are calculated using a range of discount rates from 3% to 8%.

Reduced survival rates illustrated in the Scenario 7 output reflect a shift away from positive values of NPV of net cash income (Figure 3-10). Lowered survival rates significantly impact the profitability potential as measured by positive values of NPV. There is virtually zero chance of positive NPV of the net cash income if less than average survival rates are encountered over the production planning horizon. A 50% chance level for NPV of net cash income ranges from -$375,000 to -$125,000 across all discount rate calculations. Scenario 7 illustrates the considerable impact that survival rates have on the overall profitability of the shrimp aquaculture investment.

Scenario 8 – Random Kill and Hurricane Event Probabilities Included

Scenario 8 includes risky effects of random kill and hurricane events affecting the financial outcome of the investment. In this scenario, assumptions include a stocking density calculated at 100 shrimp per m^2, a $0.66 price premium, average survival rates, original capital costs reduced by 50% to $246,997, and baseline variables (Table 3-6). The NPV of net cash income is given in for a range of discount rates from 3% to 8%.

Scenario 8 outputs reflect an improved probability of positive NPV of net cash income (Figure 3-11) relative to Scenario 7 results, which utilized lower average survival (Figure 3-10). However, these results indicate some (small) probabilities of extremely negative NPV values for the shrimp enterprise at all discount rate levels. These losses reflect the implications of multiple random kill and hurricane events over the 15-year production horizon. The significant financial losses are associated with headstart greenhouse damages sustained in the hurricane events and the resulting reconstruction costs for this production component. These extreme negative NPV values range from -$1,136,000 to -$882,000, however the probability of occurrence at these levels is less than 1%.

Summary

In summary, the various combinations of economic management and production risks including random kill and hurricane events contribute to the overall probabilities of economic success of the shrimp aquaculture investment. These combinations are summarized within 8 scenario permutations to determine the level of impact of exogenous variables on the spreadsheet model results.

- Deterministic Scenarios 1 and 2 considered stocking densities of 80 shrimp per m^2 and 100 shrimp per m^2, respectively. In both of these scenarios the point-estimate NPV of net cash flows were negative at -$462,401 and -$343,120, respectively. The negative NPV indicates that the shrimp aquaculture investment would require changes regarding baseline assumptions made within the spreadsheet model in order to become profitable. Reducing the capital costs required to build the shrimp production facility could improve the economic success of the enterprise as measured by NPV of net cash income.

- Stochastic Scenario 3 served as the first stochastic analysis of the shrimp investment to determine the probability levels of positive NPV values via a cumulative density function output. The vertical axis of the CDF represents the probability and allows the probability for certain values of NPV to be determined. 100% of the NPV values fell between -$450,000 and -$300,000 at a discount rate of 8%.

- Stochastic Scenario 4 changed the price premium amount received by the shrimp producers from $0.33 to $0.66 based on consumer willingness-to-pay a price premium of $2 per pound for fresh, never-frozen shrimp. The price premium translates into a $0.66 revenue margin for the producers based on the "Rule of Three" that is generally accepted in the restaurant industry regarding food costs. This "Rule of Three" states that "the amount charged for a food item must be at least three times the total cost of the ingredient" (Herbert, 1985). Although the probability of positive NPV values is 0 for this management strategy, increasing the price premium to $0.66 shifts the CDF function slightly to the right with NPV values falling between -$350,000 and -$225,000.

- Stochastic Scenario 5 examined the impact of reducing the capital (construction) costs by 50%. This management strategy assumes that the producer would be able to assemble the factors of production necessary to build the hypothetical production system for less than the cost of construction required for the FDACS and UF/ IRREC Commercial Scale Shrimp Demonstration Project (Wirth et al., 2004). The CDF results indicate that only a 2% probability of economic success is calculated by the spreadsheet model using an 8% discount rate. Additionally, there is a 50% chance that the NPV will be -$46,000.

- Stochastic Scenario 6 reduces the discount rate calculation for positive NPV probabilities. The baseline discount rate of 8% assumes a 5% interest rate comparable to a 30-day Treasury Bill (USDT, 2007), plus a 3% inflation premium assumption. Reducing the discount rate calculation effectively corresponds to increased levels of risk acceptance by the producer as the risk premium assumption is eroded. Although the probability of negative values of NPV exist for all discount rate calculations, positive probability values exist for discount rates ranging from 3% to 7%. However, a small probability of 5% exists for a negative NPV value of -$65,000 at the 7% discount rate.

- Stochastic Scenario 7 reduces the average survival rate from 80% to 70%. The reduction of survival rates significantly (and negatively) impacts the overall probability of economic success, as measured by the NPV of net cash income, for all discount rate calculations ranging from 3% to 8%.

- Stochastic Scenario 8 utilizes a 100 shrimp per m^2 stocking density, a $0.66 price premium, reduced capital costs, and average (80%) survival rates. This scenario also includes the impacts of random kill and hurricane probabilities. The net change of NPV probability values regarding the average survival rates (relative to Scenario Seven) and random kill and hurricane impacts indicates a relative increase in positive NPV probabilities.

The initial deterministic scenarios for the shrimp production system utilizing baseline assumption variables do not indicate positive NPV values (Scenario 1 and 2). However, by changing the baseline assumptions in the model to reflect higher stocking densities, a higher value-added price premium, lower capital costs, and average survival rates, the probability for positive NPV values increases for all discount rates considered from 3% to 8%. The addition of random kill and hurricane events reduces these positive NPV probabilities but does not completely eliminate the chance of economic success at every discount rate considered ranging from 3% to 8%.

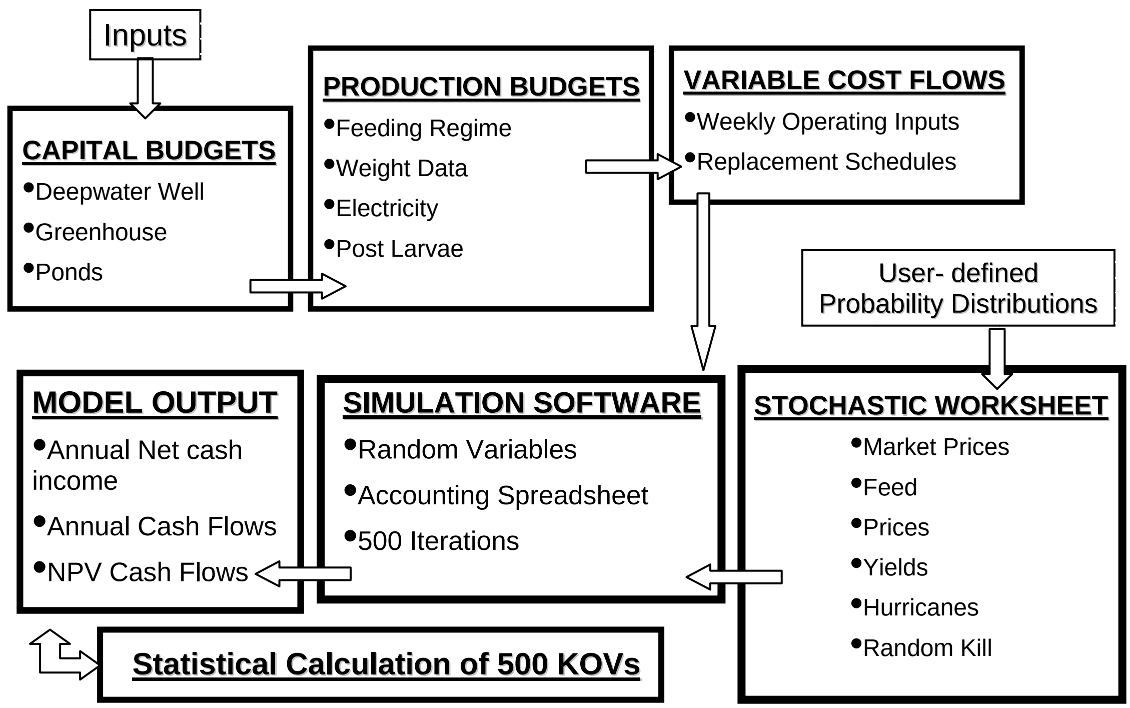

Figure 3-1. Flow chart of model component parts.

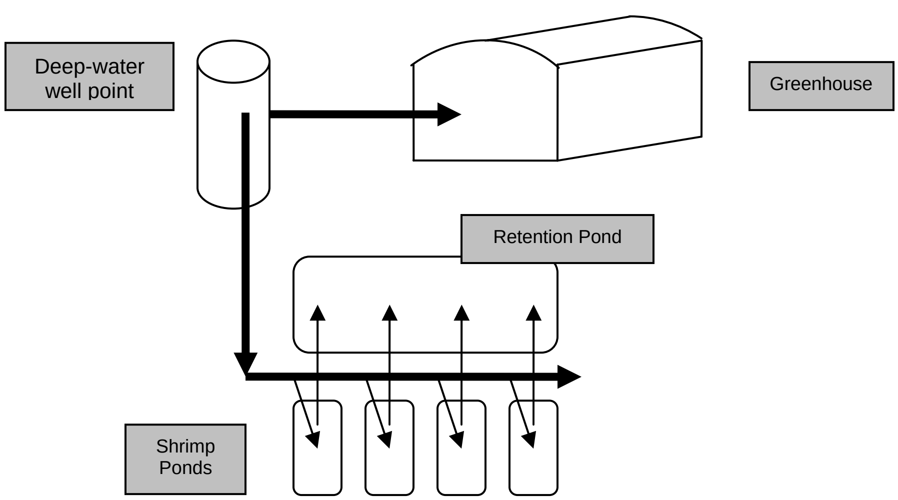

Figure 3-2. Low-salinity shrimp production system diagram.

Table 3-1. Capital costs for greenhouse.

Item	Amount ($)	Total (%)
Nursery Greenhouse Construction:	51,585	56.7
Greenhouse Electrical Installation:	10,982	12.1
Greenhouse Equipment General:	3,432	3.8
Water Testing & Shrimp Sampling Equipment	1,751	1.9
Greenhouse Equipment: Pumps & Motors	7,007	7.7
Nursery Transfer Equipment/ Supplies	1,403	1.5
Greenhouse Construction Labor:	14,800	16.3
Total	90,960	100

Table 3-2. Capital costs for four 0.29-acre ponds.

Item	Amount ($)	Total (%)
Engineering and Surveying:	12,329	3.1
Feed Storage Building	24,000	6.0
Well Construction:	62,920	15.6
Well Water Testing:	2,578	0.6
Emergency Generator:	25,531	6.3
Electrical Installation:	20,959	5.2
Earthmoving: Pond and Roadway Construction	96,899	24.0
Pond Liners and Installation:	49,849	12.4
Pond Electrical Installation:	13,904	3.4
Pond Construction Equipment:	7,623	1.9
Pond Construction Labor:	73,546	18.2
Pond Equipment: Paddlewheels	11,143	2.8
Pond Equipment: Water testing & shrimp sampling	1,751	0.4
Total	403,032	100.0

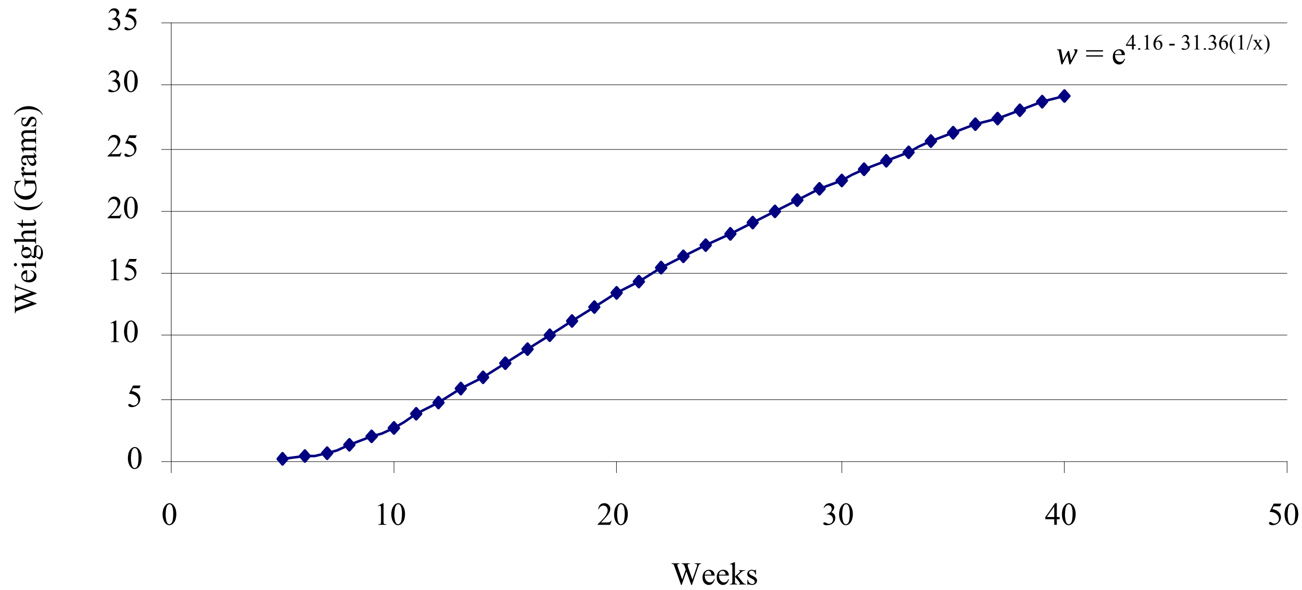

Figure 3-3. *L. vannamei* shrimp growout weight calculation.

