5-3-2008

Identification of disease and weather related loss factors and an efficiency measure affecting the U.S. farm-raised catfish industry

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IDENTIFICATION OF DISEASE AND WEATHER RELATED LOSS FACTORS

AND AN EFFICIENCY MEASURE AFFECTING THE

U.S. FARM-RAISED CATFISH INDUSTRY

By

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A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Agriculture
in the Department of Agricultural Economics

Mississippi State, Mississippi

May 2008

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Title of Study: IDENTIFICATION OF DISEASE AND WEATHER RELATED LOSS FACTORS AND AN EFFICIENCY MEASURE AFFECTING THE U.S. FARM-RAISED CATFISH INDUSTRY

Pages in Study: 88

Candidate for Degree of Master of Science

This study analyzed factors that affected catfish losses from diseases and weather events and factors that affected on-farm efficiency. A double limit tobit model was used to determine the magnitudes of losses experienced by producers due to these events, while a linear regression model was used to determine factors that affect efficiency. Results from the weather model indicate all variables are significant and positively affect loss while producer experience and pond depth were the only significant variables that affected disease loss. The efficiency model results provide information that could be increased or decreased in order to obtain a more efficient level of production. Significant inputs in the catfish efficiency model were age, experience, age/experience (interactive), catfish survival percentage, and percentage of fry and fingerlings purchased off-farm.

DEDICATION

To J.C.

I could not have completed this project without your support and encouragement.

Thank you!

EPIGRAPH

The longer I live, the more I realize the impact of attitude on life.

attitude, to me, is more important than facts. It is more important

than the past, than education, than money, than circumstances, than

failures, than successes, than what other people say or do.

It is more important than appearance, giftedness or skills. It will

Make or break a company….. a church…… a home.

The remarkable thing is we have a choice everyday regarding the attitude we embrace

that day. We cannot change our past. We cannot change the fact

that people will act in a certain way. We cannot change the inevitable.

The only thing we can do is to recognize the one weapon we have,

And that is our attitude**……..**I am convinced that

life is 10% of what happens to me and 90% of how

I react to it. And so it is with you……we are in charge of our attitudes.

- Anonymous

ACKNOWLEDGEMENTS

First, I would like to thank GOD for blessing me with the strength to complete this chapter of my life. Next I would like to express my gratitude to my family and friends for their unfailing love, support, and encouragement. I would like to thank Dr. Stan Spurlock for extending the opportunity to participate in the graduate program. To my major advisor, Dr. Terrill Hanson, I appreciate all of your help and your patience with me on this project. Your expertise on certain aspects of this project was vital to my completion. To Dr. Keith Coble, I would also like to express thanks to you for all of your help and advice on this project as well. Thank you. To Dr. Darren Hudson I would like to express my gratitude for your help and guidance as well as your guidance on issues of life. I was listening and thank you. I would also like to thank Dr. Saleem Shaik for his help and patience on this project.

To the entire Department of Agricultural Economics, I want to say thank you for your continuous support and encouragement. Whether it was a kind word, hug, or smile, I thank you. To my classmates, Jay, Sarah, Micheal, Jim, David, Roxy, Vivian, and Jin, I will miss you all and thank you for your friendship. A special thanks the David Busby, Frances Walker, Debra Price, and Patsy Brock for believing in me when I didn't believe in myself. Thank You. To my co-workers and bosses at Bovigen LLC, thank you for all of your support. And last but certainly not least, I would like to thank my Husband for his love, patience, and understanding.

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CHAPTER I

INTRODUCTION

The birth of the catfish industry occurred in the early 1960s. Rapid expansion began in the mid 1970s as catfish production became more accepted as an alternative for lands formerly planted in cotton, soybeans, and other crops. Because of catfish's popularity in the southern United States, the industry continued to expand with increased production and processing in the 1980s and 1990s. This industry has become the highest valued aquacultural species raised in the US.

The number of catfish operations in the US totals 1,160 (USDA 2006), and approximately 94% of catfish produced in the United States come from the southern states of Mississippi, Alabama, Arkansas, and Louisiana (Tucker et al. 2005). The National Fisheries Institute has placed U.S. farm-raised catfish sixth on its list of most preferred fish and seafood products among U.S. consumers (NFI 2006).

The low average annual prices received by U.S. catfish producers in 2001 ($.64/lb), 2002 ($0.56/lb) and 2003 ($0.58/lb) have caused economic hardship for many catfish producers, and as a result, many producers have exited the industry (Hanson and Sites 2006). While prices began to increase in 2004, aquaculture producers wanted to minimize future low price impacts on their operations by improving their farm's production efficiency and by reducing their financial risks. Common sources of fish losses include losses from diseases outbreaks and severe weather events. The declining market prices observed by producers in the early 2000s also caused researchers to seek methods to reduce the level of risk in aquaculture production in the United States.

Catfish producers face many on-farm production challenges, such as fish losses from a multitude of diseases and severe weather events. While management strategies to improve production efficiency levels are always being sought, insuring aquaculture production is one way to reduce production risks. However, it poses several unique challenges in its development. The most obvious distinctive feature to aquaculture production is that fish are grown in a water environment and several types of containment structures. Issues of inventorying live (and dead) fish and attaching definitive causes to fish loss events are among the most challenging aspects of developing aquaculture insurance instruments.

The United States Department of Agriculture (USDA) Agricultural Risk Protection Act of 2000 sought to include under represented agricultural crops, including aquaculture. This national research effort focused on reducing risk research effort for the U.S. aquaculture industries. The National Risk Management Feasibility Program for Aquaculture (NRMFPA), a partnership between the USDA's Risk Management Agency (RMA) and the Department of Agricultural Economics of Mississippi State University was created. The primary emphasis of this partnership was to examine the feasibility of developing insurance policies and risk management tools for RMA policymakers to use in evaluating risk reducing options for aquaculture producers. Research was to cover the catfish, salmon, trout, and baitfish aquaculture industries. The second emphasis of the partnership was to generate and analyze data pertaining to the development of non-insurance risk reducing methods and management tools.

This research focuses on identifying risk factors resulting in catfish losses from diseases and weather events. Potential factors affecting these losses may include variables such as farmer characteristics, production practices, physical farm characteristics and/or region of production. By far, the greatest cause of loss concern to U.S. catfish producers is from bacterial, viral, and fungal diseases (Tucker and Robinson 2002). Such losses can be generally grouped into diseases that typically occur during the spring, summer, and fall seasons of the year. The second highest loss concern involves loss of electricity, mainly used for aeration purposes. Hurricanes Katrina and Rita have given cause for greater attention to weather losses. Catfish weather related losses can be caused from freezing of the pond, flooding, droughts, windstorms, tornados, lightning, and hurricanes.

The research objectives of this study are to identify significant risk factor(s) affecting farm-raised catfish losses due to diseases and weather events, and to determine the significant factors affecting production efficiency on catfish farming operations. Models developed in this research provide insight into assessing individual producer's on-farm risks. This information provides a foundation for explaining approaches to mitigate these losses.

Objectives

The primary objectives of this research are to: 1) estimate the magnitude of specific loss events, and 2) estimate on-farm production efficiency. More specifically, the objectives are to:

1. Identify significant factors of losses due to weather events and determine the magnitude of losses above normal on a catfish farm from specific weather events;
2. Identify significant factors of losses due to specific diseases and determine the magnitude of losses above normal on a catfish farm for specific fall and spring diseases;
3. Identify significant factors affecting catfish production efficiency, as measured by feed conversion ratios, analyze how these factors impact production, and explore management strategies that might lead to improved production efficiency.

CHAPTER II

LITERATURE REVIEW

To achieve a better understanding of the present investigation, this chapter provides a discussion of the perils faced by channel catfish producers in the United States. Possible risk management techniques that can be used to mitigate these losses as well as strategies to improve production efficiency are discussed in this chapter. Risk can be interpreted in several different ways, but generally speaking, production risk can be thought of as a general uncertainty or doubt about the outcome of the production input/output process or as a possibility or chance of loss during the production period (Trieschmann and Greene).

For the purposes of this paper, the definition of production risk is used to refer to a loss of fish production due to one or more perils. Risk management is the organized mitigation of the loss exposure from specified perils. The notion is that losses can be managed or mitigated by proper planning and precaution. Four techniques used to address loss exposure are: 1) avoidance, 2) transfer, 3) retention, and 4) control. The latter concept of control can be further subdivided into two categories, risk prevention, which limits the frequency of the loss, and risk reduction, which limits the severity of the loss (Simmonds 1995). In aquaculture, risk control is very important because current losses can and do affect future profits.

One of the most frequently used risk management tools is insurance. Insurance products protect producers from production risks by transferring risk from one party to another in exchange for a premium (Shaik et al. 2006). In 2000, the RMA began to conduct pilot programs, as part of the Agricultural Risk Protection Program Act of 2000, to protect livestock producers from production losses and specifically aquaculture producers from disease perils and weather risks (USDA 2001). Many aspects of production risk cannot be covered by insurance policies because certain ideal conditions must be met before a peril's insurability is possible. The insurability conditions that must be met include: 1) ability to determine if a loss occurred from an insurable cause and ability to accurately measure the loss amount, 2) losses must be accidental and unintentional, 3) there must be sufficient information to conduct risk classification, 4) there must be sufficient data to establish an accurate premium rate, 5) losses must be sufficiently uncorrelated to allow for pooling, and 6) an economically feasible premium is required for there to be a market for the insurance product (Shaik et al. 2006).

The purchase of an insurance policy can be influenced by the producer's level of risk adversity, the cost of the insurance policy, and if in a Federal Crop Insurance Corporation agricultural insurance policy, the degree of the premium subsidy. Sherrick et al. (2004) identified factors that could influence crop insurance purchase decisions, such as the level of business risk, risk management options, debt use, age, education, farm size, and off-farm income. They used a two-staged estimation procedure to analyze the decision to purchase crop insurance versus use of alternative crop insurance products. Also, Smith and Baquet (1996) found numerous factors that may influence federal crop insurance purchases such as disaster relief received, debt use, debt-to-asset ratio, off-farm income, on-farm income, education, experience, age, farm size, and marketing instruments such as futures/forward contracts. Another factor that could influence the purchase of crop insurance is adverse selection problems.

Glauber (2004) stated that adverse selection problems arise when risks vary across insurance buyers and buyers know more about the risks faced than do the insurers. If indemnity payments exceed premiums costs, farmers are more likely to purchase insurance policies. However, if premium costs exceed indemnity payments, farmers are less likely to purchase policies.

Diseases

Animal disease outbreaks are major threats faced by the US agricultural sector, and because these disease outbreaks can cause major economic losses for producers, the idea of animal disease insurance has been posed to help lessen some of the risk caused by such outbreaks (Hoag et al. 2006). Channel catfish diseases are caused by organisms that parasitize and infect fish. These diseases can be caused by viruses, bacteria, fungi, protozoa, and metazoa. Many farmers consider these diseases to be the major problems faced by producers on their catfish production facilities (Tucker and Robinson 2002).

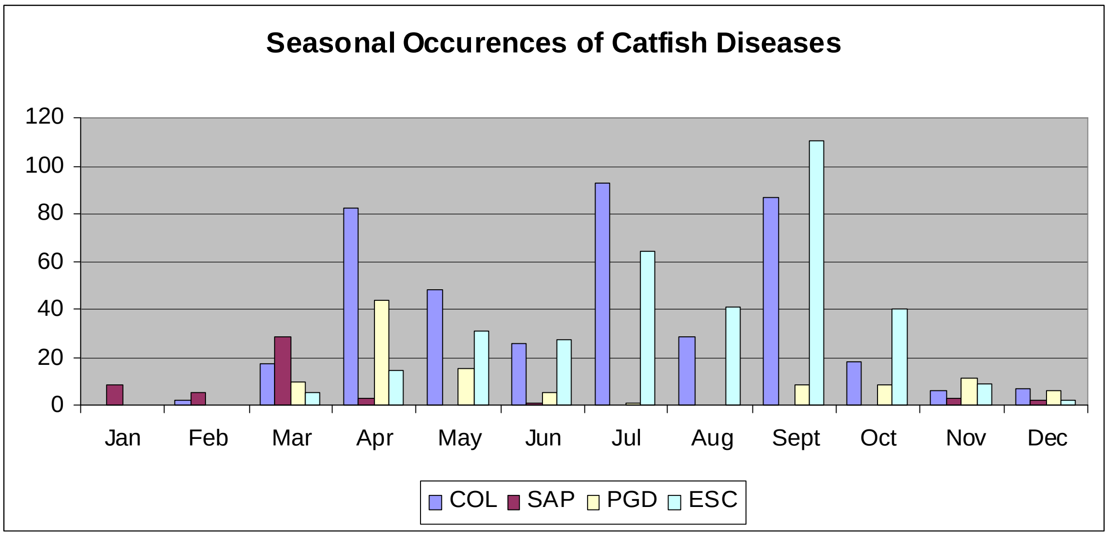
A survey conducted by the USDA, the National Animal Health Monitoring Systems (NAHMS) of the Animal and Plant Health Inspection Service in 2003 found that the three most prevalent diseases reported on catfish operations in 2002 were enteric septicemia (ESC) with 60.6% of farms having experienced this disease, columnaris (COL) occurring on 50.4% of all farms, and Saprolegnia (winter fungus) reported on 32.9% of farms. This study found that these diseases tend to increase as operation size increases. Table 1.1 presents data on the percent of US catfish operations reporting losses from the major diseases in 2002. Loss severity per disease outbreak is presented by loss category, i.e., light, moderate or severe, as defined by losses of less than 200 pounds, between 200 and 2000 pounds, and greater than 2000 pounds, respectively.

Table 1.1 Percentage of Catfish Losses, by Severity Category, Due to Disease in 2002, United States.

	Percent Operations		
	Average Loss per Outbreak (in lbs)		
	Light (< 200)	Moderate (200 – 2000)	Severe (> than 2000)
ESC	50.5	39.5	10.0
Columnaris	49.0	36.5	14.5
Ich	44.3	13.3	42.4
PGD	37.9	26.7	35.4
Anemia	32.3	25.9	41.8
Winter Fungus	40.6	33.1	26.3
Visceral Toxicosis	42.6	24.2	33.2
Trematodes	41.4	40.0	18.6
Other	22.6	41.2	36.2

Source: USDA/ APHIS/ NAHMS Catfish report 2003, Part II

The 2006 annual case summary report from the aquatic diagnostics laboratory of the Mississippi State University's College of Veterinary Medicine located at the Thad Cochran National Warmwater Aquaculture Center found that the top four catfish diseases submitted to the center in 2006 were ESC, COL, proliferative gill disease (PGD), and saprolegnia (winter fungus). ESC accounted for 11% of cases singularly but in combination with other diseases 57%, up from 2005 levels of 31%. Columnaris accounted for 14% by itself and 68% in combination with other diseases compared to 49% in 2005. PGD accounted for 18% of disease cases and winter fungus accounted for 8% of cases submitted. Figure 1.1 depicts the seasonal nature of these disease occurrences.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Totals
COL	0	2	17	82	48	26	93	29	87	18	6	7	**415**
SAP	8	5	29	3	0	1	0	0	0	0	3	2	**51**
PGD	0	0	10	44	15	5	1	0	8	8	11	6	**108**
ESC	0	0	5	14	31	27	64	41	110	40	9	2	**343**

Source: NWAC/ MSU/ 2006 CVM Aquatic Laboratory Summary

Figure 1.1 Seasonal Occurrences of Catfish Diseases in Mississippi, 2006.

While some diseases are manageable through the use of medicated feeds, vaccines or chemicals, other diseases are not treatable. The diseases do not have any known treatment nor any strategies to mitigate losses and are the type of diseases that insurance instruments would seek to cover. Experts provide general recommendations for these non-treatable diseases, such as maintaining high levels of dissolved oxygen, and good water quality, and minimizing stress to the fish, but they do not have any specific remedies if losses begin to occur. The major catfish diseases selected for use in the survey questions are briefly described below.

Columnaris (COL) is one of the oldest known diseases of warm water fish. It is the second leading cause of fish death in the southeastern US. Columnaris usually occurs during spring, summer, and fall seasons when water temperatures are usually between 77^{o} to 90^{o}F (Durborow et al. 1997). Fish infected with columnaris usually display symptoms such as brown to yellowish brown legions on their gills, skin, or fins. Fish are most susceptible to columnaris following environmental stress and fluctuating water quality. The presence of columnaris can lead to secondary infections or other diseases such as ESC (Durborow et al. 1997).

Potassium permanganate (KMnO4) and Terramycin (oxytetracyline HCL) are therapeutic chemicals used to treat columnaris, in addition to, preventative measures such as reducing stress factors caused by low oxygen, high ammonia/nitrite, high water temperatures, rough handling, and crowding (Rottmann et al. 1992). Potassium permanganate is usually dissolved directly into ponds that need to be treated, and the dosage used is normally 2mg per 1 mg KMnO4 (Durborow et al. 1998). The treatment should be applied during the morning hours to observe the ponds and to ensure that the red color persists at least four hours. Terramycin is a medicated feed dispersed at 25 to 37.5 milligrams of active ingredient per pound of fish for 10 days. After the treatment has ended, a 21 day withdrawal period must be observed before fish harvest can take place (Durborow et al. 1998).

Enteric Septicemia of Catfish (ESC), one of the most significant diseases among catfish because it accounts for approximately 30% of all disease cases in the southeastern United States and is caused by the gram negative bacterium, *Edwardsiella ictaluri* (Tucker et al. 2005). Outbreaks of ESC usually occur during fall and spring months when water temperatures range between 68^{o} to 82^{o}F (Tucker et al. 2005). Fish infected with ESC have red/white ulcers covering their skin, red spots under their heads and belly, and raised "pimples" between the eyes. Medicated feeds are the conventional treatments of catfish infected with ESC. Ponds with a history of annual outbreaks should be drained and treated with hydrated lime before refilling and stocking. Preventative measures that can be taken to manage ESC include reducing stressful factors such as handling, close confinement, improper diets, poor water quality, and temperature fluctuations (Tucker et al. 2005). Other measures that can be used are proper feeding practices and the accurate administration of drugs and chemicals. Vaccinations used for preventing ESC outbreaks, such as Formalin vaccines, have been widely used in the trout and salmon industries, but have not been widely accepted in the channel catfish industry. However, Romet 30, Romet B, and Terramycin are medicated feeds that have been approved for treatment purposes (Tucker et al. 2005).

Channel Catfish Virus Disease (CCVD) is a viral disease that occurs in fry and fingerling less than a year old and less than six inches in length (Camus 2004). This disease causes catfish to exhibit bulging eyes and a swollen abdomen. Occurrences of CCVD usually happen between June and September and when water temperatures are between 77^o and 86^{o}F (Camus 2004). There are no effective treatments of CCVD, but the effect of the disease can be minimized through best management practices of avoidance, containment, and stress reduction. CCVD avoidance stems from ensuring that water supplies do not contain any wild fish that may be infected. Containment of the disease can be implemented by sanitizing and disinfecting troughs in the hatchery or by quarantining ponds with diseased fish. Maintaining optimal water quality and high dissolved oxygen levels help reduce stress among the fish (Camus, 2004). Tucker and Robinson (2002) also state that the manipulation of water temperature and the use of antibiotics can help in controlling CCVD.

Proliferative Gill Disease (PGD), one of the most commonly diagnosed diseases of catfish in the southeastern US and generally occurs during spring and fall months when water temperatures fall between 59^o to 72^{o}F. This disease causes severe gill damage leading to suffocation of the fish. The cause of PGD is believed to be a myxozoan parasite, which uses the dero worm as a host. The dero worm lives in the mud of catfish ponds (Mischke, Terhune, and Wise 2000). Though no treatments or preventative methods for PGD have been used, several treatments appear to be effective, such as chemical treatments that break the life cycle of the parasite by eliminating the dero worm from ponds (Mischke, Terhune, and Wise, 2000). Several of the chemicals treatments, such as sodium chloride, hydrogen peroxide, formalin, potassium permanganate, and copper sulfate have been studied to determine their potential usefulness in the elimination of the dero worm in catfish ponds. However, none have been adopted. Also, maintaining dissolved oxygen concentrations at near saturation levels as possible by using supplemental aeration is another possible prevention method (Tucker and Robison 2002).

Saprolegnia or Winter Fungus is the most frequently occurring disease of channel catfish. The specie of Saprolegnia that causes the symptoms of the disease has not been isolated. Winter Fungus usually occurs between October and March when water temperatures are below 59°F (Durborow et al. 2003). Losses from winter fungus usually increase as the temperature increases and affect harvestable size fish the most. Common symptoms for winter fungus are brownish patches of fungal growth on the skin, dry skin, and sunken eyes (Durborow et al. 2003). Costly chemical treatments for the control of winter fungus have caused producers to focus more on the prevention of the disease. Some techniques being employed include maintaining proper water quality, stress reduction, maintaining dissolved oxygen levels, and treating other diseases that may predispose the fish to winter fungus, such as columnaris and ESC. Hydrogen peroxide (H_2O_2) and bronopol are potential chemicals that may be used for future treatment of saprolegniasis, but are not currently recognized (Durborow et al. 2003).

Ich or *White Spot* disease is capable of killing large numbers of fish in a short period of time. This disease usually infects fish in water between 68° and 77°F. Fish infected with Ich may have white specks on their skin. Ich causes the fish to look bumpy and slough off large amounts of mucus from their skin. Early detection and treatment is critical to the control of Ich outbreaks and the prevention of transmission of this disease to other ponds. Chemical treatments ranging from three to seven days, depending on water quality, are normally effective. If the outbreak of Ich is very severe, eradicating the ponds and starting over seems to be the best treatment. Prevention techniques for Ich include preventing wild fish from entering into ponds, examining new fish closely before introducing them ponds, and chemically treating ponds that have been previously exposed to the disease. Formalin-F, copper sulfate ($CuSO4$), potassium permanganate ($KMnO4$), and salt (NaCl) have been used to control Ich in catfish operations (Durborow, Mitchell, and Crosby 1998).

A study conducted by Wagner et al. (2002), states that approximately 60% of catfish losses reported to the Fish Diagnostic Laboratory at the Thad Cochran National Warmwater Aquaculture Center were from columnaris (*Flavobacterium columnare*) and enteric septicemia (*Edwardsiella ictaluri*). The focus of this study was to determine the proportion and number of ponds that experienced losses due to columnaris and enteric septicemia, and to determine if there was any association between management practices, pond characteristics, or owner/operator socio-demographics and the loss levels from the two diseases. Management practices included were stocking, feeding, harvesting, and health management. The analysis was conducted using a two phase survey given to catfish producers in Alabama, Arkansas, Louisiana, and Mississippi to determine if there were any statistical association between management practices and the presence of columnaris and enteric septicemia. A traditional logit model was used where each management practice was regressed against the presence or absence of a large (>5% of annual production) loss from either the ESC or columnaris diseases or a combination of ESC/columnaris at the same time. The results of this study estimated that 78% of all operations and 42% of all ponds suffered losses from ESC and columnaris. Results also showed that there were associations between each mentioned management practice and the presence of losses from ESC and columnaris.

Weather

Weather is a natural phenomenon that producers can not prevent, but there may be steps producers can take to minimize the effects of the events on losses. With regions of the US catfish production area experiencing volatile weather patterns, the topic of fish losses due to weather events has gained greater attention. Certain weather events, such as frost, freezing, wind, drought, excessive precipitation, lightening, hail, etc., have become an insurable cause of loss under many crop insurance policies (USDA 2003). Insurable crops experiencing weather-related perils include corn, soybeans, cotton, strawberries, and apples. Under these policies, producers are paid an indemnity payment for losses due to specified weather events. The salmon industry has acquired insurance coverage from the private sector, and there are two basic policies: one for hatcheries and land based systems and the other for offshore net pen systems (Forster 2003). With the exception of clam production, no other aquacultural product is currently insurable at the governmental level at this present time.

Catfish Production Efficiency

Many catfish farms seek ways to maximize their profits while operating in an efficient manner. To become more efficient, producers want to maximize output while minimizing costs associated with production. The majority of variable costs in catfish production are associated with feed and feeding practices. Feed used in commercial catfish production must have all the essential nutrients at adequate levels to meet total nutritional requirements for normal growth and development. Typical dietary components needed in catfish diets include energy supplements, protein, and amino acids, lipids, vitamins, and minerals. Specific requirement for catfish energy intake is not known but is known to be the most important component of the catfish diet (Robinson and Li 2005). Robinson and Li (2005) suggest that 28% protein feed should contain 1,080 – 1,200 kcal of digestible energy (DE) per pound, and 32% protein feed should contain 1,235 – 1,380 kcal of digestible energy (DE) per pound.

Typically, it is recommended to use a 32 percent crude protein floating feed fed in early spring and change to a 28 percent crude protein floating feed and feed to satiation as the water temperature increases and the fish begin feeding more vigorously (Robinson et al 1998). Studies show that catfish grow well on both low protein diets (24-28%) and high protein diets (32-35%), but 32-35% protein feeds is better when feeding every other day. Feeding every other day to satiation has also been found to improve feed efficiency and lessen aeration time (Robinson and Li 2005).

The measure of efficiency for the purposes of this research is catfish feed conversion ratio (FCR). FCR is defined as the number of pounds of feed required to produce a pound gain in fish weight. A good FCR value, i.e. lower value, depends on management skills and should be between 1.5 to 2.0. As the fish size increases, feed consumption as a percentage of body weight decreases and FCR values increase, becoming less efficient (Robinson et al 1998). The lower the overall farm FCR value, the more efficient the producer is at feeding and growing fish. The lower more efficient FCR values come from keeping the fish alive until harvest, and feeding at lower feeding rates have been found to decrease FCR because the feed is used for maintenance of the fish instead of growth (Robinson and Li 2005). Previous research has shown that the idea of compensatory growth will improve the efficiency of fish growth. Compensatory growth is where fish are temporarily deprived of feed, and when feeding is resumed, the fish will grow more rapidly than if they had been continually fed. This occurs because fish eat more feed and this allows them to catch up with the animals that were not deprived of feed (Robinson and Li 2005). Daily feeding to satiation is optimal, but restricting feeding is a commonly used practice when producers are low on cash and can not afford to feed to satiation each day.

The predominant practice utilized by farmers is to feed to satiation daily, because this practice provides the daily amount of feed a fish needs. Feeding to satiation may not be possible during the summer months because of water quality concerns or in multi-batch production systems with different sizes of fish in the same pond. In this case, small fish often do not get sufficient feed after the larger-sized fish have completed eating. Another concern for feeding to satiation is that many farmers do not know what their cut off point should be so they over feed their fish (Robinson and Li 2005).