Table 3-3. Inflation ratesfor inputs used in the model for years 2006-2021.

Year	Fuels	Supplies	Wage rates
2006	0.08	0.05	0.03
2007	-0.02	0.02	0.03
2008	-0.02	0.01	0.03
2009	-0.03	0.01	0.03
2010	-0.04	0.01	0.03
2011	-0.03	0.01	0.03
2012	-0.02	0.01	0.03
2013	0.02	0.02	0.02
2014	0.02	0.01	0.02
2015	0.01	0.02	0.02
2016	0.02	0.005	0.02
2017	0.03	0.011	0.02
2018	0.03	0.011	0.02
2019	0.04	0.011	0.02
2020	0.05	0.011	0.02
2021	0.05	0.011	0.02
R-Square	0.58	0.99	0.74
p-value	0.014	2.57E-09	0.001

Source: (FAPRI, 2006, for years 2007-2015)

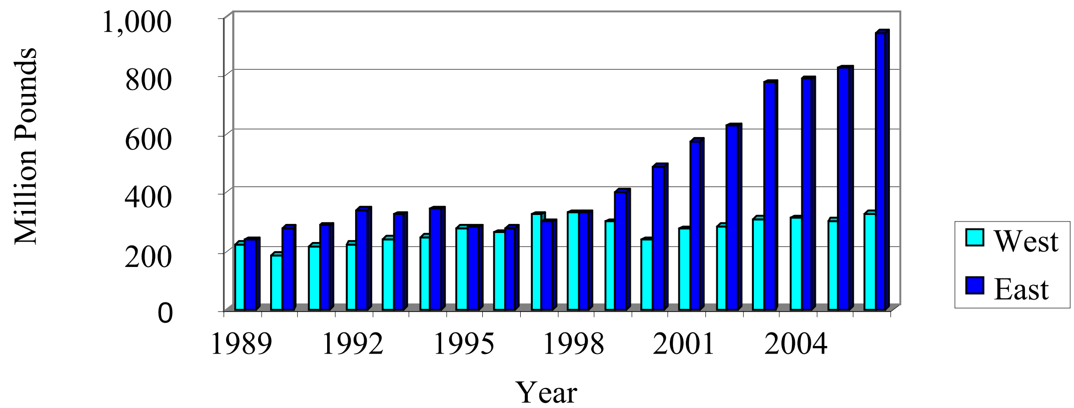

Figure 3-4. Shrimp imports (all product forms) by hemisphere for years 1989-2006. (Source: NMFS, 2007).

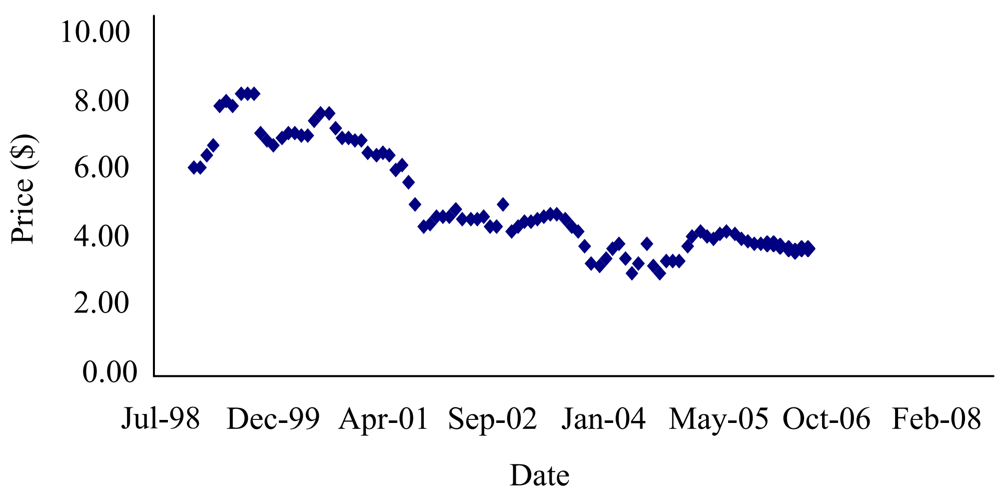

Figure 3-5. Retail (HRI) historical shrimp prices January 1999-August 2006 (31-35 tails/ lb). (Source: Comtell, 2006).

Table 3-4. Saffir-Simpson wind damage scale. Source: (NOAA, 2006).

Category	Damage	Windspeed (MPH)	Description
Tropical Storm	None or Minimal	39-73	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees.
Category 1	Minimal	74-95	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees.
Category 2	Moderate	96-110	Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers.
Category 3	Extensive	111-130	Some structural damage to small residences and utility buildings. Mobile homes and poorly constructed signs are destroyed.
Category 4	Extreme	131-155	Some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows.
Category 5	Catastrophic	>155	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage.

Table 3-5. Storm event probability and damage description for St. Lucie County.

Storm type	Probability (%)	Damage description
Tropical Storm	20	Plastic Cover of Greenhouse
Category 1 Hurricane	6	Plastic Cover of Greenhouse
Category 2 Hurricane	2	Greenhouse Structure + 2% Mortality

Table 3-6. Baseline variables for a five-acre shrimp farm investment.

Item	Value	Unit
Stocking Density Scenario One	80	m^2
Stocking Density Scenario Two	100	m^2
Survival Rate	80	%
Feed Conversion Ratio (FCR)	1.8 : 1.0	Pounds of feed : kilograms shrimp harvested
Discount Rate for NPV	8	%
Retail Price	4.20	$ per lb (tail-weight)
Local Markup Price Premium	0.33	$ per lb
PL Cost	11	$ per 1,000
Growout Feed Price	0.40	$ per lb of feed
Labor Cost	15	$ per hour

Table 3-7. Scenario 1 - Net cash income for a 5-acre shrimp farm investment at 80 shrimp per m^2 stocking density.

Income Statement	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Total Market Receipts		60,383	63,406	66,429	69,453	72,476	75,499	78,523
Greenhouse (GH) Expenses								
GH Construction Cost	90,960							
Post larvae		5,921	5,995	6,032	6,104	6,140	6,211	6,317
GH Feed		1,135	1,137	1,140	1,143	1,146	1,148	1,151
GH General Labor		3,552	3,651	3,748	3,841	3,933	4,022	4,091
GH Electrical		2,183	2,143	2,082	1,997	1,932	1,898	1,944
GH Harvest Labor		1,977	2,032	2,086	2,138	2,189	2,238	2,277
GH Supplies		1,353	940	1,253	1,084	1,286	985	1,455
Sum GH Construction Costs	90,960							
Sum GH Variable		16,121	15,898	16,341	16,307	16,626	16,502	17,235
(4) 0.29-acre Pond Expenses								
Pond Construction Cost	403,032							
Pond # 1 Feed		4,216	4,273	4,331	4,389	4,447	4,506	4,564
Pond # 2 Feed		4,216	4,273	4,331	4,389	4,447	4,506	4,564
Pond # 3 Feed		4,216	4,273	4,331	4,389	4,447	4,506	4,564
Pond # 4 Feed		4,216	4,273	4,331	4,389	4,447	4,506	4,564
Aerator Electrical		7,074	6,944	6,745	6,472	6,259	6,150	6,298
General Electrical		587	576	559	537	519	510	522
Ponds General Labor		19,350	19,350	19,350	19,350	19,350	19,350	19,350
Ponds Harvest Labor		2,160	2,160	2,160	2,160	2,160	2,160	2,160
Pond Supplies		1,671	1,692	1,702	8,445	1,852	1,753	8,739
Harvest Supplies		709	64	117	468	119	281	539
Recurring Annual		51	52	52	53	53	53	54
Sum Pond Construction Costs	403,032							
Sum Pond Variable		48,466	47,930	48,009	55,041	48,100	48,281	55,918
Carryover Loan Interest		0	876	1,472	1,896	2,897	2,982	2,693
Operating Loan		3,585	3,994	4,379	5,108	5,603	5,170	5,389
Total Expenses		68,172	68,698	70,201	78,352	73,226	72,935	81,235
Net Cash Income		-7,789	-5,292	-3,772	-8,899	-750	2,564	-2,712

Table 3-7. Continued.

Income Statement	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Total Market Receipts	81,546	84,569	87,592	90,616	93,639	96,662	99,685	102,709
Greenhouse (GH) Expenses								
GH Construction Cost								
Post larvae	6,386	6,489	6,518	6,583	6,648	6,712	6,775	6,838
GH Feed	1,154	1,157	1,159	1,162	1,165	1,168	1,170	1,173
GH General Labor	4,176	4,259	4,334	4,406	4,475	4,541	4,604	4,664
GH Electrical	1,989	2,022	2,069	2,130	2,206	2,296	2,400	2,518
GH Harvest Labor	2,324	2,370	2,412	2,452	2,490	2,527	2,562	2,595
GH Supplies	1,012	1,359	1,169	1,379	1,054	1,546	1,074	1,432
Sum GH Construction Costs								
Sum GH Variable	17,041	17,656	17,661	18,112	18,038	18,790	18,585	19,220
(4) 0.29-acre Pond Expenses								
Pond Construction Cost								
Pond # 1 Feed	4,623	4,682	4,742	4,801	4,861	4,921	4,981	5,042
Pond # 2 Feed	4,623	4,682	4,742	4,801	4,861	4,921	4,981	5,042
Pond # 3 Feed	4,623	4,682	4,742	4,801	4,861	4,921	4,981	5,042
Pond # 4 Feed	4,623	4,682	4,742	4,801	4,861	4,921	4,981	5,042
Aerator Electrical	6,443	6,550	6,703	6,903	7,148	7,438	7,775	8,157
General Electrical	534	543	556	573	593	617	645	677
Ponds General Labor	19,350	19,350	19,350	19,350	19,350	19,350	19,350	19,350
Ponds Harvest Labor	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160
Pond Supplies	1,802	1,831	9,017	1,858	1,876	9,285	1,912	1,930
Harvest Supplies	69	125	500	354	71	397	250	132
Recurring Annual	55	56	56	57	57	58	58	59
Sum Pond Construction Costs								
Sum Pond Variable	48,905	49,343	57,310	50,459	50,699	58,989	52,074	52,633
Carryover Loan Interest	2,998	2,184	1,003	298	0	0	0	0
Operating Loan	5,362	4,884	5,356	3,953	3,287	2,277	982	973
Total Expenses	74,306	74,067	81,330	72,822	72,024	80,056	71,641	72,826
Net Cash Income	7,240	10,502	6,262	17,794	21,615	16,606	28,044	29,883

Table 3-8. Scenario 2 - Net cash income for a 5-acre shrimp farm investment at 100 shrimp per m^2 stocking density.

Income Statement	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Total Market Receipts		75,479	79,258	83,037	86,816	90,595	94,374	98,153
Greenhouse (GH) Expenses								
Greenhouse Construction Cost	90,960							
Postlarvae		8,512	8,618	8,671	8,775	8,826	8,929	9,081
GH Feed		1,418	1,422	1,425	1,429	1,432	1,436	1,439
GH General Labor		3,552	3,651	3,748	3,841	3,933	4,022	4,091
GH Electrical		2,183	2,143	2,082	1,997	1,932	1,898	1,944
GH Harvest Labor		1,977	2,032	2,086	2,138	2,189	2,238	2,277
GH Supplies		1,353	940	1,253	1,084	1,286	985	1,455
Sum GH Construction Costs	90,960							
Sum GH Variable		18,995	18,806	19,265	19,264	19,598	19,508	20,287
(4) 0.29-acre Pond Expenses								
Pond Construction Cost	403,032							
Pond # 1 Feed		5,270	5,342	5,415	5,487	5,560	5,633	5,706
Pond # 2 Feed		5,270	5,342	5,415	5,487	5,560	5,633	5,706
Pond # 3 Feed		5,270	5,342	5,415	5,487	5,560	5,633	5,706
Pond # 4 Feed		5,270	5,342	5,415	5,487	5,560	5,633	5,706
Aerator Electrical		7,825	7,680	7,460	7,158	6,923	6,802	6,966
General Electrical		587	576	559	537	519	510	522
Ponds General Labor		19,350	19,350	19,350	19,350	19,350	19,350	19,350
Ponds Harvest Labor		2,160	2,160	2,160	2,160	2,160	2,160	2,160
Pond Supplies		2,046	2,072	2,085	8,832	2,241	2,147	9,140
Harvest Supplies		709	64	117	468	119	281	539
Recurring Annual		51	52	52	53	53	53	54
Sum Pond Construction Costs	403,032							
Sum Pond Variable		53,808	53,322	53,443	60,506	53,605	53,835	61,555
Carryover Loan Interest		0	154	0	0	0	0	0
Operating Loan		4,041	4,099	4,033	4,207	4,054	2,843	2,202
Total Expenses		76,844	76,381	76,741	83,977	77,257	76,186	84,044
Net Cash Income		-1,365	2,877	6,296	2,839	13,338	18,188	14,109

Table 3-8. Continued.