In addition to the compensatory growth and satiation feeding, many farmers use modified feeding regimes during the winter months because fish metabolism, feed intake, and digestion decrease, which could cause production efficiency to decrease. Research has shown that fish fed using modified feeding regimes during the winter months tend to weigh more than fish not fed during the winter months. Hatch et al. (1998) analyzed the effect of winter feeding. Three strategies were used: a full-fed strategy (feeding from November to April), a partial feed strategy (feeding during November, March, and April), and a strategy with no winter feeding. There were two fish sizes in the experiment, year 1 fingerlings weighing 22g and year 2 fish weighing 240g at stocking. Results of the study showed that fish receiving no feed during the winter months lost weight and weighed significantly less than full and partially fed fish. Hatch et al. (1998) also found that partially fed year 1 fish may weigh the same as full fed fish after the summer grow out period, reflecting the compensatory gain effect.

Water quality is also an important component in catfish production efficiency on commercial catfish farms. Poor and unhealthy water conditions can be traced to leftover feed remains that have not been removed from the ponds. These remains along with fish wastes causes the water quality to deteriorated, especially during the summer months when feeding rates are high (Tucker et al. 2005). Maintaining good water quality helps control diseases by maintaining the health of the fish, though there is always a delicate balance between intensifying production, profits, and maintaining fish health.

Several techniques that can be used to maintain good water quality have been identified: not exceeding the carrying capacity of the environment; monitoring water quality parameters; maintaining dissolved oxygen levels above 5mg/L (Rottman, Francis-Floyd and Durborow 2002), preventing the accumulations of organic debris, nitrogenous wastes, carbon dioxide, and hydrogen sulfide; and maintaining appropriate pH, alkalinity, and temperature for the aquacultural species being cultured (Tucker et al. 2005).

Tucker et al. (2005) provided an in-depth look at several factors that affect the water quality of catfish ponds: dissolved oxygen, carbon dioxide, ammonia, and nitrite. They found that dissolved oxygen concentrations can change often on a daily basis, by location, and also based on pond depth. The best health and performance of channel catfish can be recognized when dissolved oxygen levels are near 8 to 14 mg/L(near saturation) and that poor growth and immune functions can be recognized by prolonged exposure to dissolved oxygen concentrations below 5 mg/L. Since oxygen depletion is a major risk on catfish ponds, many if not all farmers have some form of aeration equipment on farm to keep dissolved oxygen levels between 8 to 14 mg/L to avoid fish loss.

Carbon dioxide does not seem to pose as significant a threat as dissolved oxygen. The primary problem with carbon dioxide is that it does not allow proper oxygen intake by the fish. Carbon dioxide can be removed by adding hydrated lime to the pond or by monitoring dissolved oxygen levels and aerating the ponds before low dissolved oxygen levels and high carbon dioxide levels kill the fish (Tucker et al. 2005).

Ammonia and nitrite also affect water quality of a catfish pond. Ammonia, a nitrogenous waste product excreted by catfish, comes from nitrogen in the feed. Ammonia can cause fish not to feed efficiently and at high levels can cause them to become severely lethargic and die (Hargreaves and Tucker 2004). Since the cause of ammonia can be traced to the feeds fed to fish, one of the ways to control ammonia would to simply manipulate feeding rate and feed protein level by limiting the feeding rate to an amount that will be consumed by fish entirely (Hargreaves and Tucker 2004; Tucker et al. 2005).

Nitrite is the transformation of ammonia to nitrate in soils and water. High concentrations of nitrite can cause brown blood disease in fish. Brown blood disease causes fish to be incapable of transporting oxygen throughout the body, therefore causing suffocation. Nitrite is usually high in the fall and spring months due to fluctuating temperatures (Hargreaves and Tucker 2004: Tucker et al. 2005). The treatment of nitrite is the same as treating ammonia. Farmers minimize the amount of nitrogen incorporated into the system by decreasing the feeding rates, and by also treating ponds with sodium chloride (NaCl, salt) (Durborow, Crosby and Brunson 1997).

CHAPTER III

METHODS AND PROCEDURES

Publicly available farm-level aquaculture data is extremely difficult to obtain. Sources such as diagnostic labs (Mississippi State University 2006), NASS Census of Aquaculture survey (USDA, 2006), and NAHMS (USDA, 2003) reports summary statistics of production, acreage and losses are a few publications that are accessible to the farmers. Information with respect to farm and producer risk factors and producer willingness to purchase insurance is seldom available. Faced with these challenges, the National Risk Management Feasibility Program for Aquaculture (NRMFPA) concluded collecting the following farm-level information from a producer survey is the most appropriate method to obtain data required to understand risk factors affecting losses and the estimation of frequency and magnitude by specific perils. The NRMFPA contracted with the National Agricultural Statistics Service (NASS) to survey catfish producers to obtain historical (objective data) and future production/loss information (subjective data).

Data

NASS conducted the Risk Management for Aquaculture survey from July 1, 2005, through August 12, 2005, in a total of 29 states. The catfish survey was administered in a total of 11 states (Alabama, Arkansas, California, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, and Texas). The catfish survey is a complete enumeration of all catfish producers in eight of the eleven states, with sampling taking place in the three largest production states of Mississippi, Arkansas, and Alabama. A total of 1,201 catfish producers within the 11 states were contacted and surveyed in person using enumerators. Four hundred twenty-four producers were screened out and 777 useable surveys (73% response rate) remained with only 567 completing the survey.

In order for a producer to complete a Risk Management for Aquaculture Survey, the producer's operation must have produced catfish in ponds for human consumption and the producer must have intended to produce in 2006 at the time of the survey. If the producer satisfied these criteria, then a face-to-face interview was completed. The producer had to be planning to produce in the next year and be a commercial food fish producing operation. Below are the two questions from the catfish survey instrument that qualified respondents to continue with the survey.

1. During 2006, do you plan to continue your catfish operation by managing catfish in ponds? (required answer: yes)

2. Is your catfish operation a non-profit organization (such as a research facility or for public recreation)? (required answer: no)

Information was collected on producer socio-demographics, farm characteristics, production, historical losses and subjective future loss estimates. Farmer characteristic information included questions concerning the number of years the owner/manager had been producing catfish, level of education, age, operation ownership, past insurance purchase, willingness to take financial risks, household income, market value of assets, and percent of total investments that was borrowed. Production practice information obtained included the production system in use, number of water acres in production, number of fish stocked, feed fed, pounds of catfish produced, and the number of employees. Physical farm characteristic information included the furthest distance between the most remote pond group and management headquarters; shortest distance between any ponds and another catfish operation; average age of the ponds; average water ponds depth of ponds; number of catfish ponds in an operation; how often ponds were reworked, and the primary water source. On-farm equipment information collected included the number of back-up electrical generators; the amount of electrical horsepower for aeration purposes; and the number of tractor-powered paddlewheels for aerations purposes.

Catfish loss event information collected included the number of times in the past ten years that the producer incurred a loss of more than five percent of the expected total annual production. Specific information on the three largest catfish losses over the past ten years was also collected. The producers had a check list of perils to choose from as well as an "other" category if a loss experienced was not available. The complete survey can be found in Appendix A.

The Double Limit Tobit Model

A double limit tobit model was used to explain the percentage of catfish losses from weather related events and from disease outbreaks in two separate models by evaluating risk factors that included producer and farm characteristics and production practices. The percentage of catfish losses was calculated using survey responses to questions concerning the three largest historical losses a producer had experienced in the last ten years, the specific cause of loss, and the expected production during the year the loss occurred.

The dependent variable of each model was the percentage of catfish losses due to weather-related events and the percentage of catfish losses from catfish diseases. The dependent variable was expected to contain a significant fraction of observations that would be zero. Since the dependent variable is the percentage of loss, i.e., loss divided by the production and would be in the range from of zero to one, use of the tobit model instead of the traditional OLS model is appropriate because the dependent variable is a percentage and must fall between 0 and 1. The double limit tobit model is appropriate for analyzing data that cannot take on values above or below a certain limit.

The tobit model, developed by James Tobin in 1958, is known as the limited dependent variable regression model because of the restrictions put on the values taken by the regressand (Gujarati 2002). The tobit model can be generally expressed as:

$$(1) \qquad Y_i = \beta' x_i + u_i \qquad \textit{if the RHS} > 0$$
$$Y_i = 0 \qquad \textit{otherwise}$$

The double limit tobit model can be expressed as follows:

$$(2) \qquad Y_i^* = \beta' x_i + u_i$$
$$Y_i = 0 \quad \textit{if} \quad Y_i^* \leq 0$$
$$Y_i = Y_i^* \quad \textit{if} \quad 0 \leq Y_i^* \leq 1$$
$$Y_i = 1 \quad \textit{if} \quad Y_i^* \geq 1$$

Where Y_i^* represents percentage losses due to a fall/spring diseases or weather related events. This variable is only observed for values that fall between 0 and 1. X_i represents the various vectors that could possibly affect Y_i^*. β represents the parameters of unknown coefficients, and u_i represents the normally distributed error term with zero mean and constant variance. The effect of the censoring of the tobit model creates an observed and unobserved portion of data.

The log-likelihood function of the lower limit censored model is expressed as:

$$(3)\quad \ln L = \sum_{y=L_i} \ln \Phi \left[\frac{y_i - x_i \beta}{\sigma} \right] + \sum_{L_i < y_i} \ln \frac{1}{\sigma} \phi \left[\frac{y_i - x_i \beta}{\sigma} \right]$$

The log-likelihood function of the upper limit censored model is expressed as:

$$(4)\quad \ln L = \sum_{y<R_i} \ln \frac{1}{\sigma} \phi \left[\frac{y_i - x_i \beta}{\sigma} \right] + \sum_{y_i = R_i} \ln \left[1 - \Phi \left(\frac{R_i - x_i \beta}{\sigma} \right) \right]$$

where L is left (lower) and R is right (upper) bound of the observed portion of the dependent data. Φ is the cumulative density function of the standard normal distribution and ϕ is the probability density function of the standard normal distribution (www.support.sas.com; Greene 2003)

The double limit tobit model is evaluated using the **Q**ualitative and **LI**mited dependent variable **M**odel procedure (QLIM) in SAS. The QLIM procedure analyzes models where the dependent variable takes on discrete values or is observed only in a limited range of values. The standard tobit model is estimated by specifically stating the endogenous variable to be truncated or censored. The double limit tobit model however requires that the model has an upper and lower bound (www.support.sas.com).

Marginal Effects – Tobit Models

One of the weaknesses of the tobit model is that the coefficients of the model cannot be interpreted as traditional regression coefficients. This often leads to misinterpretation of the coefficients which is why the marginal effects of the tobit model must be calculated to determine the effect each explanatory variable has on the endogenous variables. The marginal effect of an explanatory variable is the partial derivative of the event probability with respect to a specific explanatory variable tells how much the event probability changes when that specific explanatory variable changes by one unit (www.support.sas.com and Greene 2003). The marginal effect is expressed as:

(5) $$\frac{\partial E[y_i | x_i]}{\partial x_i} = \beta \ x \ Prob[L_i < y^*_i < R_i]$$

The calculation of marginal effects for dummy variables is different from the above equation. To obtain accurate marginal effects for dummy variables, cumulative distribution function (Φ), of the regression must be divided by sigma (σ) for the dummy variable valued both at one and zero. Next, the cdf/sigma value at zero is subtracted from the cdf/sigma valued at one, and then multiplied by the initially calculated dummy variable coefficient (Greene 2003).

To estimate the risk factors affecting percentage losses due to weather and disease occurrences the following equation was used:

(6) $$Y_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + u ,$$

where Y_i represents the LHS variables: *LweatherP* and *LdiseaseP*. X_i represents a set of explanatory variables that could affect Y_i. Explanatory variables common to both models are education (X_1), pond water depth (X_2), and the number of ponds on an operation (X_3). Added explanatory variables for the weather model (LweatherP) are: dummy variable for the type of productions system in use (X_4), a dummy variable indicating whether an historical loss (within the last ten years and greater than 5 percent of on-farm inventory) from oxygen depletion due to electrical breakdown from off-farm causes (X_5), a dummy variable indicating whether an historical Columnaris/ESC disease event had occurred (X_6), and a regional dummy variable South (X_7). Added explanatory variable for the disease model *(LdiseaseP)* are experience (X_8) and pond age (X_9).

McDonald and Moffit (1980) showed that the tobit model can be decomposed for better analysis of the coefficients. They found that tobit coefficients can be used to determine changes in probability of being above the limit and the changes in the value of the dependent variable if it is already above the limit.

Theoretically the tobit model utilizing the McDonald-Moffit decomposition should began:

$$(7) \qquad \begin{aligned} Y_t &= X_t\beta + u_t && \text{if } X_t\beta + u_t > 0 \\ Y_t &= 0 && \text{if } X_t\beta + u_t \le 0 \\ & && t = 1, 2, \ldots\ldots N \end{aligned}$$

where N is the number of observations, Y_t is the dependent variable, X_t is a vector of independent variables, β is the vector of unknown coefficients, u_t is the normally distributed error term.

The expected value of Y in the model is:

$$(8) \qquad Ey = X\beta F(z) + \sigma f(z),$$

where $z = X\beta/\sigma$, $f(z)$ is the unit normal density and F(z) is the cumulative normal distribution function. The expected value of Y for observations above the limit, Y^*, is $X\beta$ plus the expected value of the truncated normal error term.

$$(9) \quad EY^* = E(y|y>0)$$

$$= E(y|u > - X\beta)$$

$$= X\beta + \sigma f(z)/F(z)$$

The decomposition method McDonald and Moffitt (1980) obtained considering the partial effect of a change in the i^{th} variable of X on y:

$$(10) \quad \delta Ey/\delta X_i = F(z)(\delta Ey^*/\delta X_i) + Ey^*(\delta F(z)/\delta X_i)$$

The total change in y can be disaggregated into two parts: 1) the change in y of those above the limit, weighted by the probability of being above the limit, and 2) the change in the probability of above the limit, weighted by the expected value of y if above the limit (McDonald and Moffit 1980).

Also, Roncek (1992) used McDonald and Moffitt's decomposition in a study concerning the austerity protests in debtor nations. He used the decomposition method to determine two effects: 1) an effect representing an increase in the severity of protests in countries that have experienced protests, and 2) an effect representing a change in the probability of experiencing austerity protests in countries that recorded no protests at all.

Ordinary Least Squares (OLS) Regression Analysis

A liner regression model was used to explain efficiency on catfish operations through feed conversion ratios (FCR). FCR was calculated by multiplying expected tons of feed fed in 2006 (multiplied by 2000 to put it into pounds) and dividing by expected pounds of catfish produced in 2006. The traditional OLS model was used for this model because of the expectation of a linear relationship between the dependent and independent variables. The regression model was estimated using the Proc Reg procedure in SAS.

Gujarati expresses the linear regression model as:

(11) $Y_i = \beta_0 + \beta_i' X_i + u_i$

where Y_i represents the endogenous variable; FCR. X_i represents a vector of explanatory variables that could affect Y_i. β_i represents the parameters of unknown coefficients, β_0 represents the intercept coefficient, and u_i represents the normally distributed error term with zero mean and constant variance (Gujarati 2002).

The following equation was used to estimate the FCR model,

(12) $$Y_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + u ,$$

Explanatory variables in the FCR model are education Age (X_1), Education (X_2), Experience (X_3), expected number of water acres to be used in production (X_4), percentage of fry-fingerlings expected to be purchased off farm (X_5), percentage of fish expected to be custom harvested (X_6), type of production system (X_7), Age/Experience (X_8), percentage of fish expected to survive until 2006 harvest (X_9), expected stocking rates for fry (X_{10}), expected stocking rates for fingerlings (X_{11}), expected stocking rates for stockers (X_{12}), expected amount of electrical horsepower for aeration (X_{13}), and expected number of tractor powered paddle wheels expected for aeration (X_{14}).

Tobit Model Variables

The following section gives more insight on the explanatory variables, why they were chosen for this study, and how they are anticipated to affect the dependent variable.

Weather Loss Model Variables

Table 3.1 lists the explanatory variables used in the weather loss model.

Table 3.1 Weather Loss Model Variables and Expected Signs.

Variable Name	Explanation	Expected Sign
Education (Edu)	High School or less = 1 and >HS =0	(+)
Num_Ponds	Number of ponds on an operation (scaled: divided by ten)	(+)
Pond depth	The average water depth (feet) of catfish ponds	(-)
Psystem	Production system type where multiple batch = 1 and single batch plus modular = 0	(+)
LoxygenD	The occurrence of a past fish loss from oxygen depletion[a] = 1, else = 0	(+)
Lcolumnaris_escD	The occurrence of a past fish loss from the COL and/or ESC disease[b] = 1, else = 0	(+)
South	Regional dummy for the southern states of MS, AL, AK, LA = 1, other states = 0	(+)

[a]LoxygenD represents oxygen depletion due to electrical breakdown from off-farm causes
[b]Lcolumnaris_escD represents losses from columnaris disease, enteric septicemia of catfish or a combination of columnaris/enteric septicemia

Education is expected to be positive. The less educated the producer, it is expected that they are less likely handle losses from weather events and therefore losses will increase. The number of catfish ponds on an operation is expected to have a positive relationship meaning as the number of ponds on an operation increases, losses will increase because more ponds are affected by a weather occurrence and the more challenging it will be for management to deal with all ponds in a short time period. Average water depth of ponds is expected to have a negative sign also showing an inverse relationship. As pond depth increases, catfish losses will decrease from the occurrences of weather events such as lightning storms, droughts, and freezing of ponds. The production system variable is expected to have a positive effect indicating that multiple batch systems would increases losses, while as a single batch production system would decrease losses from weather related events. This could be attributed to the fact that multiple batch systems contain a variety fish sizes and a loss from a weather related cause would definitely kill valuable larger fish as well as smaller categories of fish. Depending on when the weather loss event occurs the single batch system will only have one year class of fish in each pond. Thus, if it is early in the production cycle the fish will be smaller and have a lower value, but if the production cycle is far along, then all fish in the pond will be larger and more valuable. Typically, on a medium size farm using the single batch system there ponds will be in various stages of fish production and size/value.

A positive sign is expected for the LoxygenD variable. LoxygenD represents oxygen depletion due to electrical breakdown from off-farm causes. A positive sign would indicate that one of the three largest historical losses was from oxygen depletion and would be thought to increase losses due to weather events in the future. The logic here is that supplemental oxygen is required for the operation as the producer is holding many pounds of fish above the natural carrying capacity of the system and any off-farm disruption of power to electrical aerators would again result in losses.

The dummy variable for Lcolumnaris_escD is expected to have a positive sign indicating that the combination of columnaris/enteric septicemia of catfish was one of the three largest historical losses noted by farmers, and indicates the presence of these diseases and their potential for losses again under severe weather events. The regional dummy variable representing the southern states where catfish is grown is expected to be positive because of possible severe weather conditions in the southern region.

Disease Loss Model Variables

The following table lists the explanatory variables used in the disease loss model.

Table 3.2 Disease Loss Model Variables and Expected Signs.

Variable name	Explanation	Expected Sign
Experience	The number of years the respondent has been producing catfish	(-)
Education	High School or less = 1 and >HS =0	(+)
Pond Age	The average age of the ponds on the catfish operation	(-)
Pond depth	The average water depth (feet) of catfish ponds	(-)
Num_Ponds	Number of ponds on an operation (scaled: divided by ten)	(+)

The number of years one has been producing catfish represents an experience variable and is expected to be inversely related to losses. As the number of years a manager has been producing catfish increases, losses due to diseases are likely to decrease due to gained experience/knowledge in early disease detection and quick, correct preventative techniques being applied to control losses. Education is expected to have a positive relationship, with lower levels of formal education resulting in increased losses from disease events.

The expected sign for the pond age variable is negative because older ponds are expected to decrease disease losses. New or reconstructed ponds seem to increase the occurrences of proliferative gill disease (PGD), but do not increase the occurrence of other common diseases such as COL or ESC. The average pond depth variable is expected to be positive indicating that shallower pond could see more sediment build-up and less pond water volume in the pond resulting in a higher fish density which can stress fish and make them more susceptible to diseases. The number of catfish ponds on an operation is expected to have a positive relationship meaning as the number of ponds on an operation increases, more ponds could be affected by disease outbreaks. This, in turn, could limit the ponds receiving quick mitigating actions from management. Appropriate medicated feed applications would also be very expensive to treat and could become a cash flow consideration in the timeline of treatment actions.

Feed Conversion Ratio (FCR) Efficiency Model Variables

The following table lists the explanatory variables used in the FCR efficiency model.

Table 3.3 Catfish Efficiency Model Variables and Expected Signs.

Variable Name	Explanation	Expected Sign
Age	Age of catfish operator	(-)
Education (Edu)	High School or less = 1 and >HS =0	(+)
Experience	Number of years operator has been producing catfish	(-)
Age_Experience	Age interacting with experience	(-)
SurvivalPercnt	Expected survival percentage of fish stocked until projected harvest in the next year	(-)
TotalWaterAcres	Total water acreage expected to be used in the next production year	(-)
FFPurchasePercnt	Percentage of fry and fingerlings expected to be purchased from off-farm sources	(-)
AvgStockFry	Expected average fry stocking rate (#/acre) in the next production year	(-)
AvgStockFing	Expected average fingerling stocking rate (#/acre) in the next production year	(-)
AvgStockStock	Expected average stocker stocking rates (#/acre) in the next production year	(-)
CustHarvstPercnt	Percentage of harvested fish expected to be custom harvested in the next production year	(-)
ElecAer	Electrical aeration horsepower expected to be available for the next production year	(+)
PddlAer	Number of tractor powered paddlewheels expected to be available for the next production year	(+)
Psystem	Production system type where multiple batch = 1 and single batch plus modular = 0	(+)

Age, experience, and the interactive age_experience variable are expected to have inverse relationships to the feed conversion ratio (FCR). As age and experience increase, the efficiency of the catfish operation should increase, thus the feed conversion ratio should decrease due to increased knowledge and skills developed related to managing the operation for greater production. Education is expected to have a positive relationship FCR. Producers with high school level education or below are expected to increase the feed conversion ratio.

The variables for the percentage of fish stocked in ponds and expected to survive until harvest (SurvivalPercnt), average stocking rate for fry (AvgStockFry), average stocking rate for fingerlings (AvgStockFing), and average stocking rate for stockers (AvgStockStock) are also expected to have an inverse relationship to the efficiency of the farm operation as measured by the overall farm FCR. The logic for the indirect relationship is that the larger these variables are, the larger the expected pounds of production will be, which the denominator of the FCR calculation is. The numerator of the FCR model is the actual pounds of fish produced, and this value excludes fish that have eaten feed but died before harvest, thus efficiency as measured by FCR, also includes the concept of good management, that is keeping the stocked fish alive until harvest. As the denominator of the FCR equation becomes larger the FCR will become smaller or more efficient.

As the total amount of water acres increases on an operation (TotalWaterAcres), total fish production is expected to increase which will decrease FCR, as in the case with the stocking variables. However, it could be argued that more ponds on an operation will increase total water acres but will also increase FCR. This is because more ponds on an operation may result in laborers over- or under-feeding fish since all ponds must be fed within the same twenty four hour period (actually less than 24 hours as feeding at night is not routine).

The two aeration variables, the amount of fixed aeration electrical horsepower (ElecAer) and number of tractor powered paddlewheels (PddlAer), could be either positive or negative. Aeration in sufficient amounts at critical times help the catfish grow and survive when dissolved oxygen levels are near saturation (8 to 14 mg/L). However, not having sufficient aeration when dissolved oxygen levels are low in ponds for prolonged periods of time can possibly kill fish and ultimately increase your FCR (Tucker 2005; Tucker et al. 2005).

The percent of fry and fingerlings purchased off-farm is expected to decrease FCR as specialization in foodfish production allows more time and effort toward this effort, so the sign for this variable is expected to be negative. Likewise, for the custom harvest percentage, with farm labor directed toward producing fish and not distracted by harvesting, the efficiency of the farm is expected to improve, and thus, the sign for this variable is expected to be negative.

The production system dummy variable (Psystem) is expected to indicate that the use of the multiple batch production system would increase FCR as not all size classes of fish get all the feed they need daily due to competition among fish sizes and water quality concerns limiting the amount of feed that can be put into a pond each day. Single or modular batch production systems have been shown to be more efficient but are not in use by the majority of producers because they do not effectively manage off-flavor problems as well as multiple-batch production systems. So, in contrast to the prior statements, it could be said that the multiple-batch production system could lower the FCR as it allows some on-flavor catfish to be harvested at any given time and this would increase overall pounds produced (and harvested).

CHAPTER IV

RESULTS

The intended purpose of this research is two-fold: 1) to analyze the effect that certain explanatory variables have on the probability of losses due to weather events and losses due to disease above that which normally occurs on catfish operations; and 2) to identify variables that significantly affect catfish farm operation efficiency as measured by feed conversion ratio. This chapter will present and analyze the results of the models developed.

Descriptive Statistics for the Weather Loss Model

Summary statistics for the variables included in the weather loss model are presented in Table 4.1. The weather loss variable indicates that 0.22 % of losses occurring on catfish farms are from events such as freezing of the pond, flooding, droughts, windstorms, tornados, lightning, and hurricanes. The mean of the education variable indicates that forty-eight percent of producers had a high school diploma or less education. The mean number of ponds on a catfish operation was approximately 20, with a range from one pond to the largest farm having 713 ponds. The mean of the production system variable (Psystem) indicates that 80 percent of producers use the multiple batch system and only 20% use either the single batch or modular production system. The average pond depth was approximately 5.5 feet deep, with a minimum water depth of 0.4

feet and a maximum depth of 20.5 feet. From the three largest historical loss events on farms, 30.8 % of losses were reported to be from oxygen depletion due to electrical breakdown from off-farm causes, and 17.7 % of these historical loss events were from columnaris, ESC, or a combination of these two diseases. The mean of the regional "South" dummy variable indicates that 69 % of respondents were from the southern states of Mississippi, Arkansas, Alabama, and Louisiana.

Table 4.1 Descriptive Statistics for the Weather Loss Model.

Variable Name	N	Mean	Std Dev	Min	Max
LweatherP	553	0.0022	0.0149	0.00	0.10
Education	553	0.4896	0.6360	0.00	1.00
Num_Ponds [1]	553	1.9945	6.5396	0.10	71.30
Psystem	553	0.8003	0.5085	0.00	1.00
Pond Depth	553	5.4878	2.7710	0.40	20.50
LoxygenD	553	0.3077	0.5872	0.00	1.00
Lcolumnaris_escD	553	0.1774	0.4860	0.00	1.00
South	553	0.6941	0.5863	0.00	1.00

[1]variable scaled by 10

Descriptive Statistics for the Disease Loss Model

Of the three largest historical losses, approximately 53.2 percent of losses were due to ESC, columnaris, PGD, and winter fungus diseases, Table 4.2. The mean of the experience variable, that is the number of years the operator has been growing catfish, is approximately 13.7 years, with a minimum number of experience years being one and the maximum number of experience years was 54. As with the weather loss model, the education indicates that approximately 48.9 percent of producers have a high school diploma or less. The mean for the pond depth variable is 5.5 feet. The mean for the number of ponds variable has not changed from the previous model, and is approximately 20 ponds per operation. The mean of the pond age variable was approximately 11.8 years with a range from one to 50 years.