Income Statement	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Total Market Receipts	101,932	105,711	109,490	113,269	117,049	120,828	124,607	128,386
Greenhouse (GH) Expenses								
Greenhouse Construction Cost								
Postlarvae	9,180	9,327	9,369	9,463	9,556	9,648	9,739	9,829
GH Feed	1,442	1,446	1,449	1,453	1,456	1,460	1,463	1,466
GH General Labor	4,176	4,259	4,334	4,406	4,475	4,541	4,604	4,664
GH Electrical	1,989	2,022	2,069	2,130	2,206	2,296	2,400	2,518
GH Harvest Labor	2,324	2,370	2,412	2,452	2,490	2,527	2,562	2,595
GH Supplies	1,012	1,359	1,169	1,379	1,054	1,546	1,074	1,432
Sum GH Construction Costs								
Sum GH Variable	20,123	20,783	20,802	21,283	21,237	22,018	21,842	22,504
(4) 0.29-acre Pond Expenses								
Pond Construction Cost								
Pond # 1 Feed	5,780	5,854	5,928	6,002	6,077	6,152	6,227	6,303
Pond # 2 Feed	5,780	5,854	5,928	6,002	6,077	6,152	6,227	6,303
Pond # 3 Feed	5,780	5,854	5,928	6,002	6,077	6,152	6,227	6,303
Pond # 4 Feed	5,780	5,854	5,928	6,002	6,077	6,152	6,227	6,303
Aerator Electrical	7,127	7,245	7,414	7,635	7,906	8,227	8,600	9,023
General Electrical	534	543	556	573	593	617	645	677
Ponds General Labor	19,350	19,350	19,350	19,350	19,350	19,350	19,350	19,350
Ponds Harvest Labor	2,160	2,160	2,160	2,160	2,160	2,160	2,160	2,160
Pond Supplies	2,207	2,242	9,430	2,275	2,297	9,711	2,341	2,363
Harvest Supplies	69	125	500	354	71	397	250	132
Recurring Annual	55	56	56	57	57	58	58	59
Sum Pond Construction Costs								
Sum Pond Variable	54,622	55,137	63,178	56,412	56,742	65,128	58,312	58,976
Carryover Loan Interest	0	0	0	0	0	0	0	0
Operating Loan	1,248	0	0	0	0	0	0	0
Total Expenses	75,993	75,920	83,980	77,695	77,979	87,146	80,154	81,480
Net Cash Income	25,939	29,791	25,510	35,574	39,070	33,682	44,453	46,906

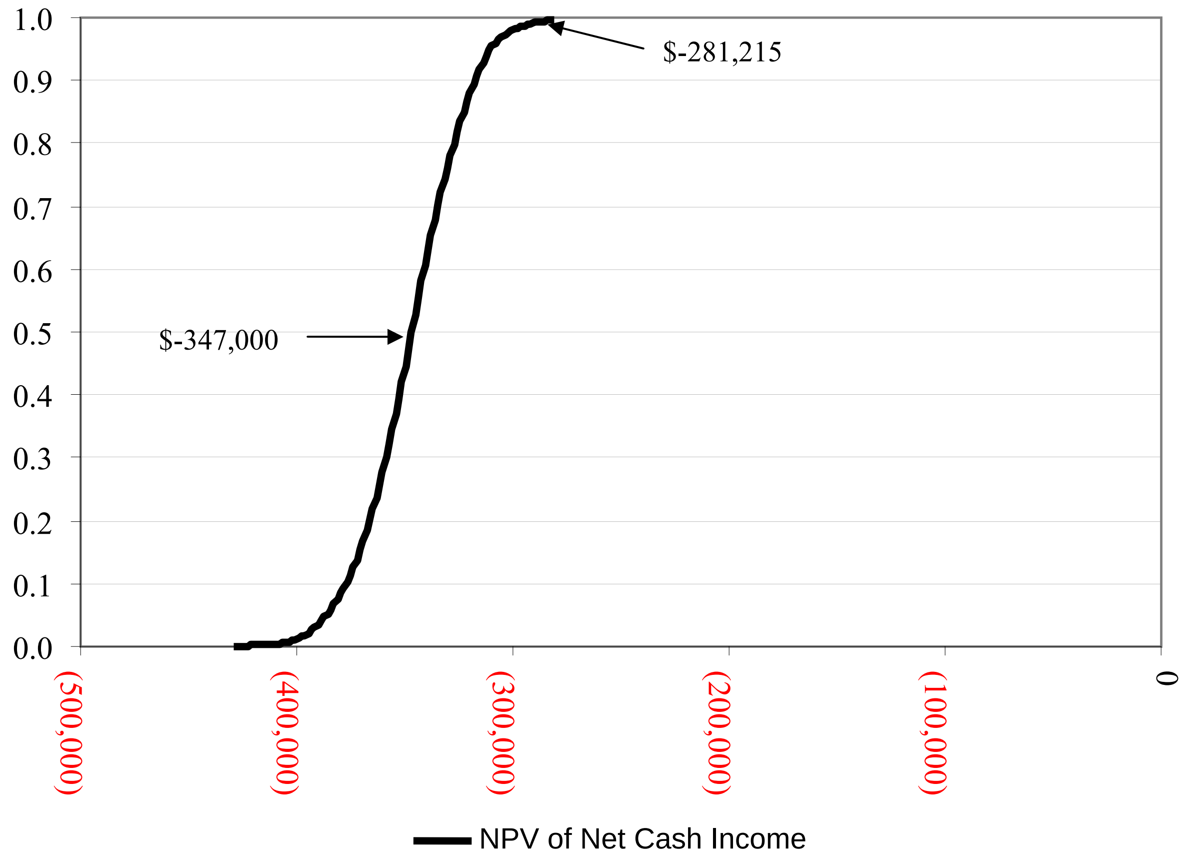

Figure 3-6. Scenario 3 – CDF of net present value of net cash income with 100 shrimp per m^2 stocking density.

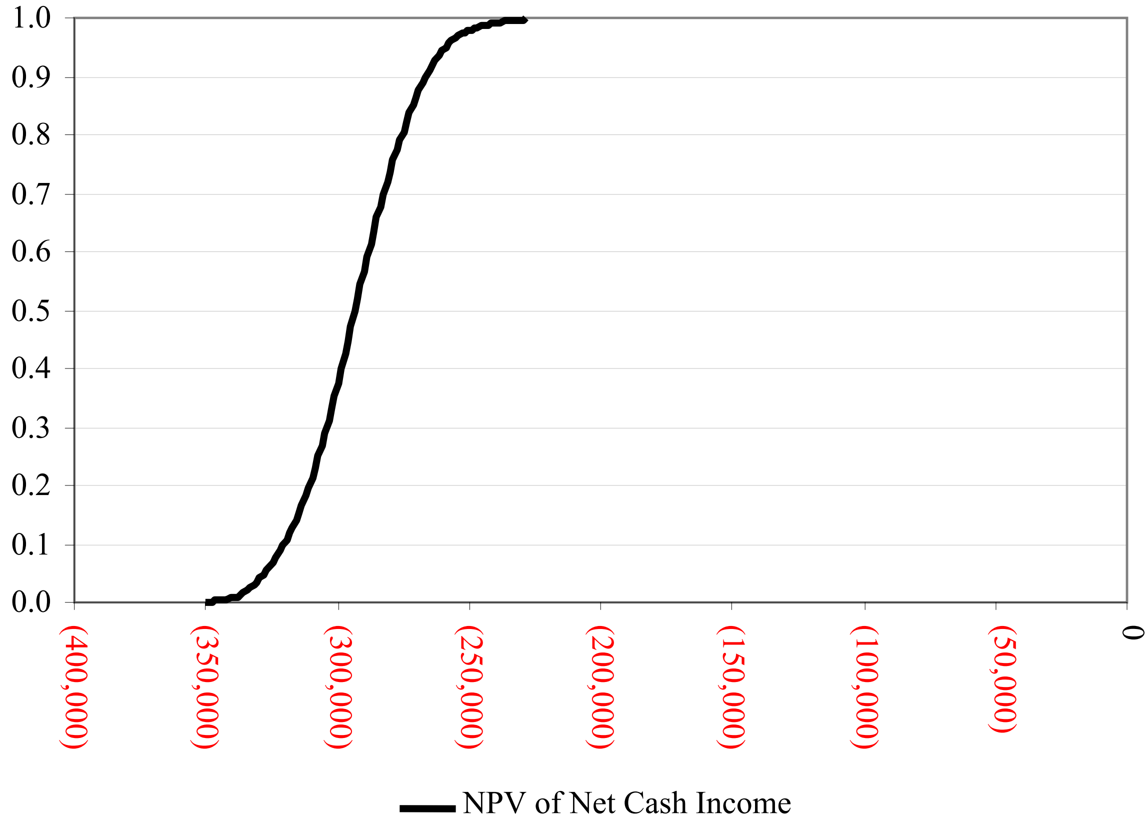

Figure 3-7. Scenario 4 –CDF of net present value of net cash income with $0.66 price premium.

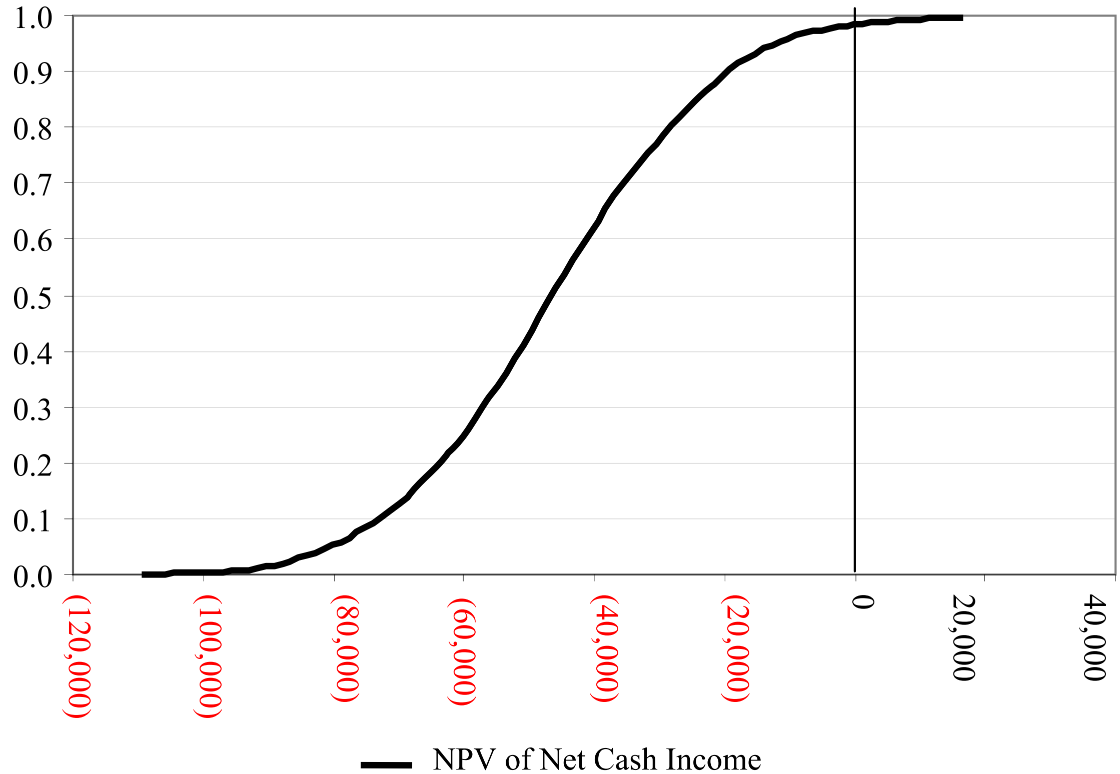

Figure 3-8. Scenario 5 – CDF of net present valued of net cash income with 50% reduced capital costs.

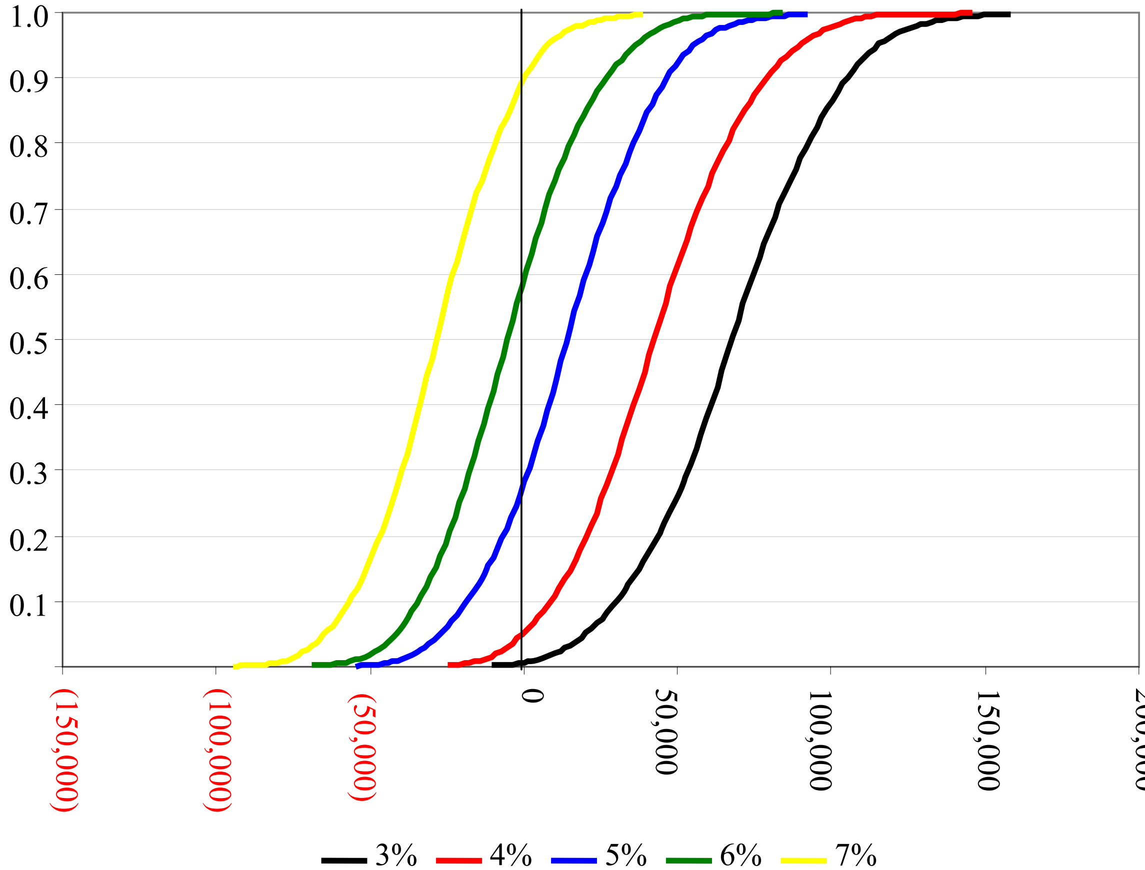

Figure 3-9. Scenario 6 – CDF of net present value of net cash income at varying discount rates.

Table 3-9. Scenario 6 - Probability values for calculated discount rates ranging from 3% to 7% and corresponding 50% NPV values.

Discount rate (%)	Positive NPV probability (%)	NPV of net cash income 50% probability ($)
3	99	66,198
4	94	52,785
5	72	52,785
6	39	2,300
7	9	(39,502)

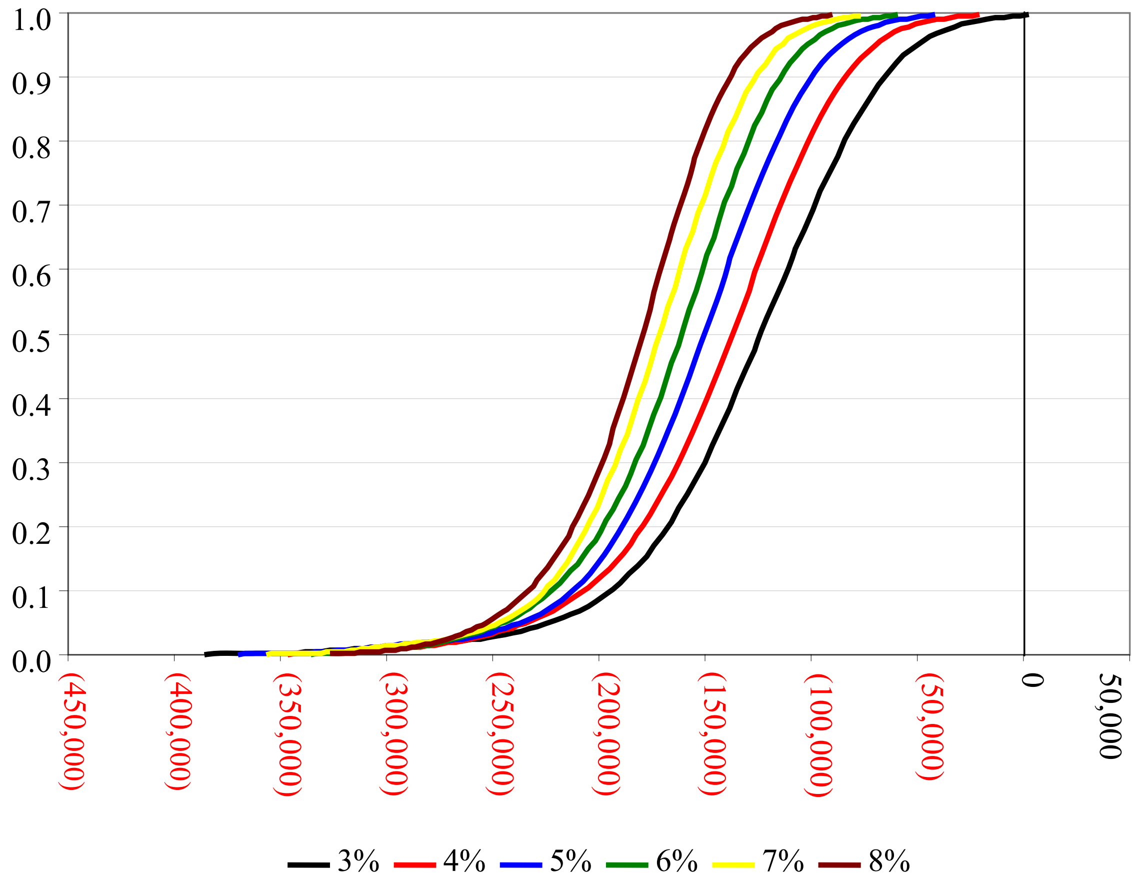

Figure 3-10. Scenario 7 – CDF of net present value of net cash income with reduced shrimp survival at varying discount rates.

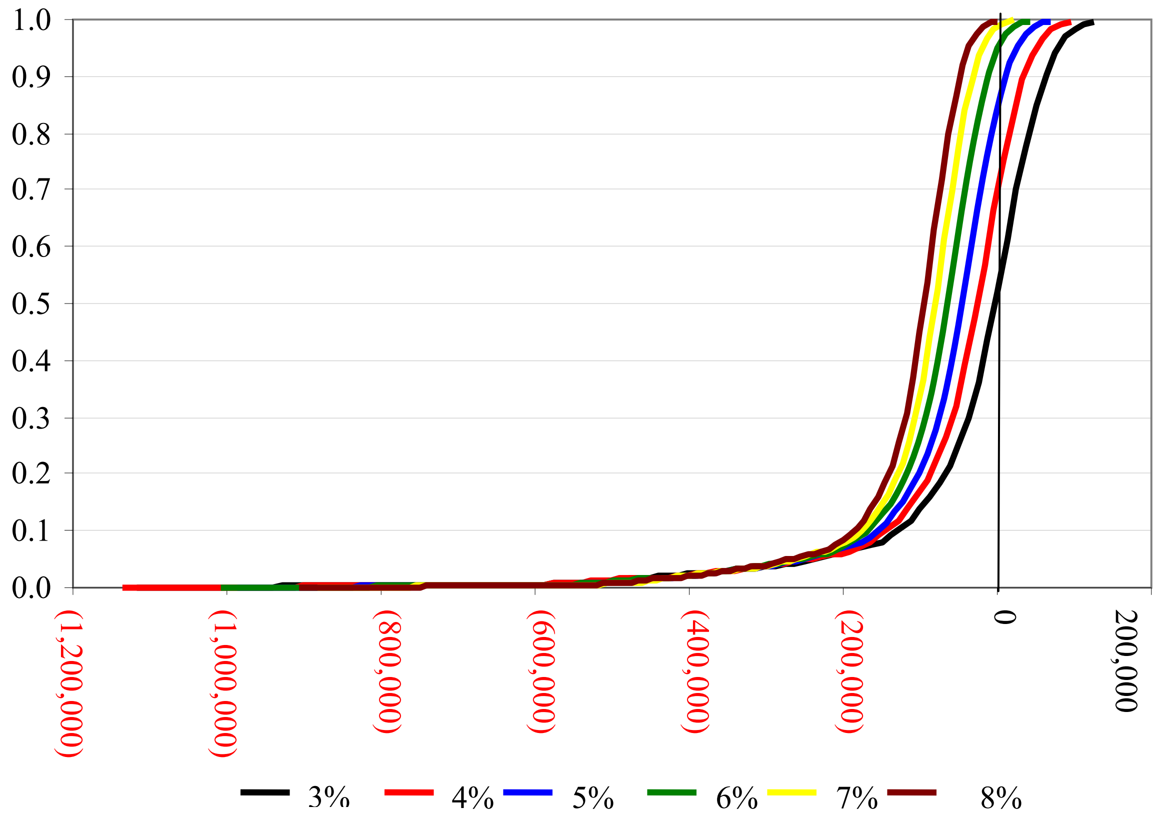

Figure 3-11. Scenario 8 – CDF of net present value of net cash income with random kill and hurricane events at varying discount rates.

CHAPTER 4
PROBABILISTIC FINANCIAL ANALYSIS FOR TWO AGRICULTURAL ENTERPRISES: APPLICATION FOR A GRAPEFRUIT & SHRIMP DIVERSIFICATION STRATEGY

Introduction

Grapefruit producers in Florida have been exposed to multiple production risks recently. These producers have been particularly affected by the landfall of four hurricanes during the 2004 hurricane season that drastically reduced fruit yields and facilitated the spread of citrus canker disease. In addition to the hurricanes' immediate impact on 2004-2005 grapefruit yields, the protocols for a state-mandated Citrus Canker Eradication program (CCEP) resulted in thousands of citrus acres being eradicated in an attempt to control the disease. Although the CCEP was halted in January 2006 (White & van Blokland, 2006), a reduction in tree health and vigor are expected to be long-term impacts resulting from the spread of disease. The resulting short and long-term financial uncertainty emanating from the 2004-2005 hurricane season has begged the question of risk-management alternatives for grapefruit producers.

A crop diversification strategy has important financial implications for producers seeking to mitigate production and price risks associated with a grapefruit-only production strategy. This risk management strategy decreases the producer's exposure to risk if activities are selected that tend to have good and poor performance in different years (Olsen, 2004). Diversification seeks to reduce the dispersion of overall returns by combining activities that are low or negatively correlated. These correlations may include financial implications associated with disease or pest incidents, weather events, or input and market prices (Hardaker et al., 2004). Low-salinity shrimp aquaculture production has been discussed by many grapefruit producers as a diversification strategy. However, the lack of financial data required for an economic analysis has impeded further consideration of this diversification strategy.

The mitigation of production risks gained through diversification is dependent upon the degree of production and price correlation between the crop enterprises under consideration; negative correlations can mitigate variability of potential returns to the producer over time (Olsen, 2004). Returns from traditional agricultural crops typically demonstrate a strong positive correlation due to similar production and marketing parameters including weather and rainfall events, as well as input prices, and market prices. Shrimp production, as a diversified cropping strategy for grapefruit producers, suggests low or negatively correlated returns due to dissimilarities in production practices, input and output price trends, and harvest schedules. Market prices for shrimp and grapefruit exhibit properties of a moderate negative correlation, as indicated by a Pearson-product-moment correlation of -0.47.