Table 4.2 Descriptive Statistics for the Disease Loss Model.

Variable Name	N	Mean	Std Dev	Min	Max
LdiseaseP	556	0.0053	0.01824	0.00	0.10
Experience	556	13.7059	11.4390	1.00	54.00
Education	556	0.4886	0.6344	0.00	1.00
Pond Age	556	11.7929	10.0507	1.00	50.00
Pond Depth	556	5.4940	2.7664	0.40	20.50
Num_Ponds[1]	556	1.9837	6.525	0.10	71.30

[1]variable scaled by 10

Descriptive Statistics for the Catfish Efficiency Model

The mean of the calculated catfish feed conversion ratio (*cat_fcr*) was 2.36, while the lowest FCR was 1.50 and the highest FCR was 5.00, Table 4.3. The average age of producers in 2005, the year the survey was administered, was 54 with the oldest producer being 88 years old and the youngest being 24. The average number of years of operator experience was 13.8, with 54 and 1 years being the highest and lowest respectively. The interactive term, Age_Experience, is calculated by multiplying the age of the producer by the number of years in the catfish operation.

The education variable mean indicates that 45 percent of producer had a high school diploma or less. Producers believed that approximately 87 percent of the fish stocked in ponds would survive until the 2006 harvest. The average number of total water acres on an operation was 180, with a maximum 8,308 acres and a low of one acre. Approximately 61 percent of fry and fingerlings were expected to be purchased off farm (FFPurchasePercnt) in 2006. Some producers reported no purchases off-farm while other producers reported they expected to buy all fry and fingerlings off farm. The average expected stocking rates (fish/acre) for fry, fingerling, and stockers in 2006 were expected to be 79,930, 13,610, and 599, respectively.

The expected percentage of custom harvested catfish (CustHarvstPercnt) was approximately 53 percent for the 2006 production year. The electric and paddlewheel aeration variables, ElecAer and PddleAer, respectively, had an average total electrical horsepower of 296 and an average number of paddlewheels on the farm for aeration purposes of eight. The production system variable in this model indicated that 79 percent of producers preferred to use the multiple batch production system over the single-batch or modular production systems.

Table 4.3 Descriptive Statistics for the Catfish Efficiency Model.

Variable Name	N	Mean	Std Dev	Min	Max
Cat_fcr	372	2.36	0.71	1.50	5.00
Age	558	1951.49	12.74	1917.00	1981.00
Age_Experience	555	26886.97	18191.76	1957.00	104112.00
Education (Edu)	567	0.45	0.50	0.00	1.00
Experience	564	13.82	9.33	1.00	54.00
SurvivalPercnt	560	86.80	10.22	40.00	100.00
TotalWaterAcres[1]	553	18.02	52.68	0.10	830.80
FFPurchasePercnt	558	61.05	46.88	0.00	100.00
AvgStockFry[2]	180	79.93	107.09	0.01	900.00
AvgStockFing[2]	452	13.61	25.66	0.01	300.00
AvgStockStock[3]	223	5.99	8.27	0.02	50.00
CustHarvstPercnt	563	53.12	49.06	0.00	100.00
ElecAer[3]	545	2.96	8.64	0.00	105.00
PddlAer	564	8.13	18.47	0.00	200.00
Psystem	567	0.79	0.41	0.00	1.00

[1]variable scaled by 10, [2]variable scaled by 1000, [3]variable scaled by 100

Empirical Results

The results of the following models were obtained by utilizing the double limit tobit model and simple OLS regressions. Explanatory variables included in the weather loss model are education, the number of ponds on an operation, pond depth, production system, historical large losses from oxygen depletion due to off-farm power outages (dummy variable), historical large losses from COL/ESC (dummy variable), and a regional South variable. The explanatory variables included in the disease loss model are experience and educational levels of the operator, pond age, pond depth and the number of ponds on a catfish operation.

The explanatory variables included in the catfish efficiency (FCR) model are age, education and experience of the operator, age/experience interactive variable, stocked fish survival (SurvivalPercnt), expected water acres in next year's production (TotalWaterAcres), percent of fry and fingerlings expected to be purchased off-farm for next year's stocking (FFPurchasePercnt), expected average fry stocking rate (AvgStockFry), expected average fingerling stocking rate (AvgStockFing), expected average stocker stocking rate (AvgStockStock), percent of fish that will be custom harvested (CustHarvstPrcnt), electrical aeration horsepower in operation (ElecAer), number of tractor paddlewheel horsepower (PddlAer), and production management system (Psystem).

Weather Loss Model

The results of the weather model show all explanatory variables to be statistically significant, Table 4.4. The parameter coefficients for number of ponds on a catfish operation and pond depth are signed positively while education, production systems (Psystem), losses from oxygen depletion (LoxygenD), losses from columnaris/esc (Lcolumnaris_escD), and the regional dummy variable are all negatively signed. However the marginal effect coefficients indicate a positive relationship for all variables in the event that weather related loss would occur. The results for both number of ponds on an operation (Num_Ponds) and pond depth (Pond Depth) indicate that a decrease in both will cause a decrease in losses due to weather events. The number of ponds variable can be interpreted as a 10 percent decrease in ponds leads to a 0.012 percent decrease in the percentage of catfish lost from weather-related events. An obvious explanation is that increasing farm size, as measured by additional ponds, will possibly increase the total number of ponds exposed to weather events. A reduction in pond depth resulted in a 0.326 percent reduction in catfish losses from weather events.

The results of the education variable can be interpreted as any degree below high school will increase losses by 0.2 percent. This was expected because it was hypothesized that lower levels of education would not prepare an operator for such events as weather and disease. However, educational practices learned by producers with degrees higher than a high school diploma may not be practical for on-farm situations and would thus increase the losses, also. Productions system results show that using a multiple batch system would increase losses as opposed to using a single batch / modular system by 0.098 percent. A possible explanation may be that the most common production system employed by producers may have been the multiple batch system, where stocking densities are increased by moving fish from one pond to the multiple ponds as the fish grow out. If more producers used this type of production system; the occurrence of a weather event would decrease a percentage of total fish production.

The past experience of losses from oxygen depletion would increase losses by 0.195 percent. The LoxygenD variable tells us that producers did in fact experience losses from oxygen depletion due to off farm causes, and these off-farm causes could have been such has tornadoes, windstorms, or flooding. These specific weather events could have adversely affected farm equipment causing aerators not to function properly, leaving farmers with inadequate amounts of aeration. The Lcolumnaris_ecsD variable indicates that a past experience of columnaris disease or enteric septicemia of catfish would cause a 0.558 percent increase in losses from weather events. A possible explanation for Lcolumnaris_escD, could be that the experience gained from past disease losses resulted in better risk management mitigation techniques for disease losses, and did not prepare producers for losses from weather events since weather events are very rare and most of the losses associated with a catfish production are from the various diseases.

The regional dummy variable South was statistically significant showing that the southern states of Mississippi, Arkansas, Alabama, and Louisiana are 0.67%more likely to experience weather losses than other regions in the US. This is partly due to diverse weather patterns for the southern region of the country. Since the majority of catfish production comes from the southern states of Mississippi, Alabama, Arkansas, and Louisiana, we have to take into the account of the different weather patterns that these states may face during a year. Our left hand side variable for weather includes freezing of the pond, flooding, droughts, windstorms, tornados, lightning, and hurricanes the

Arkansas and Mississippi deltas often experience floods and lightning storms. East Mississippi and Alabama catfish producers experience tornadoes and lightning. Louisiana producers could experience flooding and hurricane losses.

Table 4.4 Tobit Regression Results Along with Marginal Effects for Percent Losses Due to Weather Related Events.

Parameters	Estimates	Marginal Effects	t value	Pr > |t|
Intercept	-0.069139		-3.36	0.0008
Education	-0.37043	0.00200	-2.73	0.0062
Num_Ponds	0.002184	0.00012	2.69	0.0072
Psystem	-0.026180	0.00098	-2.03	0.0423
Pond Depth	0.005765	0.00326	2.79	0.0053
LoxygenD	-0.058429	0.00195	-3.45	0.0006
Lcolumnaris_ESCD	-0.056249	0.00558	-2.18	0.0293
South	-0.072495	0.00676	-4.80	<.0001
Sigma	0.073476		8.24	<.0001
Log Likelihood	-33.10936			
Max Absolute Gradient	3.37256E-7			
Number of Iterations	36			
AIC	84.21872			
Schwarz Criterion	127.37498			

Disease Loss Model

The results of the disease model shows the significant variables in the model are experience and pond depth, Table 4.5. The parameter coefficients and the marginal effects indicate that these two variables have an indirect relationship on disease losses. The number of years one has been producing catfish (experience) was expected to decrease catfish losses as producers gain experience in handling outbreaks and more knowledge about diseases and preventative techniques to control losses. For each additional year of experience a farmer has, losses due to disease will by 0.015 percent. Education level is not significant, which indicates experience on the farm explains risk reductions better than education level attained.

Pond depth results indicate that an increase in pond depth yields a 0.114 percent decrease in catfish losses due to diseases. Many catfish producers in the east Mississippi and west Alabama have been using deeper ponds than those in the Mississippi Delta. Records for east Mississippi producers indicate greater production per water acre as compared to the Mississippi Delta. This could mean reduced mortality for east Mississippi producers but the data is not readily available for analysis (Hanson et al. 2007).

The negative sign on the pond depth variable in the disease model is in contrast to the positive coefficient sign for the same variable in the weather-related loss model. Since the majority of losses on farms are disease-related, the average producer may be better off increasing pond depth in line with reducing disease loss chances, i.e., adopting measures to increase pond depth, rather than making pond depth decisions in line with reducing weather loss chances (decreasing pond depth). The number of ponds on an operation was also found to be insignificant. This variable was included in the model based on the hypothesis that the larger the farm operation (meaning the actual number of ponds), the larger the losses caused by diseases. However, according to these results, this is not the case.

Table 4.5 Tobit Regression Results Along with Marginal Effects for Percent Losses Due to Disease Related Events.

Parameters	Estimates	Marginal Effects	t value	Pr > |t|
Intercept	0.011595		1.70	0.0898
Experience	-0.000588	-0.00015	-2.57	0.0103
Education	0.004113	0.00002	1.29	0.1979
Pond Age	-0.000474	0.00001	-1.83	0.0672
Pond Depth	-0.004367	-0.00012	-4.10	<.0001
Num_Ponds	-0.000035540	-0.00114	-0.12	0.9081
Sigma	0.035066			

Log Likelihood	1.9926908
Max Absolute Gradient	0.0002343
Number of Iterations	18
AIC	-384.53817
Schwarz Criterion	-350.96969

To obtain the frequency of losses for the weather and disease models, two elements are required to calculate the expected percentage loss for a peril: the conditional percent loss and the frequency percent loss. The conditional percent loss is the aggregated pounds lost to a specific peril divided by the expected production during the years in which the specified perils caused large losses. The frequency percent loss is the probability of any loss greater than 5 percent occurring on an operation over the last ten years multiplied by the probability that a specific peril was reported in the top three largest historical losses, Table 4.6 (Hanson et al. 2007).

The total probability of experiencing losses to weather events and various diseases is 1.35 and 6.78 percent respectively. Flood and drought have the highest probabilities (0.52 percent) of occurring in respect to weather variables. The probability of losses from windstorm, tornado, lightning, and hurricane is most unlikely with a probability of only 0.20 percent. The total probability of experiencing losses to diseases is 6.78 percent. The combination of columnaris/esc has the highest probability of occurring at 2.07 percent and for each disease singularly, the probability of columnaris disease related catfish deaths is 1.02 percent and 0.32 percent for enteric septicemia of catfish. The probability of catfish death by proliferative gill disease and saprolegnia are 1.45 percent and 1.15 percent, respectively.

Table 4.6 Annual Expected Percent Loss of Catfish from Weather and Disease Perils.

Peril	N	Pounds Lost[1]	Production Pounds Expected	Conditional Percent Loss	Frequency Percent	Expected Percent Loss
Weather Loss Perils						
Freezing of Pond	*	1,960,212	35,670,346	5.50	0.10	0.01
Flood	21	594,614	872,804	68.13	0.52	0.36
Drought	21	1,083,247	16,631,889	6.51	0.52	0.03
Windstorm, tornado, lightning,or hurricane	*	546,942	5,924,393	9.23	0.20	0.02
Total					1.35	0.42
Disease Loss Perils						
Columnaris	41	2,878,938	22,783,916	12.64	1.02	0.13
Enteric Septicemia	13	452,323	5,929,004	7.63	0.32	0.02
Col/ESC	83	8,872,665	116,978,409	7.58	2.07	0.16
Channel Catfish Virus	10	8,534,388	55,424,877	15.40	0.25	0.04
Proliferative Gill Disease	58	5,071,735	53,877,039	9.41	1.45	0.14
Saprolegnia(Winter Fungus)	46	4,275,463	62,104,378	6.88	1.15	0.08
Ich/white spot disease	21	1,216,311	13,411,585	9.07	0.52	0.05
Total					6.78	0.61

* Not published to avoid disclosure of individual operations.
[1]Cumulative loss total includes first, second, and third largest losses over the prior ten years of production.
Source: NRMFPA project

Catfish Efficiency Model

There were a total of 66 observations used in the FCR model with an R-Square value of 0.47 indicating the model variables explain 47% of the variability of the dependant variable. The results of the catfish feed conversion ratio model indicates that there are several significant explanatory variables at the 5% level, Table 4.7. Model

Table 4.7 Empirical Results for the Catfish Efficiency Model.

Variable Name	Parameter Estimates	Std Error	t-value	Pr > |t|
Intercept	102.56508	24.59705	4.17	0.0001
Age	-0.05175	0.01259	-4.11	0.0001
Education (Edu)	-0.23687	0.21933	-1.08	0.2852
Experience	-4.26995	1.10132	-3.88	0.0003
Age_Experience	0.00219	0.00056618	3.86	0.0003
SurvivalPercent	0.02165	0.00849	2.55	0.0139
TotalWaterAcres	0.00093588	0.00135	0.69	0.4920
FFPurchasePercnt	-0.00505	0.00215	-2.35	0.0229
AvgStockFry	-0.00092633	0.00069847	-1.33	0.1907
AvgStockFing	-0.00019231	0.00366	-0.05	0.9583
AvgStockStock	-0.01500	0.01047	-1.43	0.1578
CustHarvstPercnt	-0.00226	0.00201	-1.12	0.2678
ElectricalAeration	-0.00751	0.00565	-1.33	0.1896
PddlwheelAeration	0.00077905	0.00416	0.19	0.8523
Psystem	-0.45691	0.23135	-1.97	0.0537
R-Square	0.4765			
Adj R-Square	0.3328			
F Value	3.32			
Pr > F	<.0008			

results show that age, experience, survival, off-farm fry/fingerling purchases, age/experience (interactive), and production system (at 5.37 alpha level) variables are significant.

Three farmer attribute variables covering age (measured as birth year), experience (number of years spent producing catfish), and an age/experience interactive term are significant and must be considered together to correctly interpret their effects on the dependent variable, FCR. Age and experience variables have negative signs, while the age/experience interactive term is positive. Interpretation of the age variable can be tricky as birth year of the operator is being used as a proxy for actual age. Thus, the interpretation of the age variable coefficient indicates that as the birth year decreases, FCR increases, that is, as one becomes older, FCR increases by 0.05175 percent. Thus, there is a decrease in efficiency as the age of the operator increases.

The experience variable coefficient also has a negative sign, and an increase of one year in experience would decrease FCR by 4.27%, which is good, as a lower feed conversion ratio indicates a more efficient operation. However, with opposite FCR directions from these two variables, the age/experience interactive term becomes important in determining the actual effect of operator age and years of catfish producing experience on farm efficiency as measured by feed conversion ratio.

The interpretation of the interactive variable age/experience is less straight forward than interpreting the parameter estimates of non-interactive variables in OLS linear regression models. The partial derivative with respect to any non-interactive variable the beta coefficient value is the effect on the dependent variable from a one unit change in the variable. In the case of the interactive term, in this case the

Age_Experience variable, the change in FCR with respect to a change in Age for the Age_Experience variable is the beta coefficient for the Age variable plus the beta coefficient for the Age_Experience variable multiplied by the Experience variable mean. Put into an equation form, using only the age, experience and age_experience variables from the FCR model for this example and holding the other variables constant, the equation would be:

(13) $FCR = b_0 + b_1Age + b_2Experience + b_3Age\_Experience$

When actual beta values from the FCR model results are entered, the equation is:

(14) $FCR = 102.565 - 0.05175Age – 4.26995Experience + 0.00219Age\_Experience$

When taking the derivative of the Age variable, you get the change in FCR with respect to the change in Age equaling $b_1 + b_3$*Experience variable mean, as the value to interpret for the Age and Age/experience variables and the result will be:

(15) $FCR = -0.05175 + (0.00219 * 13.82) = -0.05175 + 0.0303 = -0.02148.$

This implies that each one year decrease in birth year, say 1954 to 1953 and the operator's age is older by one year, the result is an increase in FCR by 0.02148, a decrease in efficiency.

In a similar manner, interpretation of the operator's experience in the FCR model must consider the Experience variable and the Age_Experience interactive term. In this case, the change in FCR with respect to Experience will be $b_2 + b_3$*Age (in our shortened version of the model), and upon entering beta coefficient values for these variables from the FCR model and the mean Age (birth year) value, the result will be:

(16) $FCR = -4.26995 + (0.00219 * 1951.49) = -4.26995 + 4.2738 = 0.0038.$

This implies that each additional year of experience for the producer results in an increase in FCR by 0.0038, which is a small decrease in efficiency.

Thus, it appears from the FCR model that increasing age and increasing years of experience results in an increase in FCR, which is a reduction in efficiency on farm operations. This result seems contradictory to theory in some aspects. As experience increases one would not expect FCR to increase, however, as age increases producers may be less likely to try innovative techniques or completely discontinue current, but less effective, production practices.

Expected survival of food fish to harvest (SurvivalPercnt) is positive and FCR is expected to increase by 0.02165 as the food fish survival percent increase, which indicates that the farm's operation will become less efficient. This differs from the expected negative sign anticipated. This could be due to higher survival percentages increasing the time to achieve harvest size fish and this might require more feed which would increase the feed conversion ratio.

The sign and significance of the off-farm purchase of fry and fingerlings (FFPurchasePercnt) indicates an increase in the number of fry and fingerlings purchased off farm will result in a 0.005 decrease in FCR. This is good, as lower feed conversion ratios mean improved production efficiency. As expected, this variables negative sign may indicate that specializing in growing food size fish is preferred, rather than diversifying into fry and fingerling production to meet stocking needs, which could from their main goal.

Additionally, the production system variable is significant at the 5.4% level of confidence, just above the 5% cutoff level. When the multiple-batch production system is used there is a 0.45691 reduction in the expected feed conversion ratio, which agrees with the anticipated sign and effect. It appears that the multiple-batch production system lowers FCR through getting some on-flavor catfish to market when single-batch systems may not have any ponds of harvest size fish on-flavor. Multiple-batch systems will usually have some harvest size fish in every pond, whereas the single batch system will only have some ponds with harvest size fish. This gives the multiple-batch system a big advantage over single-batch systems and would increase overall pounds produced, that is harvested and sent to the processor.

The remaining variables, education, average fry stocking number (AvgStockFry), total water acres on the operation (TotalWaterAcres), average stocker stocking number (AvgStockStock), custom harvest percentage (CustomHarvst), electrical aeration horsepower (ElectricalAeration), and paddlewheel aerator number (PaddlewheelAeration) are all insignificant.

It is surprising that some of the variables in the FCR model were not significant, especially the variables pertaining to the amount of aeration horsepower available on the farm. The electrical aerator is the predominant aeration system used on operations and has the correct negative sign, but the more mobile tractor paddlewheel did not have the expected sign. It could be that additional aeration horsepower could muddy the water if used for long periods, making it difficult for fish to efficiently feed or want to eat. None of the stocking variables were significant, but all had negative signs that at least indicated that greater stocking numbers tended toward reducing, i.e., improving, feed conversion efficiency. Increasing water acres on the farm had a weak tendency to increase FCR.

CHAPTER V

SUMMARY AND CONCLUSIONS

Catfish has become the leading aquacultural species raised in the United States. The majority of catfish production is produced in the southern states of Mississippi, Louisiana, Arkansas, and Alabama. The aquacultural industry is unique from other livestock industries because of the open water environment and containment structures the fish are grown in.

Summary

The primary objective of this study was to identify risks associated with catfish losses in the production process for the U.S. farm-raised catfish industry. The specific objectives were to determine the magnitude of losses from weather and disease events as well as determining significant explanatory variables that could improve production efficiency. The objectives were met through the analysis of survey response data provided by the National Risk Management Feasibility Program for Aquaculture (NRMFPA). Specific model explanatory variables were chosen according to their relevance to the dependent variables, that is, percent of catfish losses from weather events (*LweatherP*) or disease events (*LdiseaseP*) operational efficiency as measured by catfish feed conversion ratios (*Cat_FCR*). The weather and disease models were analyzed using a double limit tobit model because both endogenous variables were percentages and must be between 0 and 1.

The tobit model variable effects were demonstrated through the calculated marginal effects. Tables 4.4 and 4.5 summarize the results from the two tobit models, while table 4.6 summarizes the expected conditional percent loss and frequency of occurrence to estimate the expected annual percent loss from specific weather and disease perils. In the catfish weather loss model, all variables were found to be statistically significant. Initially, education and pond depth displayed negative coefficients, but after additional analysis of the marginal effects for variables was performed the signed changed showing a positive relationship between the variables and dependent variable, LweatherP.

In the disease loss model, only experience and pond depth were found to be significant with an inverse relationship to catfish losses, meaning as experience and pond depth increases, fish losses due to diseases would decrease. Education, pond age, and number of ponds were not found to be significant. The insignificance of the education is very interesting and can be the subject of future research projects, because education was found to be significant in the weather loss tobit model, but was found to be non-significant in the disease loss tobit model. It seems that one could learn more about various disease mitigation techniques than possible weather mitigation techniques since weather is random and difficult to predict.

The linear regression model for the FCR efficiency model also produced some unexpected results, Table 4.7. Age, experience, catfish survival percentage, percentage of fry and fingerlings purchased off-farm, the interaction variable age/experience, and production system (at the 5.37 level of significance) were significant, having negative signs with the exception of the survival percentage and age/experience variables having positive signs. The variables found to be non-significant were education, total water acres, average stocking rates for fry, average stocking rates for fingerlings, average stocking rates for stockers, percentage of fish custom harvested, and both aeration variables. Based on results of this model a better FCR can be obtained if producers were more experienced and they increased the number of fry and fingerling purchased off farm. The results also indicated that FCR would increase, if catfish survival percentage was increased.

Conclusions

The results from each model in the analysis provided new information on how producers might protect and mitigate losses on their operations from risks associated with weather and diseases events. Model results included significant factors (variables) that may be able to help producers by describing the inputs that could be increased or decreased in order to obtain a more efficient level of production. The experience factor was found to have an identifiable impact on catfish losses due to disease and in reducing the FCR (or improving the operational production efficiency). Education, however, did not have a significant impact on disease or efficiency, but did have an impact on catfish losses due to weather events. As a result of this study, we found that common factors between the three models differed greatly by model and significance.

Although any loss experienced by producers is reason for concern, producers should know and develop strategies that are unique to their operations, region of production, and level of operation. Although the results of this analysis indicate how an increase or decrease in a specific variable would affect losses or efficiency, this information may not be pertinent to all producers, but overall this work could be beneficial to the U.S. farm-raised catfish industry.

The data used for this analysis was from a producer survey with two initial questions used to screen out certain producers. Producers were asked a broad a variety of questions and asked to give their best estimates. This survey method employed produced satisfactory information for the purposes of this analysis. The major advantage of the survey instrument is that it obtained actual on-farm data with respect to magnitude of losses, types of losses, production variables, etc. One potential drawback of any survey of this sort is the potential for producers to over- or under- estimate, or exaggerate, on certain survey questions. If this is suspected, then that is one less observation that could be used in a study.

Beneficiaries of Research

The results of this research will benefit aquaculture producers, policy makers, and economists. This analysis provides them with information on factors affecting weather, disease, and efficiency losses. This analysis will benefit aquaculture producers by providing information about weather and disease loss factors and how production inputs and farm characteristics might affect loss quantities, and can provide producers information on the magnitude of catfish losses from specific weather and disease occurrences. The results of the efficiency analysis will assist producers in determining the proper amount of a certain inputs or management practices in order to produce in a more efficient manner. Knowing this information will allow producers to avoid revenue losses due to the lack of efficiency by finding the weaknesses in their operation. This analysis will benefit policy makers and economists that are seeking ways to develop risk reducing measures such as insurance policies for aquacultural products, by supplying them with information on magnitudes of losses from specific perils, which are one criterion that must be known in order to determine the insurability of a crop.

Future Research and Limitations

This analysis has shown that there are factors that do affect the amount of losses from weather or disease events. But, could it be argued that there are more factors that could significantly affect these models? Yes. There are always other underlying factors that could affect on-farm losses, for example, the number of employees and stocking densities. Too many employees may cause shirking among some laborers and many responsibilities may become over looked, while too few employees may cause laborers to become overworked while not allowing them to perform many of the daily responsibilities fully. Variables of importance for future consideration could be education, experience, management practices, number of employees, and stocking densities. Dependant upon what producers, researcher, or economists believe to be the most important, variables could become numerous or few.

In respect to the FCR model, there were many variables found to be insignificant that many producers would think should be significant in decreasing their FCR values. Could it be argued that these factors are not as important as producers think they are? Yes. Many producers are older and do not necessarily want to modify the current methods they utilize or they do not want to shift their focuses from aspects that they have deemed to be the most important. One limitation of this study is the fact that there is not any previous literature or research on factors that affect catfish losses due to weather and disease events. Therefore, the results should be used as a basis for future research analysis.

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APPENDIX A

SURVEY INSTRUMENT USED TO COLLECT DATA

NATIONAL
AGRICULTURAL
STATISTICS
SERVICE

Risk Management Feasibility Study for Catfish

National Agricultural Statistics Service
U.S. Department of Agriculture,
Rm 5829, South Building
1400 Independence Ave., S.W.
Washington, DC 20250-2000
1-800-727-9540 Fax: 202-690-2090
E-mail: nass@nass.usda.gov

Form Approved
O.M.B Number 0563-0074
Approval Expires 2/29/2008
Project Code 919

Please make corrections to name, address and Zip Code if necessary.

The National Risk Management Feasibility Program for Aquaculture, a partnership between Mississippi State University and USDA's Risk Management Agency, is conducting a survey to better understand the on-farm risks faced by aquaculture producers. The information obtained from the survey will be used to understand the frequency and magnitude of risks aquaculture producers face.

Response to this survey is confidential and voluntary. We encourage you to refer to your farm records as you complete the survey.