Problem Setting

The producer's diversification problem regarding a specific multi-cropping strategy takes on many of the analytical aspects traditionally used by financial investors facing a portfolio selection problem (Johnson, 1967). Portfolio selection seeks to determine if the variability in expected returns from a grapefruit-only producing enterprise can be abated via a diversification investment in low-salinity shrimp aquaculture. The expected value and variability of the discounted net present value of cash flows and annualized net cash income are determined through a farm-level aquaculture simulation model developed in Microsoft Excel®. The simulation software, Simetar©, can run stochastically to pattern the annual income statements, cash flows, and other financial information including discounting the net present value (NPV) of cash flows (Richardson et al., 2004) for the grapefruit enterprise, the shrimp enterprise, and a combination grapefruit/ shrimp enterprise. The enterprise scenarios under consideration in the model include: a five-acre shrimp-only investment, a fifty-acre grapefruit-only investment, and a fifty-acre combined grapefruit (45-acre) and shrimp (5-acre) investment.

Due to the inclusion of stochastic variables defined for this model, additional information exists for the decision maker when risk is considered to be part of the decision-making process. This study discusses results from the spreadsheet model as both a portfolio selection problem and as a stochastic simulation problem. The additional risk information provided within the findings of a stochastic probability solution includes financial impacts associated with forecasted financial consequences from hurricane events. The analysis contains results with respect to three cropping scenarios: a grapefruit-only investment, a shrimp-only investment, and a combined grapefruit/ shrimp investment. The portfolio selection approach is presented first, followed by the stochastic probability solution.

Portfolio Selection Problem

Microeconomic theory suggests that a profit-maximizing firm chooses inputs and outputs with the sole consideration of maximizing profit (Nicholson, 2002). In a portfolio analysis context, however, this hypothesis fails to consider diversification benefits that may reduce risk exposure to the investor regarding income variability over time (Markowitz, 1952). Portfolio selection for the agricultural producer makes the assumption that minimizing the variability (variance) of overall returns of an enterprise mix, at an acceptable expected return, would be preferred to potentially higher profits at higher probabilities of financial loss. Ideally, it is purely theoretical that all variance can be eliminated and realistically the investor can gain expected return by taking on variance, or reduce variance by giving up expected return (Markowitz, 1952). The mean-variance (EV), or efficiency rule, is a method of decision analysis that can be used in third-party model development when the producer's risk preferences are unknown (Hardaker et al., 2004). This rule allows the producer to examine the expected returns and variance associated with an enterprise mix to determine acceptable profits that may accrue with a diversification strategy.

Agricultural investors using EV for portfolio selection can utilize the suggested steps (Markowitz, 1952; Sharpe, 1963) to utilize EV for portfolio selection purposes:

Step 1) Make a probability estimate of future performances of each investment enterprise,
Step 2) Analyze the estimates to determine an efficient set of selected enterprises, and
Step 3) Select from that set the choice that best suits each investor's risk preferences

Farm decision makers are generally assumed to be risk averse in this analysis; however, risk preferences and utility theory (Step 3) are not addressed in this analysis. The portfolio analysis of the investment enterprises under consideration in this study illustrates Step 1 and Step 2 in considering the expected performance of a shrimp-only investment, a grapefruit-only investment, and a combined shrimp and grapefruit investment. The potential EV results for the cropping combinations may be illustrated geometrically on the expected value and variance axis relative to the efficient frontier (Figure 4-1). The efficient frontier would be located at a point where expected values are relatively high and the variability of returns are relatively low.

Stochastic Simulation Problem

The steps used to create the stochastic model used for this analysis are based on the modeling technique developed for using probabilistic cash flows to incorporate risk into financial decisions (Richardson & Mapp, 1976).

- The first step in quantifying the risky elements associated with an enterprise investment is to identify the critical, stochastic variables that are expected to influence the success or failure of the investment over the planning horizon. These stochastic variables are defined as uncertain quantities within a definite range of values that can be attained within a defined probability distribution (Uspensky, 1937). A mathematical (often, a least-squares estimate) equation is used to generate a deterministic forecast equation of the critical variables.

- In the second step, a probability distribution for these stochastic variables is defined by the sample set of historical trend data.

- The third step is to link the probability distribution to a forecast of the stochastic variable mathematical (often econometric) equation. For example, the yield for grapefruit can be forecast via a least squares estimate using historical yield data and a probability distribution that is defined by the historical data.

- The fourth step is to link the defined stochastic variables to a financial accounting framework for the proposed investment.

The Simetar© software utilizes a stratified sampling technique known as a Latin-hypercube sampling procedure (Inman et al., 1981) that is efficient in selecting random variables from the cumulative density function of the stochastic variable distribution. The Latin hypercube sampling procedure segments the probability distribution into *n* components, with *n* being the number of iterations used, to ensure that all portions of the distribution are sampled. This procedure has advantages over the Monte Carlo sampling technique that randomly selects values from the probability distribution, thereby over-sampling the means, while under-sampling the tails (Richardson, 2006). During repeated sampling in an iterative process, this procedure avoids clustering and ensures that all areas of the probability distribution are considered (Richardson, 2006).

Through this iterative procedure ($n = 500$), the accounting formulas are calculated by means of random sampling of the probability distributions (Anderson, 1974) to produce financial outcomes such as net cash income or net present value. The financial outcomes are called Key Output Variables (KOVs) and are the variables being considered as a measure of risk in the analysis. The iterations represent 500 individual states of nature: each being one solution that generates a value for the key output variables in the model (Richardson, 2006). From the iterated output, simple statistics describe the probabilities of economic success in terms of NPV of net cash income and annual net cash incomes for each investment scenario under consideration. In essence, the risk associated with this procedure is reduced into a single variable (Richardson, 1976).

Model Development

Shrimp Production System

The framework for modeling a hypothetical low-salinity shrimp production system is based on the University of Florida/ Indian River Research and Education Center (UF/ IRREC) Shrimp Demonstration Project. In 2003, Florida Department of Agriculture and Consumer Services (FDACS) funded a commercial-scale shrimp demonstration project constructed at the UF/IRREC site in Ft. Pierce, Florida. With the assistance of a project manager, researchers were commissioned to build and operate a commercial-scale shrimp demonstration facility utilizing low-salinity groundwater. The findings of this two-year demonstration project chronicled the farm design, cost considerations, production processes, and marketing environment for the production and harvest of market-size *L. vannamei* shrimp in four low-salinity ponds located in South Florida (Wirth et al., 2004). Based on the information provided in the Final Project Report for the SDP, the revenues and expenses for a hypothetical 5-acre, low-salinity shrimp aquaculture production system were assembled into a series of financial accounting spreadsheets for the purpose of estimating future cash flows for this investment.

For the purposes of this study, the minimum size shrimp culture facility investment is five acres, which includes four plastic-lined production ponds, a nursery headstart greenhouse, and a retention pond area. A portion of the surrounding area is used as a source of fill material to increase the elevation of the ponds above the local water table. The area used for fill is assumed to be rendered as a wetlands area due to water intrusion from the high water table in the St. Lucie County area. Although one five-acre parcel is denoted as a minimum "unit" of production, results will be given for a per acre basis.

. The original capital costs were derived from the FDACS-sponsored commercial-scale shrimp demonstration project (SDP) at UF/IRREC in Ft. Pierce, Florida. The capital costs for the SDP production system totaled $493,993 with specific costs of $90,961 for the headstart greenhouse and $403,032 for the four-pond production system. Assuming that a grapefruit producer considering a shrimp aquaculture investment has access to idle factor inputs (such as labor and equipment), the access to capital inputs may lead to cost efficiencies during the construction process. Considering that the $493,993 capital outlay for the SDP in Ft. Pierce was the result of a state-sponsored allocative process via contract basis, a privately-sponsored construction effort would likely incur a capital cost less than this amount. The portfolio analyses in this study assume a 50% reduction of the SDP capital costs. The capital costs assumed for the portfolio analyses in this study total $246,997 to build a headstart greenhouse and four-pond production system. The specific UF/ IRREC costs are detailed in Appendix A and B. No initial cash reserves are assumed for the shrimp production enterprise as operating loans cover cash shortfalls at a 9.25% interest rate. Production acreage is valued at $17,000 (Connelly, 2007) in the spreadsheet model and assumed to be owned by the investor; no land rental rates apply. The expected values of calculated variable costs for the shrimp production enterprise (per pound of tails) over the 15-year planning horizon are given in Table 4-1.

Shrimp production is assumed to take place within the Indian River production region of Florida, which is a major grapefruit-producing area. The one-crop production period of thirty-five weeks in the model corresponds to four weeks of greenhouse head start and thirty-one weeks of pond production for a 25-gram whole shrimp. Pond stocking is assumed to occur in April with harvest in November. The product form of harvested shrimp is fresh (head-on), while the size class approximately corresponds to 31-35 tail count shrimp. The non-processed, whole-shrimp product is assumed to be direct marketed to local restaurants in Florida.

Grapefruit Production System

Commercial grapefruit production in Florida ranges from a few small parcels to groves consisting of thousands of acres. The representative size of the grapefruit grove used in this analysis is assumed to be 50 acres and is representative of a small land-holder proprietorship in Florida (Skvarch, 2007). The production acreage is valued at $17,000 (Connelly, 2007) in the spreadsheet model and assumed to be owned by the investor; no land rental rates apply. The land value of the 50 acre grove is $850,000. No initial cash reserves are assumed for the grapefruit enterprise as operating loans cover cash shortfalls at a 9.25% annual interest rate.

The elements used to construct the grapefruit portion of the spreadsheet accounting model incorporate budget data published by the University of Florida's Citrus Research and Education Center (UF/ CREC) in Lake Alfred, Florida. The grapefruit budgeting cost and return data for the Indian River production region of Florida is developed from survey data collected from custom operators, input suppliers, growers, and scientists at the UF/ CREC and UF Indian River Research and Education Center in Ft. Pierce, FL (UF/ IRREC) (Muraro & Hebb, 2005). The variable cost data included in the spreadsheet model for a 50-acre, custom-managed grapefruit grove includes fertilizer, herbicide, pruning, irrigation and drainage, management, and harvest costs (Table 4-2).

Forecast of the Critical Variables

In the financial spreadsheet model, risk can be quantified by examining critical variables that significantly influence the variability of cash flows for each enterprise under consideration. Exogenous variables that are considered to be stochastic in the model include shrimp and grapefruit yield, shrimp and grapefruit market prices, shrimp feed prices, shrimp random kill events, and hurricane events. Grapefruit price and yield estimates were forecasted by economic researchers with the Florida Department of Citrus (FDOC, 2007). A $0.66 price premium is added to the forecasted shrimp prices calculated in the spreadsheet model. This price premium is based on consumer willingness-to-pay up to an additional $2 per pound for fresh, never-frozen shrimp (Davis & Wirth, 2001). A direct-marketing strategy to Florida restaurants utilizes the food cost principle of the "General Rule of Three" to calculate premium benefits received by the producer. This principle is simply stated as, "the amount charged for a food item must be at least three times the total cost of the ingredient" (Herbert, 1985). Based on this information, benefits to the producer are derived by using a 33% food cost percentage (of the $2 additional consumer price charged by the restaurant operator) that computes a $0.66 price premium for the fresh, never-frozen shrimp aquacultured shrimp product.

Average shrimp yields were estimated by a shrimp consulting service (Manzo, 2006). Random kill events were forecasted from estimations within aquaculture stochastic modeling literature (Griffin & Thacker, 1994). Hurricane event estimates were forecasted via a historical archive of storm wind data (NOAA, 2006). The future shrimp market prices and shrimp feed prices were extrapolated via least-squares estimates using historical time series data, assuming that future variability is similar to the historical variability as revealed by Equation 4-1

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x + \hat{\varepsilon} \tag{4-1}$$

where, $\hat{y}$ is an estimate of the dependent variable, $\hat{\beta}_0$ is the intercept estimate, $\hat{\beta}_1$ is an estimate of the slope coefficient, x is the independent variable, and $\hat{\varepsilon}$ is the prediction error estimate of unexplained variability of the critical variable.

This classic least-squares method chooses β_0 and β_1 to minimize the prediction error given in Equation 4-2 (Ott & Longnecker, 2004):

$$\hat{\varepsilon} = \Sigma(y_i - \hat{y}_i)^2 = \Sigma[y_i - (\hat{\beta}_0 + \hat{\beta}_1 x_i)]^2 \tag{4-2}$$

where, y_i is the observed variable and $\hat{y}_i$ is the predicted variable (Figure 4-2).

Forecast of Stochastic Distributions

When operating in the deterministic mode, the software calculates the least-squares estimates that minimize the error terms of all formulated equations in the spreadsheet accounting model. The deterministic mode generates the best linear prediction (expected value) of all formulated variables for an NPV output calculation. However, when the software mode is changed from deterministic to stochastic mode, the error term and its assigned probability distribution are then calculated as random variables (Table 4-3). The variability (error term) of the historical data is then used as an additional component to the least-squares equation formulas.

The stochastic forecasting procedure using the Simetar© software is two-fold. First, future grapefruit and shrimp prices and grapefruit yields are estimated via least-squares regression. Second, the probability distributions are then determined via an empirical distribution function from the historical data. For example, the GRKS probability distribution used to model shrimp yields, utilizes three user-defined data points (minimum: 0.70, mode: 0.80, and maximum: 0.90) to independently calculate the harvest yield for each of the four production ponds (Richardson et al., 2006). The three data points used as yield estimates reflect anecdotal yield results provided by a shrimp consulting service (Manzo, 2006). The probability of a random kill event occurring in a single pond is assumed to be 6% of the standing crop per pond (Griffin & Thacker, 1994). When a pond experiences a random kill, the GRKS distribution for the mortality ranges from 50% -75% as defined by the data points (minimum: 0.50, mode: 0.625, and maximum: 0.75) (Manzo, 2006). The hurricane probabilities were calculated from an archived hurricane windspeed database with results indicating a 6% probability of tropical storm or category 1 hurricane impacting the St. Lucie County area of Florida and a 2% probability of a category 2 hurricane impact based on the Saffir-Simpson Hurricane Scale (NOAA, 2006). The probability of hurricane occurrence is calculated in the stochastic mode via a discrete empirical probability.

Expected Value Calculation

The expected value and variance of the Key Output Variables (KOVs) (e.g. net present value of net cash income and annual net cash income) can be plotted on the EV axis as an illustration of the investment risk associated with an investment in each enterprise strategy under consideration. The calculation of each KOV is illustrated in equations 4-3 and 4-4 (Higgins, 2004)

$$NPV = \sum_{t=0}^{n} \frac{C_t}{(1+r)^2} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^2} - C_0 \tag{4-3}$$

where, NPV is net present value of cash flows , C is cash flows, t is time, n is the investment horizon of 15 years, and r is the baseline discount rate of 5%. Depreciation is not included in the net cash income calculation. Net cash income represents cash available to farm operators to meet expenses and debt payments (USDA, 2003). An initial capital (construction) investment is assumed to occur in $t = 0$ for the shrimp investment. This capital investment is calculated as a negative value at time zero.

$$NI = \sum_{t=1}^{15} TR - (FC - VC) \tag{4-4}$$

where, NI is net cash income, FC are fixed cash costs, and VC are variable costs (cash operating costs).

When the software operates in the deterministic mode, the calculated value of each stochastic variable is the central expected value that is defined by the probability distribution assigned to that variable (Richardson, 2006). These expected values are calculated to be either 1) the mean for empirical distributions (grapefruit prices, grapefruit yields, shrimp prices, and shrimp feed prices), 2) the mode for GRKS distributions (shrimp yields and random kill mortality), or 3) the weighted probability of occurrence for the discrete empirical estimation (hurricane events). The expected value for the stochastic variables, as explained by Uspensky (1937) in Equation 4-5, assumes that a stochastic variable possesses n values ($x_1, x_2 \ldots x_n$) and ($p_1, p_2 \ldots p_n$) denotes the respective probabilities (p_i) of x. By definition, the mathematical expectation of $E(x)$ is

$$E(x) = p_1 x_1 + p_2 x_2 + \ldots p_n x_n \tag{4-5}$$

The variability of the NPV of net cash income and annual net cash incomes for each enterprise is measured via the coefficient of variation (C.V.) to account for the scale discrepancy between the representative grapefruit and shrimp investments. Using the C.V. as a standardized measure of variability gives results as a percentage of the mean of NPV values for each enterprise (Finney, 1980) as illustrated in Equation 4-6

$$C.V. = \frac{\sigma}{\bar{y}} * 100 \tag{4-6}$$

where, σ is the standard deviation and $\bar{y}$ is the mean of the NPV calculation. The C.V. is calculated via the scenario simulation of each enterprise; however, in the EV portfolio analysis the random kill and hurricane probabilities are not included in the calculations.

The results of the NPV calculations from the spreadsheet model are illustrated graphically in a portfolio analysis context. The returns for each enterprise investment are presented as an expected value calculation and the variability of each enterprise is measured by the coefficient of variation. The results of the NPV calculations in the portfolio analysis are presented on a per acre basis for the three investment scenarios. Shrimp, grapefruit, and combined shrimp and grapefruit enterprises are illustrated graphically according to the traditional portfolio analysis concept.

Stochastic Probability Calculations

In the stochastic setting, the simulation results of the KOV calculations are presented as probabilities of occurrence. The introduction of uncertainty transforms net returns from a single value to a probability distribution related to stochastic variables affecting the proposed investment (Richardson & Mapp, 1976). Simulated results are presented as a cumulative density function of the net present value of net cash income for each investment strategy.

Results

Per acre NPV of net cash income for the three investment scenarios indicate that the mean calculation for the grapefruit investment ($17,864) is greater than the mean for shrimp investment ($3,505) (Figure 4-3). Additionally, the coefficient of variation for the shrimp investment (151) is greater than the coefficient of variation for the grapefruit investment (20). The diversified (combined) enterprise investment return NPV calculation ($16,491) is less than the grapefruit-only investment. Portfolio selection for the agricultural producer makes the assumption that minimizing overall return variability via a diversified crop mix, at an acceptable return, would be preferred to potentially higher profits at higher probabilities of financial loss. However, no benefits of diversification appear to accrue to the investor from a combined shrimp-grapefruit enterprise due to the lower returns and higher variability associated with the shrimp investment.

Model output is presented as a cumulative probability density function (CDF) for the NPV net cash income for each of the investment scenarios (Figure 4-4). The CDF for the shrimp investment reveals a 72% probability that the NPV will be positive. The CDF for the grapefruit and combined grapefruit/ shrimp enterprise investments both produce 100% probabilities of positive NPV values for the 15-year planning horizon. Additionally, the relatively large slope of the shrimp enterprise CDF in comparison to the smaller slope for the grapefruit and combined enterprise CDF is indicative of a wider range of potential NPV values on the horizontal axis at every probability on the vertical axis. The larger ratio corresponds to a higher variability (C.V.) in NPV calculations that was illustrated in the portfolio analysis (Figure 4-3).

Summary

This paper discusses two different approaches to analyzing the diversification decision facing Florida grapefruit producers regarding the investment decision of shrimp aquaculture. This study utilizes the capabilities of stochastic simulation software in an accounting spreadsheet framework. The stochastic mode considers the probability of financial performance, as measured by a CDF of the NPV of net cash income, for a shrimp enterprise, a grapefruit enterprise, and a combined shrimp and grapefruit enterprise.

The portfolio approach strategy examines the relative trade-off between the expected returns per acre, as measured by the NPV net cash income, and variability of returns, as measured by the coefficient of variation, for each enterprise mix. The calculated discount rate is 5% which is a rate that is comparable to the risk-free return on U.S. Treasury Bills without risk or inflation premium. At higher discount rates the shrimp aquaculture investment is not considered to be economically successful as measured by probability of positive NPV of net cash income. The per acre expected value of NPV of net cash income for the shrimp, grapefruit, and combined shrimp and grapefruit enterprises are $3,505, $17, 864, and $16,491, respectively. The expected return on the grapefruit investment reflects FDOC grapefruit price forecasts which considered yields reductions within this industry as a result of the 2004 hurricane season. The forecasts indicate higher prices for grapefruit (relative to previous years) due to supply shocks within the marketplace. Based on the expected value of NPV for each investment, the grapefruit scenario returns the highest per acre discounted dollar value for the investor.

Additionally, benefits may accrue to the investor in a diversification strategy if the expected return variability from a crop investment can be minimized with the addition of a second crop. However, the variability of expected returns (measure by the coefficient of variation) of the shrimp investment at 151 is higher than the grapefruit variability of 20 and a combined shrimp/ grapefruit cropping strategy increases the overall variability to 22 for the diversified crop mix. The results of the side-by-side returns for each enterprise investment indicate that the investment in a shrimp investment would be a counterproductive investment strategy for Florida grapefruit farmers, based on model assumptions. The results of the diversification strategy using a portfolio approach indicates that shrimp aquaculture returns a lower expected value of net cash returns and a higher variability of those returns compared to the grapefruit investment. Therefore, the portfolio analyses indicate no positive benefits associated with a shrimp aquaculture investment by Florida grapefruit producers using the assumptions outlined in this study.

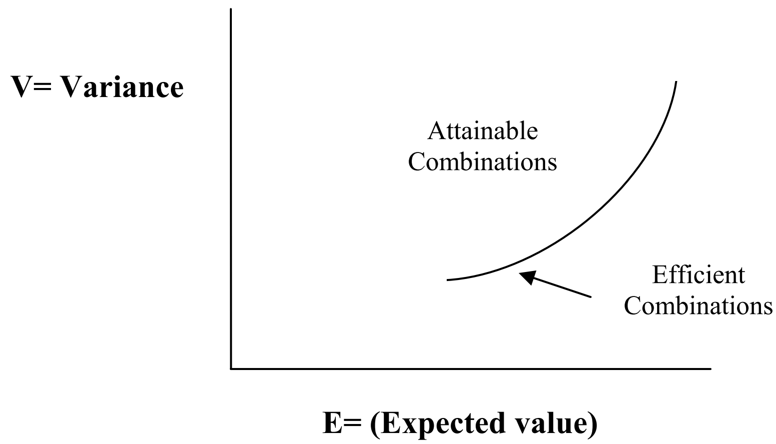

Figure 4-1. Geometric interpretation of cropping combinations for portfolio analysis.

Table 4-1. Calculated shrimp variable costs (V.C.) per pound (tail-weight) at two stocking densities, 80 shrimp/ m^2 and 100 shrimp/ m^2.

YEAR	V.C. at 80 shrimp/ m^2	V.C. at 100 shrimp/ m^2
Year 1	4.73	4.28
Year 2	4.81	4.35
Year 3	4.83	4.37
Year 4	5.64	5.02
Year 5	5.64	5.03
Year 6	5.00	4.52
Year 7	5.49	4.92
Year 8	5.25	4.73
Year 9	5.14	4.66
Year 10	6.57	5.80
Year 11	5.14	4.67
Year 12	5.58	5.02
Year 13	5.83	5.24
Year 14	5.33	4.84
Year 15	7.42	6.52

Table 4-2. Grapefruit variable costs (VC) per acre, assuming 95 trees planted per acre.

Year	V.C. per acre
Year 1	1,386
Year 2	1,385
Year 3	1,376
Year 4	1,367
Year 5	1,358
Year 6	1,363
Year 7	1,389
Year 8	1,410
Year 9	1,434
Year 10	1,452
Year 11	1,481
Year 12	1,513
Year 13	1,551
Year 14	1,595
Year 15	1,645

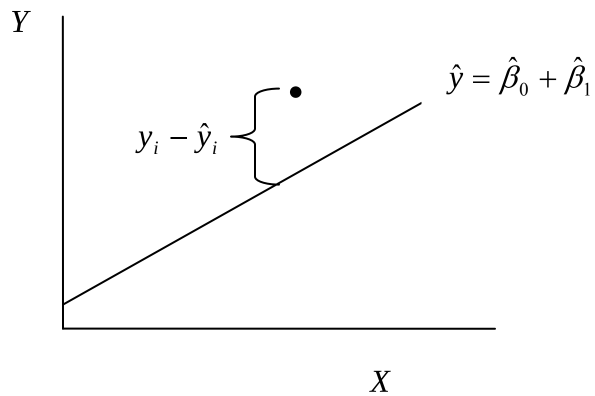

Figure 4-2. Prediction error illustration.

Table 4-3. Type of probability distributions defined for each stochastic variable.