In this survey "catfish" are defined to include groups of fry (less than two pounds per thousand), fingerlings (between two and 60 pounds per thousand); stockers, (between 61 and 750 pounds per thousand), and food-sized (over 750 pounds per thousand, including broodfish) fish in ponds on the farm. We consider catfish to be of the species channel catfish (*Ictalurus punctatus*), blue catfish (*Ictalurus furcatus*) or a hybrid of the two species. Catfish found on the farm in other locations such as hatcheries should not be included in your responses.

1. During 2006 do you plan to continue your catfish operation by managing catfish in ponds?

   YES [Continue.] NO [Stop Survey.]

2. Is your catfish operation a non-profit organization (such as a research facility or for public recreation)?

   YES [Stop Survey.] NO [Continue.]

SECTION 1 – GENERAL INFORMATION

1. How many years have you been producing catfish?. . . . . Years — 2101
2. In 2006, how many water acres do you expect to be used for catfish production, including all water acres owned, rented, or managed for someone else?. . . . . Acres — 2121
3. How many pounds of catfish do you expect to produce in 2006 including food-sized fish and
fingerlings sold to other producers?. . . . . .Pounds — 2113
4. How many catfish ponds are in your operation?. . . . . Ponds — 2102
5. How far is the most remote pond group located from the management headquarters?. . . . . .Miles — 2117 . __ __
6. What is the shortest distance between any of your ponds and another catfish operation?. . . . . Miles — 2118 . __ __
7. In what state and county is the majority of your catfish production located?
   a. State: ____ — 2103
   b. County: ____ — 2104
8. What is the average age of the ponds in your operation?. . . . . Years — 2105
9. What is the average water depth, in feet, of your ponds?. . . . . Feet — 2122 . ___
10. What percentage of ponds on your farm is reworked every year?. . . Percent — 2123
11. What is the primary source of water?
    - ☐ **1** – Well or ground water
    - ☐ **2** – Stream
    - ☐ **3** – Other Specify__________________.. . . . . Code — 2112
12. Which of the following best describes the ownership of this operation?
    - ☐ **1** – Sole Proprietorship
    - ☐ **2** – Corporation . . . . Code — 2106
    - ☐ **3** – Partnership
13. Have you ever purchased any kind of general liability coverage for your
    - ☐ **1** – YES
    - ☐ **2** – NO — 2107
14. On a scale of 1 to 5 where 1 indicates highly unwilling and 5 indicates highly willing, how would you rate your willingness to take financial risks?
    - ☐ **1** - Highly Unwilling
    - ☐ **2** - Somewhat Unwilling
    - ☐ **3** - Neutral or Indifferent . . . . Code — 2108
    - ☐ **4** - Somewhat Willing
    - ☐ **5** - Highly Willing

15. What percent of fish stocked in ponds do you expect to survive until harvest in 2006?. . . . . Percent | 2109 %

16. What percent of fish that are stocked in ponds do you expect to be lost due to disease in 2006?. . .. . Percent | 2110 %

17. If a catastrophic loss were to occur on your farm and kill a significant number of fish, in your opinion what are the chances (in percentages) you would be at least partially covered for your losses by the federal government (for example, through a disaster program administered by the USDA's Farm Service Agency (FSA) or Animal and Plant Health Inspection Service (APHIS)?. . . . | 2111 %

SECTION 2 – ASSESSMENT OF HISTORICAL CATFISH PRODUCTION

This section will provide us with an overview of the likelihood and size of catfish production losses **excluding "normal" or "background**" production losses (see handout). Responses to the three biggest or largest production losses should be based on the **last ten years** of your catfish production history.

1. In the last ten years, indicate the number of times your have incurred a loss of more than 5% of the expected total annual production (after accounting for normal losses) for the year?. . . . . Number | 2201

Largest Production Loss

2. In the last ten years, in what year did you experience your largest production loss?. . . . . Year | 2202 _ _ _ _

3. In the loss year, indicate the production lost in pounds.. . . . . Pounds | 2203

4. What were the expected pounds of production in the loss year?. .. . . Pounds | 2204

5. From the size categories provided below, indicate the category most affected in the loss year:
   - ☐ **1** – Fry/Fingerlings
   - ☐ **2** – Stockers.. . . . . Code | 2206
   - ☐ **3** – Food-sized fish

6. Please indicate the peril that best describes the major cause of loss in the loss year: | 2207

- ☐ **101** –Oxygen depletion due to electrical breakdown from off-farm causes
- ☐ **102** –Freezing of pond
- ☐ **103** –Flood
- ☐ **104** –Drought
- ☐ **105** –Windstorm, tornado, lightning or hurricane
- ☐ **201** –Columnaris disease
- ☐ **202** –Enteric septicemia (ESC) (Hole in the Head disease)
- ☐ **203** –Combination of Enteric Septicemia (ESC) & Columnaris disease
- ☐ **204** –Channel catfish virus (CCV)
- ☐ **205** –Proliferative gill disease (Hamburger gill disease)
- ☐ **206** –Toxic algae
- ☐ **207** –Visceral toxicosis (VTC)
- ☐ **208** –Winter fungus (winter kill or saprolegnia)
- ☐ **209** –Ich/white spot disease
- ☐ **301** –Other: (specify)______________________________________

Second-Largest Production Loss

7. In the last ten years, in what year did you experience your second-largest production loss?. . . . . . . .Year	2208 ____
8. In the loss year, indicate the production lost in pounds.. . . . . Pounds	2209
9. What were the expected pounds of production in the loss year?. . . . . Pounds	2210

10. From the size categories provided below, indicate the category most affected in the loss year:
    - ☐ **1** – Fingerlings
    - ☐ **2** – Stockers.. . . . . Code
    - ☐ **3** – Food-sized fish

2212

11. Please indicate the peril that best describes the major cause of loss in the loss year:

2213

- ☐ **101** –Oxygen depletion due to electrical breakdown from off-farm causes
- ☐ **102** –Freezing of pond
- ☐ **103** –Flood
- ☐ **104** –Drought
- ☐ **105** –Windstorm, tornado, lightning or hurricane
- ☐ **201** –Columnaris disease
- ☐ **202** –Enteric septicemia (ESC) (Hole in the Head disease)
- ☐ **203** –Combination of Enteric Septicemia (ESC) & Columnaris disease
- ☐ **204** –Channel catfish virus (CCV)
- ☐ **205** –Proliferative gill disease (Hamburger gill disease)
- ☐ **206** –Toxic algae
- ☐ **207** –Visceral toxicosis (VTC)
- ☐ **208** –Winter fungus (winter kill or saprolegnia)
- ☐ **209** –Ich/white spot disease
- ☐ **301** –Other: (specify)______________________________________

Third-Largest Production Loss

12. In the last ten years, in what year did you experience your third-largest production loss?. . . . . Year	2214 ____
13. In the loss year, indicate the production lost in pounds.. .. . . Pounds	2215
14. What were the expected pounds of production in the loss year?. . . . . Pounds	2216

15. From the size categories provided below, indicate the category most affected in the loss year:
    - ☐ **1** – Fingerlings
    - ☐ **2** – Stockers.. . . . . .Code
    - ☐ **3** – Food-sized fish

2218

16. Please indicate the peril that best describes the major cause of loss in the loss year:

2219

☐ **101** –Oxygen depletion due to electrical breakdown from off-farm causes

☐ **102** –Freezing of pond

☐ **103** –Flood

☐ **104** –Drought

☐ **105** –Windstorm, tornado, lightning or hurricane

☐ **201** –Columnaris disease

☐ **202** –Enteric septicemia (ESC) (Hole in the Head disease)

☐ **203** –Combination of Enteric Septicemia (ESC) & Columnaris disease

☐ **204** –Channel catfish virus (CCV)

☐ **205** –Proliferative gill disease (Hamburger gill disease)

☐ **206** –Toxic algae

☐ **207** –Visceral toxicosis (VTC)

☐ **208** –Winter fungus (winter kill or saprolegnia)

☐ **209** –Ich/white spot disease

☐ **301** –Other: (specify)_________________________________

SECTION 3 – ASSESSMENT OF FUTURE CATFISH PRODUCTION AND RISK

This section will provide us with an indication of future catfish production risks. Please answer based on expected catfish production in 2006.

Question 1 addresses **normal losses** incurred year-in and year-out that are part of production and question 2 addresses **losses from specific perils** that are identified in the handout. Refer to the handout when answering questions 1 and 2.

1. What percentage of the total possible annual production in 2006 do you expect will be lost due to "normal" production losses? Included in the normal losses are year-in and year-out production losses; for example, bird predation, normal fingerling losses and seining losses.. . . . . Percent [2301 ______ %]

2. The following questions ask how likely you think the perils identified in the handout (and listed below) will cause losses on your farm in 2006. For example, if you think there is a one in ten chance (10%) of experiencing a loss between 0 and 5 percent of total production in 2006 due to the identified perils then the answer to question a will be 10 percent.

Oxygen depletion due to electrical breakdown from off-farm causes
Freezing of pond
Flood
Drought
Windstorm, tornado, lightning or hurricane
Columnaris disease
Enteric septicemia (ESC) (Hole in the Head disease)
Combination of Enteric Septicemia (ESC) & Columnaris disease
Channel catfish virus (CCV)
Proliferative gill disease (Hamburger gill disease)
Toxic algae
Visceral toxicosis (VTC)
Winter fungus (winter kill or saprolegnia)
Ich/white spot disease
Exotic diseases that have not occurred on your farm
Unknown diseases

Enumerator: Questions 2a through 2e must sum to 100%

	Percent
a. What are the chances you will lose between 0 and 5 percent of your total production in 2006?. . .. . **+**	2302 %
b. What are the chances you will lose between 5 and 15 percent of your total production in 2006?. . . . . **+**	2303 %
c. What are the chances you will lose between 15 and 30 percent of your total production in 2006?. . . . . **+**	2304 %
d. What are the chances you will lose between 30 and 50 percent of your total production in 2006?. . .. . **+**	2305 %
e. What are the chances you will lose between 50 and 100 percent of your total production in 2006?. .. . . **+**	2306 %
f. **TOTAL**. . . . . =	**100%**

3. What do you expect the average stocking rates will be for Fry in fish per acre in 2006? . . . . fish/acre [2321 ______]

4. What do you expect the average stocking rates will be for Fingerlings in fish per acre in 2006? . . . . .fish/acre [2322 ______]

5. What do you expect the average stocking rates will be for Stockers in fish per acre in 2006? . . . . fish/acre	2323
6. How many tons of feed do you expect to feed your catfish in 2006?Tons	2307
7. What percentage of fry and fingerlings do you expect to purchase off-farm in 2006?. . . . . Percent	2308 %
8. What percentage of fingerlings stocked in 2006 do you expect to vaccinate? . . . . Percent	2310 %
9. What is your most common foodfish production system: single, multiple batch or modular? ☐ **1** – Single batch-having one size/age of fish in the pond at a time ☐ **2** – Multiple batch-having fish of multiple sizes/age in the pond at the same time ☐ **3** – Modular-systematically decreasing stocking density by moving the fish from one pond to multiple ponds as the catfish grows to food-size	2324
10. What percentage of harvested fish do you expect to have custom harvested in 2006?. . . . . Percent	2325 %
11. How many times do you expect your operation to experience an electrical power outage of at least 30 minutes during the peak production season between May and October 2006?. . . . . . Number	2315
12. How many back-up electrical generators do you expect to have on your catfish operation in 2006?. . . . . Generators	2326
13. How much electrical horsepower do you expect to have on your catfish operation for aeration purposes in 2006? . .. . Total Horsepower	2327
14. How many tractor-powered paddlewheels do you expect to have on your catfish operation for aeration purposes in 2006?.. . . Paddlewheels	2328
15. How many full-time equivalent employees do you expect to monitor and manage dissolved oxygen from May through October in 2006?. . . . . Employees	2314

SECTION 4 – ASSESSMENT OF WILLINGNESS TO PAY FOR AN INSURANCE POLICY

The questions in this section will be used to assess the willingness to pay for an insurance policy that will protect producers from **shortfalls in production** (valued at a predefined price) caused by those production perils as defined in the handout. The liability and premium for the policy are determined by a specific coverage level and premium rate. If production is less than the expected production multiplied by the coverage level, the producer is paid on the production shortfall.

1. If the coverage level for the policy is _____ percent and the premium rate is ____ percent, would you be willing to purchase the insurance?

   - ☐ **1** – YES [Go to **Item 2**.]
   - ☐ **2** – NO [Go to **Item 3**.]

   1160

2. On a scale of 1 to 5, where 1 indicates completely uncertain and 5 indicates completely certain, how certain are you that you would purchase this coverage? **After answering go to item 4**

   - ☐ 1 - Completely Uncertain
   - ☐ 2 - Somewhat Uncertain
   - ☐ 3 - Neutral or Indifferent
   - ☐ 4 - Somewhat Certain
   - ☐ 5 - Completely Certain

   1161

3. If your answer to item 1 is NO, would you be willing to pay any amount for this policy with an ____ percent coverage level?

   - ☐ **1** – YES
   - ☐ **2** – NO

   1162

4. Would you be willing to purchase a catastrophic insurance policy with a coverage level of 50 percent and a premium rate of 1 percent?

   - ☐ **1** – YES
   - ☐ **2** – NO

   1163

SECTION 5 – PRODUCER CHARACTERISTICS

1. What percentage of your household's gross income for 2006 do you expect to come from your catfish operation?. . . .. Percent — 1164 %
2. What percentage of your household's gross income for 2006 do you expect to come from any household members working off-farm?. . . . . .Percent — 1165 %
3. In what range would you place the total market value of the assets in your catfish operation?