Stochastic variable	Type of probability distribution
Grapefruit Prices	Empirical
Grapefruit Yields	Empirical
Shrimp Prices	Empirical
Shrimp Yields	GRKS
Feed Prices	Empirical
Hurricane Events	Discrete Empirical
Random Kill	GRKS

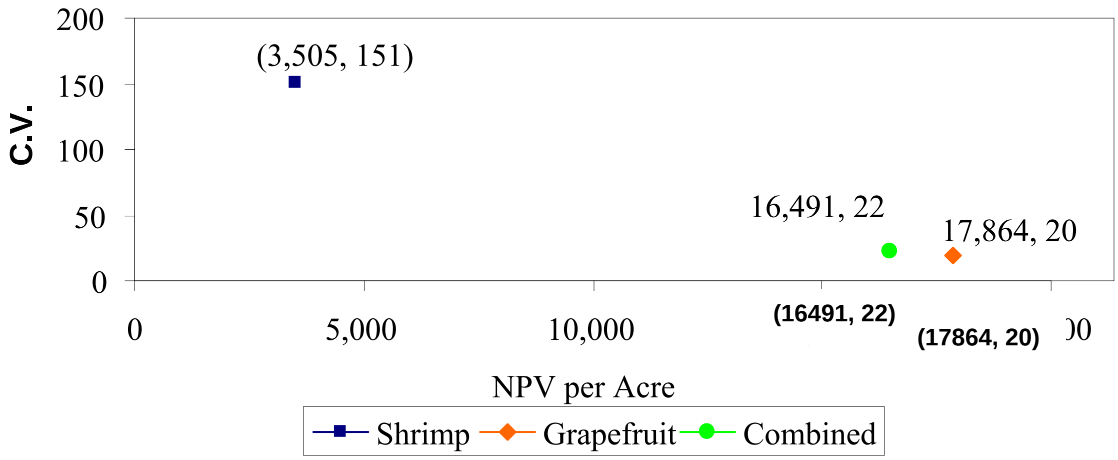

Figure 4-3. Portfolio frontier for NPV of net cash income for three investment scenarios.

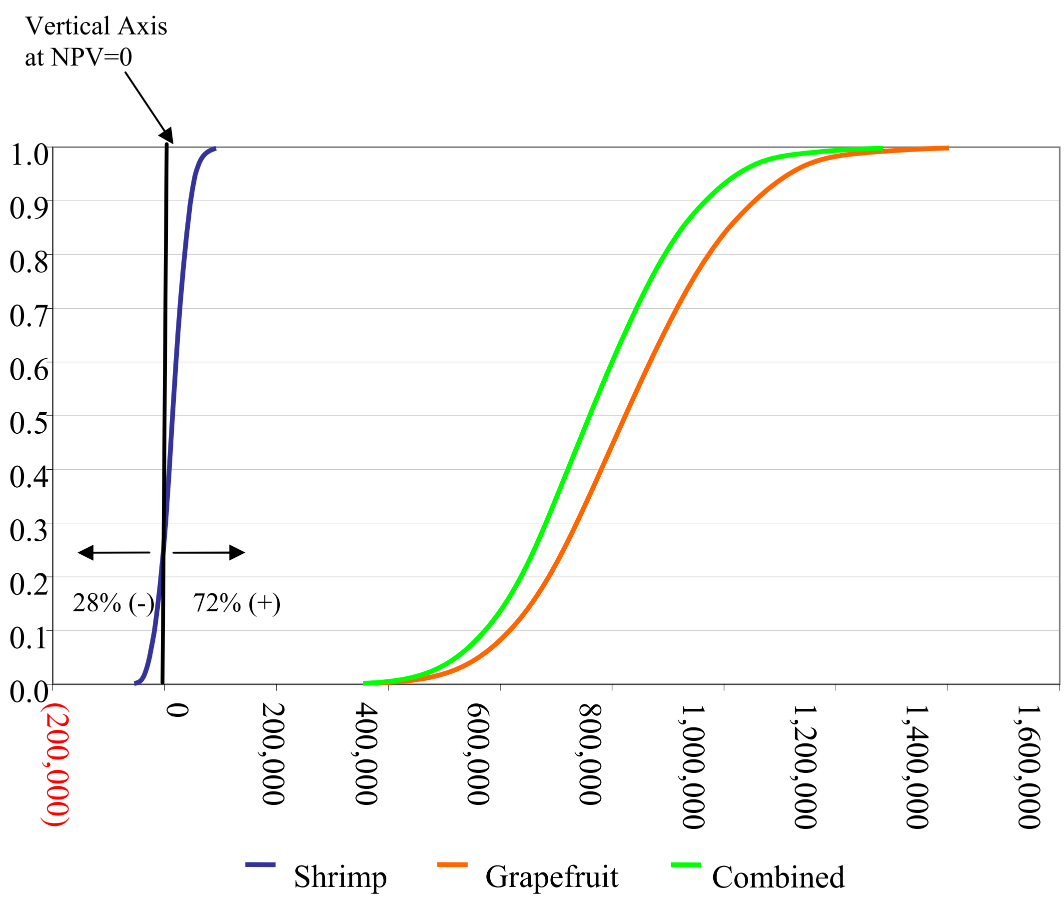

Figure 4-4. CDF of net present value of cash flows (NPV) for each enterprise.

CHAPTER 5
SUMMARY, CONCLUSIONS, AND IMPLICATIONS

Disease outbreak and hurricane events introduced unprecedented production risks recently for grapefruit producers in the Indian River production region of Florida. Low-salinity shrimp aquaculture, as a crop diversification and risk management strategy, has been considered as a potential investment for grapefruit producers in the Indian River production region of Florida. Although generalized production technologies have been well-documented for the culture of *Litopenaeus vannamei* shrimp in low-salinity conditions, the financial and risk implications of this investment can be difficult to generalize and therefore have not been widely disseminated. This lack of conclusive financial analyses associated with low-salinity shrimp aquaculture production are due to the many permutations regarding site-specific facility construction costs (shrimp greenhouse and production ponds) and assumed management decisions (shrimp stocking density and assumed survival for feed calculations) that can be made during the production and marketing process. Additionally, uncertain (stochastic) variables exist that, when considered, contribute to the probability of financial success resulting from an investment in a shrimp culture enterprise. Consideration of these variables may include grapefruit yields and prices, shrimp yields and prices, shrimp feeds, survival rates, random kill and hurricane events.

In three distinct studies, the objective of this thesis focuses on:

1) Defining the business strategy environment that may lead to competitive advantages via a direct-marketing effort to local restaurants
2) Defining parameter size and scope for a representative low-salinity shrimp production enterprise and the creation of a computer-based stochastic spreadsheet production model to analyze the crop diversification decision
3) Analyzing the risk management decision regarding crop diversification from grapefruit monocropping strategy to a combined grapefruit and shrimp enterprise

Together, these three objectives are used to address the hypotheses initially posed in this thesis regarding an investment by grapefruit producers into low-salinity shrimp aquaculture in the Indian River production region of Florida. Restated, the hypotheses are:

- An investment into shrimp aquaculture production in low-salinity ponds is relatively capital intensive and may not be a profitable investment
- Probability of acceptable financial performance (as measured by the net present value of net cash income) is dependent upon premium market prices, lowered capital construction costs, higher survival rates, the discount rate calculation used, and the impact of uncertain variables including weather and random kill events
- A shrimp aquaculture investment may not minimize the variance of returns associated with a diversification strategy for grapefruit producers in the Indian River production region
- By using historical data to estimate future probabilities of financial performance, investment risk can be quantified and analyzed via stochastic simulation to reflect their implications on investment returns.

Conclusions

Economic theory suggests that within a monopolistically competitive environment, producers who sell a slightly differentiated product can receive marginal benefits if consumers perceive value in the differentiated product. In a global shrimp-commodity market, the producers are price takers and supply and demand equilibrium dictates market prices. Therefore, agricultural producers who are able to communicate additional value attributes to their customers may be able to receive a market price higher than world price.

Consumer research data indicates that consumers in Florida are willing to pay a price premium up to $1.00 per pound for locally-grown shrimp (Wirth and Davis, 2001b) and up to $2.00 more per pound for fresh, never-frozen shrimp (Davis and Wirth, 2001). A direct-marketing approach to local Florida restaurants may be a feasible strategy for Florida shrimp producers who are able to communicate the quality benefits perceived by consumers to restaurant managers who are their primary buyers in the direct-marketing strategy. Use of a collaborative state and producer-sponsored marketing campaign, such as the Florida Agricultural Marketing Campaign may be cost effective in delivering consumer education information regarding the availability of fresh, locally-grown shrimp at local Florida restaurants. Based on typical restaurant food-cost calculations, the producer may expect to negotiate an approximate price premium of \$0.33 to \$0.66 per pound (tail-meat) of shrimp sold. This price premium is added to the commodity shrimp price in the calculation of shrimp investment revenues generated by the hypothetical shrimp production system.

A stochastic spreadsheet accounting model was developed based on the production results of the hypothetical shrimp production system. Estimated capital outlay for construction costs to build a low-salinity shrimp aquaculture production facility was \$493,993. Cash shortfalls were assumed to be covered through operating loans. Processing costs were not directly included in the cost estimates although the cost of ice was included in the model as a harvesting cost to account for the whole-shrimp, direct-marketing strategy assumed in the model.

The NPV of net cash income for the fifteen-year planning horizon, considering two stocking densities in the deterministic analysis, were -\$462,401 and -\$343,120 for the stocking densities of 80 shrimp per m^2 and 100 shrimp per m^2, respectively. The discount rate used in the deterministic NPV calculation was 8%. Changing the management variables to positively influence the profitability of the investment was the focus of the various management scenarios within this study. These variables included a higher price premium received by the producer, lower capital costs, and varying levels of the discount rate calculation. All scenarios were analyzed at the higher stocking density of 100 shrimp per m^2. Random kill and hurricane impacts were examined after the various management scenarios were analyzed.

The analysis of capital costs and returns indicates that the shrimp aquaculture investment is relatively capital intensive. Additionally, this investment was only profitable with a combination of a local price premium, lower capital costs, higher survival rates, and at discount rates lower than 8%. This may not be an attractive investment for agricultural producers as the risk-free investment alternative return for U.S. Treasury Bills is 5.25% (USDT, 2007). However, non-risk adverse investors with available acreage may prefer to invest in low-salinity shrimp aquaculture if a solid marketing strategy and long-term benefits are perceived from this investment.

The diversification decision can be approached via traditional portfolio analysis and stochastic analysis. The portfolio analysis includes the all of the risk elements provided by the stochastic variables and provides a measure of the expected value-variance tradeoff that may be realized with a diversification investment from grapefruit to shrimp production. However, the expected value of returns for the shrimp investment is lower than the expected value of returns for the grapefruit investment. Additionally, the variance associated with the shrimp returns is higher than the variance associated with the grapefruit returns. Based on the portfolio theory, no beneficial tradeoff effects between expected value and variability (over the long-term, fifteen-year planning horizon) appear to reduce the risk to the investor via crop diversification.

The stochastic analysis indicates that the grapefruit investment returns a 100% probability of positive NPV considering all of the stochastic variables. The shrimp investment enterprise returns a 72% probability of a positive NPV of net cash income. A risk averse investor may not wish to consider an investment in shrimp aquaculture with a 28% probability of negative NPV. Crop diversification into shrimp aquaculture does not minimize the variance of returns associated with a diversification strategy for grapefruit producers in the Indian River production region of Florida.

Implications

Production technologies for culturing the marine shrimp, *Litopenaeus vannamei*, in low-salinity water continue to evolve in Florida. The development of this financial accounting spreadsheet utilized production parameters and operating variables assumed to affect the investment decision regarding a low-salinity shrimp aquaculture investment in Florida. It appears that the shrimp aquaculture investment decision is capital intensive and less profitable than an investment in grapefruit production in the Indian River production region of Florida. However, technological changes may increase the probability of economic success of this investment. A risk-preferring investor may perceive potential benefits from investing in this type of production enterprise, especially if factors of production (land, skilled labor, equipment) are available to reduce capital costs.

Recent hurricane events in Florida serve as a reminder that the production risks associated with hurricane events are valid and that crop and facility destruction is of prudent consideration with regard to Florida investors. The financial implications that include potential losses due to hurricane or random kill events indicate greater overall loss potential for the shrimp aquaculture investment (relative to the grapefruit investment) as measured by NPV of net cash income. The shrimp investment scenario output indicates a low percentage of high-value loss associated with rebuilding the greenhouse structure due to hurricane impacts. The capital re-investment required for continued operations may not be a feasible strategy for some investors. Technological advancements in structural design may reduce the risk of greenhouse failure and increase the overall probability of economic success of this type of shrimp production system investment.

This study outlined a direct-marketing business strategy for Florida shrimp farmers to consider for the purpose of establishing a premium pricing strategy for a fresh, never-frozen and locally-grown product. Establishing an industry based on a product's credence attributes may prove challenging. However, factor inputs are available in the St. Lucie County area specific to highly-mineralized fresh water and skilled labor availability. The "Fresh from Florida" state marketing campaign may also lend positive economic benefits for the establishment of this industry. Anecdotal evidence within the aquaculture industry indicates that establishing a marketing channel for aquacultured product, prior to pond stocking, is essential to minimizing potential investment loss at harvest time due heavy bio-loads associated with shrimp stocked at 100 per m^2 and the impact on water chemistry (e.g., oxygen, ammonia, and nitrite). The delay in harvest scheduling while investigating potential markets increases the investor's risk of a catastrophic pond die-off and subsequent loss of profit. Due care should be taken to investigate the long-term marketing potential for aquacultured shrimp prior to the initial capital outlay for pond system construction.

Finally, the scenario output indicates that low survival rates significantly impact the shrimp investment returns. The learning curve for aquacultured products is less forgiving than traditional agrarian crops due to the complexity of changing water chemistry at high stocking densities required to return acceptable profits. Consultant advice, especially at the onset of this type of investment, may significantly reduce the investor's potential for crop loss associated with poor water quality conditions and non-optimized variable costs associated with feed and labor inputs. Experienced consultant advice may also provide the investor with timely insights regarding alternative marketing and distribution channels that may become necessary at some point in the future for expansion or to efficiently move product out of the production system should primary market channels become unstable. Remember that the adage is that, "you aren't a shrimp aquaculturist until you've killed a million shrimp." An experienced consultant has already paid many dues regarding this perspective of the learning curve.

Future Research Needs

According to the model, the probabilistic forecasts for a low-salinity shrimp aquaculture investment in Florida require a considerable degree of risk acceptance by investors. However, the development of a stochastic spreadsheet model has the potential to provide interdisciplinary researchers with a tool aimed at optimizing biological and economic performance based on quantifiable input parameters. The spreadsheet model may be used to analyze cost efficiencies associated with construction costs as these costs seem to greatly influence the probability of economic success of the investment. For example, economies of size and scale may be investigated via computer simulation prior to a capital intensive investment. Increasing the pond size incrementally from the 0.29 acre size up to 5 acres or increasing the number of ponds per production "unit" may reduce the capital costs per unit of output. Additionally, this research model may provide a template for other species currently being considered as candidates for aquaculture investment. Potential dual-cropping investments (i.e., fish and shrimp) may make the capital investment more profitable. Utilizing the ponds in the cool weather with a cool-water species may improve NPV values for the aquaculture investment. Finally, the development and dissemination of the model components and findings may contribute to the development of different design and input parameters to measure the financial performance for risk-accepting investors who continue to search for information regarding the development of a low-salinity shrimp production industry in Florida. These design parameters could include structural changes to the greenhouse design to withstand hurricane impacts and minimize rebuilding costs. Using computer modeling and stochastic analysis as a farm or extension tool to quantify investment risks associated with aquaculture investments may promote cost-efficient investment alternatives for Florida agricultural producers.

APPENDIX A

HYPOTHETICAL SHRIMP PRODUCTION SYSTEM CONSTRUCTION COSTS

Table A-1. Greenhouse Capital Cost Budget.

Greenhouse budget item	Item cost	Total
Construction and equipment costs		$90,961
Earthmoving	2,000	
PVC materials	664	
Greenhouse permit fees	93	
Quonset greenhouse package and assembly	17,786	
3"PVC, screws, fittings	719	
50 treated 2'x12'x12'	749	
PVC pipe and fittings	1,966	
Fittings, valves, bits, PVC glue	553	
TEK screws (400) #14x3"	26	
TEK screws, bolts, nuts, washers	70	
Floor, set sump, drain pipe/fixtures	22,624	
Lumber, treated	1,440	
TEK screw (600) #14x2.5"	48	
Sacrete, bolts, turnbuckles, washers	45	
Lumber treated & Portland cement	102	
Lumber, treated	37	
Reimburse Grainger strapping kit	63	
Fittings, screws, screw eyes	189	
Nylon screening standpipes	108	
Banding & banding buckles	139	
Reimburse PVC materials	12	
Omni threaded ball valve	50	
Pulleys, ratchets for transfer system	22	
White rock gravel	15	
PVC and tap screws	34	
PVC and mesh for media boxes	202	
EPDM liners	1,829	
Nursery Greenhouse Construction:		$51,585
Greenhouse Electrical Installation:		$10,982
Proline bacteria fresh and salt	74	
Rustol, saw blades, chalk, knife	38	
Channel lock plier and 4" vise	61	
Band tool	84	
Washers, tap screws, nylon ties	17	
Kaldness bio-filter media	999	

Table A-1. Continued.

Greenhouse budget item	Item cost	Total
O2 regulator	96	
Rubber Maid garden cabinet	189	
Reel mount, rubber plug & cord	77	
Hose & reel, electric cord, nozzles	112	
PVC elbow and pipe	35	
Sacrete (168) and lumber	630	
Sacrete, screws, PVC slips/adapters	725	
4' fiberglass stepladder	118	
Big wheel 50-gal trash can	152	
11' black nylon ties	25	
Greenhouse Equipment General:		$3,432
DOmeter, pH, YSI Spectrophotometer and reagents	1,320	
Ohaus scale, refractometer	261	
Ohaus Scout scale	170	
Water Testing and Shrimp Sampling Equipment		$1,751
Sweetwater and centrifugal pumps	2,082	
Blowers (2) and float switches (2)	1,290	
Bead filter, controllers, relays	3,426	
Flotec 1.5hp pump	209	
Greenhouse Equipment: Pumps and Motors		$7,007
Juvenile transport tank and cage fittings	322	
O-ring for transfer tank	3	
PVC for transfer tank	15	
PVC cement for transfer assembly	16	
PVC Suction hose 6" x 100'	786	
PVC, couplings, ties for transfer	261	
Nursery Transfer Equipment/ Supplies		$1,403
Project Mgt (2 months for G.H. construction)	10,000	
Skilled Labor	4,800	
Greenhouse Construction Labor:		$14,800

Table A-2. Four 0.29-Acre Ponds Capital Cost Budget

Pond budget item	Item cost	Total
Total site and pond construction costs		$403,032
Surveying services	1,809	
Easement engineering	1,500	
Well, electric, generator engineering	5,490	
Miscellaneous fees	180	
Engineering & drafting as-built plans	3,350	
Engineering and Surveying:		12,329
Feed Storage Building		24,000
Deep well	57,943	
Deep well pump	4,977	
Well Construction:		62,920
Deep well 800'	617	
Deep well 800'	51	
Deep well 940'	765	
Deep well 1070 TDS	130	
Bioassays on deep well	250	
Deep well 1070	765	
Well Water Testing:		2,578
Emergency generator, delivered	20,576	
Generator slab and extension, wall	4,955	
Emergency Generator		25,531
Electrical Installation		20,959
Total Site Prep Fixed Costs		$148,317

Table B-1. Continued.

Pond budget item	Item cost	Total
Earthmoving contract	48,032	
Site clearing & road const	4,423	
15'x30' alum culvert	249	
Coquina FL rock-563.71 yds@18	10,147	
Coquina rock delivery; 52.5hrs@$50	2,625	
Seeding pond levees	1,549	
Borrow pit expand	3,999	
Contract change order	1,961	
Sod pond levees	4,550	
Sod retention pond levee	1,664	
12'x40' culvert/flap gate	1,600	
Culverts	4,879	
Donated heavy equipment services	10,000	
Gate materials	686	
Tools and hardware	535	
Earthmoving: Pond and Roadway Construction		96,899
Transportation of HDPE	2,500	
30-mil HDPE	15,000	
Install 88,626 ft^2 liner	27,244	
Portable toilets	105	
Anchor trenching-ponds 1&2	5,000	
Pond Liners and Installation		49,849
Pond Electrical Installation		13,904
Rope and pipe for dividers	2,824	
Lumber for dividers	286	
PVC couplings, valves, netting	2,202	
Dock materials-ponds and retention	800	
Lumber, hanger nails, bolts, washers	126	
Gate valves	113	
Rope, screws, washers, nylon ties	159	
Gate and ball valves	800	
8" PVC and clamps for standpipes	136	
Liquid nails for standpipe	4	
PVC, nuts, washers for standpipes	12	
PVC and cleaner-pond water valves	35	
Rope 0.5" white nylon (600')	126	
Pond Construction Equipment:		7,623

Table B-1. Continued.

Pond budget item	Item cost	Total
Project Mgmt 10 months (construction and training)	50,000	
Install concrete pads in ponds	726	
water lines-well to 1&2	987	
Dock labor at WCC	1,375	
Install docks-ponds and retention	2,200	
Install posts and dividers, ponds 1&2	2,658	
Construction manager profit-well, generator, elec.	6,000	
Skilled labor	9,600	
Pond Construction Labor:		73,546
12 paddlewheel aerators	10,632	
Paddlewheel spare motor	276	
Paddlewheel spare gearbox	235	
Pond Equipment: Paddlewheels		11,143
DO and pH meter, YSI spectrophotometer and reagents	1,320	
Ohaus scale, refractometer	261	
Ohaus Scout scale	170	
Pond Equipment: Water testing & shrimp sampling		1,751
Total Pond Construction and Equipment Costs		$254,715

APPENDIX B
HYPOTHETICAL SHRIMP PRODUCTION SYSTEM REPLACEMENT SCHEDULE

Table B-1. Greenhouse Component Estimated Useful Life

Greenhouse component	Useful life
Nursery Greenhouse Plastic Covering	4 years
Kaldness Bio-filter media	20 years
O2 regulator	15 years
Rubber Maid Garden Cabinet	10 years
Reel mount, rubber plug & cord	5 years
Hose & reel, electric cord, nozzles	5 years
4' fiberglass stepladder	5 years
Big wheel 50-gal trash can, garbage can, and straps	3 years
DOmeter, pH, YSI Spec & reagents	4 years
Ohaus scale, refractometer	4 years
Ohaus Scout scale	2 years
Sweetwater and cent. pumps	5 years
Blowers (2) & float switches (2)	5 years
Bead filter, controllers, relays	20 years
Flotec 1.5hp pump	3 years
Juv. transport tank and cage fittings	5 years
O-ring for transfer tank	Annually
PVC cement for transfer tank and assembly	5 years
PVC Suction hose 6" x 100'	15 years
PVC, couplings, ties for transfer	5 years
Trash can, WD-40, caulk, glue gun	2 years
Rope for shadecloth	2 years
garden hoses (2) & nozzle	2 years
Push brooms (2)	2 years
Hose adaptors	2 years
Handles (2) - push brooms	2 years
10' 2x4s, coater broom	2 years
Instant Ocean Salt	Annually
Chlorine	Annually
Proline Bacteria fresh H2O (4 x gal)	Each stocking
Aqua ammonia and acid	Each stocking
Fittings and batteries	6 months
Roof coater brooms (2)	2 years
Paper towels	2 months
Dustpan, brush, screwdriver set	3 years

Table B-2. Pond Component Estimated Useful Life

Pond component	Useful life
Rope & pipe for dividers	5 years
Lumber for dividers	5 years
PVC couplings, valves, netting	5 years
Dock materials - ponds and retention	3 years
Lumber, hanger nails, bolts, washers	3 years
gate valves	5 years
Rope, screws, washers, nylon ties	5 years
gate and ball valves	10 years
8" pvc & clamps for standpipes	4 years
Liquid Nails for standpipe	4 years
PVC, nuts, washers for standpipes	4 years
PVC & Cleaner - pond water valves	5 years
Rope 0.5" white nylon (600')	3 years
12 Paddlewheel Aerators	15 Years
DOmeter, pH, YSI Spec & reagents	4 years
Ohaus scale, refractometer	4 years
Ohaus Scout scale	2 years
Nitrite, pH, Potassium starter kit	Annually
Nitrite reagent replacement kit	Annually
Molasses	Annually
Paddlewheel Spare Motor	3 years
Paddlewheel Spare Gearbox	3 years
Pillow block	3 years
Paddlewheel oil (1/2 Gallon or 1.8 Liters)	Aerator on
Pails and handles	2 years
Two 2-bu. Baskets	2 years
Tap screws, washers, nuts, hose clamps	3 years
Big wheel 50-gal trash cans	3 years
Door pulls, wooden stakes	Annually
hose clamps & PVC male adapters	3 years
PVC Ls, hose clamps, tap screws	3 years
adapter/shrimp harvest	5 years
well screen	3 years
tracking trailers (2)	3 years
Aquaculture Certification:	Annually

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BIOGRAPHICAL SKETCH

Jennifer Clark is a native Floridian, born in Winter Haven and raised in Vero Beach. After completing an Associate of Science degree in aquaculture production technology from Indian River Community College and Harbor Branch Oceanographic Institution in 1999, she accepted a position as department leader at a research and development aquaculture facility in Florida. During a brief training period in Mexico, she developed the technical skills necessary to implement a high-health shrimp broodstock program for this firm in a biosecure, recirculating environment.

During her employment with this firm, Jennifer continued her education and completed prerequisite courses to transfer into the Food and Resource Economics Agribusiness Management program at the University of Florida. She graduated with honors in 2004 with a Bachelor of Science degree in Agribusiness Management degree and entered the University of Florida's Food and Resource Economics graduate program that year to pursue her Master of Science degree. After graduation, she plans to remain in Gainesville, Florida where she has accepted a faculty lecturing position within the Food & Resource Economics Department at the University of Florida.