   - ☐ 1 - Less than $100,000
   - ☐ 2 - $100,000 to $499,999
   - ☐ 3 - $500,000 to $999,999
   - ☐ 4 - $1,000,000 to $1,999,999
   - ☐ 5 - $2,000,000 to $4,999,999
   - ☐ 6 - $5,000,000 or more

   1166

4. What percent of the total dollars invested in your catfish operation are borrowed?. . . . . Percent

1167 %	
1168 __ __ __ __	

5. In what year were you born?. . . . . Year

6. What is the highest level of formal education you have completed?

- ☐ 1 - Less than high school
- ☐ 2 - High School diploma
- ☐ 3 - Some college
- ☐ 4 - Completed 2 – year degree (A.A. or A.S.)
- ☐ 5 - Completed 4 – year degree (B.A. or B.S.)
- ☐ 6 - Graduate school

1169

Respondent Name: ____

Phone: (___________) __________________ Date: _________________________

Response		Respondent		Mode		Enum.	Eval.	Julian	Office	
1-Comp 2-R 3-Inac 4-Office Hold 5-R – Est 6-Inac – Est 7-Off Hold – Est 8-Known Zero	9901	1-Op/Mgr 2-Sp 3-Acct/Bkpr 4-Partner 9-Oth	9902	1-Mail 2-Tel 3-Face-to-Face 4-CATI 5-Web 6-e-mail 7-Fax 8-CAPI 19-Other	9903	098	100	987	789 __ __ __ - __ __ __ - __ __ __	
									Optional Use	
									407	408
S/E Name										

According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The time to complete this information collection is estimated to average
35 minutes per response.

APPENDIX B

SAS CODE USED TO COMPUTE RESULTS

```
data Losses1 ;
set catfish2 ;

/* Largest Production loss*/
/* L = loss; EP = expected pounds; A = largest production loss*/

If ic2207 = 101 then Loxygen_depA = ic2203;          else Loxygen_depA = 0;
If ic2207 = 101 then EPoxygen_depA = ic2204;         else EPoxygen_depA = 0;

If ic2207 = 102 then LfreezingA = ic2203;            else LfreezingA = 0;
If ic2207 = 102 then EPfreezingA =ic2204;            else EPfreezingA = 0;

If ic2207 = 103 then LfloodA = ic2203;                    else LfloodA = 0;
If ic2207 = 103 then EPfloodA = ic2204;              else EPfloodA = 0;

If ic2207 = 104 then LdroughtA = ic2203;             else LdroughtA = 0;
If ic2207 = 104 then EPdroughtA = ic2204;            else EPdroughtA = 0;

If ic2207 = 105 then Lsevere_weatherA = ic2203;      else Lsevere_weatherA = 0;

If ic2207 = 105 then EPsevere_weatherA = ic2204;  else EPsevere_weatherA = 0;

If ic2207 = 201 then LcolumnarisA = ic2203;          else LcolumnarisA = 0;
If ic2207 = 201 then EPcolumnarisA = ic2204;         else EPcolumnarisA = 0;

If ic2207 = 202 then Lent_septicemiaA = ic2203;   else Lent_septicemiaA = 0;
If ic2207 = 202 then EPent_septicemiaA = ic2204;  else EPent_septicemiaA = 0;

If ic2207 = 203 then Lesc_columnarisA = ic2203;   else Lesc_columnarisA = 0;
If ic2207 = 203 then EPesc_columnarisA = ic2204;  else EPesc_columnarisA = 0;

If ic2207 = 204 then Lchannel_catA = ic2203;         else Lchannel_catA = 0;
If ic2207 = 204 then EPchannel_catA = ic2204;        else EPchannel_catA = 0;

If ic2207 = 205 then Lgill_diseaseA = ic2203;        else Lgill_diseaseA = 0;
If ic2207 = 205 then EPgill_diseaseA = ic2204;       else EPgill_diseaseA = 0;

If ic2207 = 206 then Ltoxic_algaeA = ic2203;         else Ltoxic_algaeA = 0;
If ic2207 = 206 then EPtoxic_algaeA = ic2204;        else EPtoxic_algaeA = 0;

If ic2207 = 207 then Lvisceral_toxA = ic2203;        else Lvisceral_toxA = 0;
If ic2207 = 207 then EPvisceral_toxA = ic2204;       else EPvisceral_toxA = 0;

If ic2207 = 208 then Lwinter_fungusA = ic2203;       else Lwinter_fungusA = 0;
If ic2207 = 208 then EPwinter_fungusA = ic2204;      else EPwinter_fungusA = 0;
```

```
If ic2207 = 209 then Lich_diseaseA = ic2203;                else Lich_diseaseA = 0;
If ic2207 = 209 then EPich_diseaseA = ic2204;               else EPich_diseaseA = 0;

If ic2207 = 301 then LotherA = ic2203;                          else LotherA = 0;
If ic2207 = 301 then EPotherA = ic2204;                     else EPotherA = 0;

/* Second Largest Production loss*/
/* L = loss; EP = expected pounds; B =  second largest production loss*/

If ic2213 = 101 then Loxygen_depB = ic2209;                 else Loxygen_depB = 0;
If ic2213 = 101 then EPoxygen_depB = ic2210;                else EPoxygen_depB = 0;

If ic2213 = 102 then LfreezingB = ic2209;                   else LfreezingB = 0;
If ic2213 = 102 then EPfreezingB =ic2210;                   else EPfreezingB = 0;

If ic2213 = 103 then LfloodB = ic2209;                          else LfloodB = 0;
If ic2213 = 103 then EPfloodB = ic2210;                         else EPfloodB = 0;

If ic2213 = 104 then LdroughtB = ic2209;                    else LdroughtB = 0;
If ic2213 = 104 then EPdroughtB = ic2210;                   else EPdroughtB = 0;

If ic2213 = 105 then Lsevere_weatherB = ic2209;   else Lsevere_weatherB = 0;
If ic2213 = 105 then EPsevere_weatherB = ic2210;  else EPsevere_weatherB = 0;

If ic2213 = 201 then LcolumnarisB = ic2209;                 else LcolumnarisB = 0;
If ic2213 = 201 then EPcolumnarisB = ic2210;                else EPcolumnarisB = 0;

If ic2213 = 202 then Lent_septicemiaB = ic2209;             else Lent_septicemiaB = 0;
If ic2213 = 202 then EPent_septicemiaB = ic2210;  else EPent_septicemiaB = 0;

If ic2213 = 203 then Lesc_columnarisB = ic2209;             else Lesc_columnarisB = 0;
If ic2213 = 203 then EPesc_columnarisB = ic2210;  else EPesc_columnarisB = 0;

If ic2213 = 204 then Lchannel_catB = ic2209;                else Lchannel_catB = 0;
If ic2213 = 204 then EPchannel_catB = ic2210;               else EPchannel_catB = 0;

If ic2213 = 205 then Lgill_diseaseB = ic2209;               else Lgill_diseaseB = 0;
If ic2213 = 205 then EPgill_diseaseB = ic2210;              else EPgill_diseaseB = 0;

If ic2213 = 206 then Ltoxic_algaeB = ic2209;                else Ltoxic_algaeB = 0;
If ic2213 = 206 then EPtoxic_algaeB = ic2210;               else EPtoxic_algaeB = 0;

If ic2213 = 207 then Lvisceral_toxB = ic2209;               else Lvisceral_toxB = 0;
If ic2213 = 207 then EPvisceral_toxB = ic2210;              else EPvisceral_toxB = 0;
```

```
If ic2213 = 208 then Lwinter_fungusB = ic2209;            else Lwinter_fungusB = 0;
If ic2213 = 208 then EPwinter_fungusB = ic2210;   else EPwinter_fungusB = 0;

If ic2213 = 209 then Lich_diseaseB = ic2209;              else Lich_diseaseB = 0;
If ic2213 = 209 then EPich_diseaseB = ic2210;             else EPich_diseaseB = 0;

If ic2213 = 301 then LotherB = ic2209;                              else LotherB = 0;
If ic2213 = 301 then EPotherB = ic2210;                             else EPotherB = 0;

/* Third Largest Production loss*/
/* L = loss; EP = expected pounds; C =  third largest production loss*/

If ic2219 = 101 then Loxygen_depC = ic2215;               else Loxygen_depC = 0;
If ic2219 = 101 then EPoxygen_depC = ic2216;              else EPoxygen_depC = 0;

If ic2219 = 102 then LfreezingC = ic2215;                 else LfreezingC = 0;
If ic2219 = 102 then EPfreezingC =ic2216;                 else EPfreezingC = 0;

If ic2219 = 103 then LfloodC = ic2215;                              else LfloodC = 0;
If ic2219 = 103 then EPfloodC = ic2216;                             else EPfloodC = 0;

If ic2219 = 104 then LdroughtC = ic2215;                  else LdroughtC = 0;
If ic2219 = 104 then EPdroughtC = ic2216;                 else EPdroughtC = 0;

If ic2219 = 105 then Lsevere_weatherC = ic2215;           else Lsevere_weatherC = 0;
If ic2219 = 105 then EPsevere_weatherC = ic2216;  else EPsevere_weatherC = 0;

If ic2219 = 201 then LcolumnarisC = ic2215;                         else LcolumnarisC =
0;
If ic2219 = 201 then EPcolumnarisC = ic2216;              else EPcolumnarisC = 0;

If ic2219 = 202 then Lent_septicemiaC = ic2215;           else Lent_septicemiaC = 0;
If ic2219 = 202 then EPent_septicemiaC = ic2216;   else EPent_septicemiaC = 0;

If ic2219 = 203 then Lesc_columnarisC = ic2215;           else Lesc_columnarisC = 0;
If ic2219 = 203 then EPesc_columnarisC = ic2216;  else EPesc_columnarisC = 0;

If ic2219 = 204 then Lchannel_catC = ic2215;              else Lchannel_catC = 0;
If ic2219 = 204 then EPchannel_catC = ic2216;             else EPchannel_catC = 0;

If ic2219 = 205 then Lgill_diseaseC = ic2215;             else Lgill_diseaseC = 0;
If ic2219 = 205 then EPgill_diseaseC = ic2216;            else EPgill_diseaseC = 0;

If ic2219 = 206 then Ltoxic_algaeC = ic2215;              else Ltoxic_algaeC = 0;
```

```
If ic2219 = 206 then EPtoxic_algaeC = ic2216;          else EPtoxic_algaeC = 0;

If ic2219 = 207 then Lvisceral_toxC = ic2215;          else Lvisceral_toxC = 0;
If ic2219 = 207 then EPvisceral_toxC = ic2216;         else EPvisceral_toxC = 0;

If ic2219 = 208 then Lwinter_fungusC = ic2215;         else Lwinter_fungusC = 0;
If ic2219 = 208 then EPwinter_fungusC = ic2216;        else EPwinter_fungusC = 0;

If ic2219 = 209 then Lich_diseaseC = ic2215;           else Lich_diseaseC = 0;
If ic2219 = 209 then EPich_diseaseC = ic2216;          else EPich_diseaseC = 0;

If ic2219 = 301 then LotherC = ic2215;                       else LotherC = 0;
If ic2219 = 301 then EPotherC = ic2216;                      else EPotherC = 0;

/* summation to get the total losses of each peril*/
/* T = total losses; P = percent loss; D = dummy variable */
Loxygen_depT = (sum(Loxygen_depA,Loxygen_depB,Loxygen_depC));
EPoxygen_depT = (sum(EPoxygen_depA,EPoxygen_depB,EPoxygen_depC));
if EPoxygen_depT > 0 then Loxygen_depP = Loxygen_depT / EPoxygen_depT ; else
Loxygen_depP = 0;
If Loxygen_depT > 0 then Loxygen_depD = 1;
                    else Loxygen_depD = 0;

LfreezingT = (sum(LfreezingA, LfreezingB, LfreezingC));
EPfreezingT = (sum(EPfreezingA, EPfreezingB,EPfreezingC));
If EPfreezingT > 0 then LfreezingP =  LfreezingT / EPfreezingT;            else
LfreezingP = 0;
If LfreezingT > 0 then LfreezingD = 1;
                    else LfreezingD = 0;

LfloodT = (sum(LfloodA,LfloodB,LfloodC));
EPfloodT = (sum(EPfloodA, EPfloodB,EPfloodC));
If EPfloodT > 0 then LfloodP = LfloodT / EPfloodT;
          else LfloodP = 0;
If LfloodT > 0 then LfloodD = 1;
                    else LfloodD = 0;

LdroughtT = (sum(LdroughtA, LdroughtB, LdroughtC));
EPdroughtT = (sum(EPdroughtA, EPdroughtB, EPdroughtC));
If EPdroughtT > 0  then LdroughtP =  LdroughtT / EPdroughtT;
          else LdroghtP = 0;
If LdroughtT > 0 then LdroughtD = 1;
                    else LdroughtD = 0;

Lsevere_weatherT = (sum(Lsevere_weatherA,Lsevere_weatherB, Lsevere_weatherC));
```

```
EPsevere_weatherT = (sum(EPsevere_weatherA, EPsevere_weatherB,
EPsevere_weatherC));
If EPsevere_weatherT > 0 then Lsevere_weatherP = Lsevere_weatherT /
EPsevere_weatherT;          else Lsevere_weatherP = 0;
If Lsevere_weatherT > 0 then Lsevere_weatherD = 1;
                                        else Lsevere_weatherD = 0;

LcolumnarisT = (sum(LcolumnarisA, LcolumnarisB, LcolumnarisC));
EPcolumnarisT = (sum(EPcolumnarisA, EPcolumnarisB,EPcolumnarisC));
If EPcolumnarisT > 0 then LcolumnarisP = LcolumnarisT / EPcolumnarisT;      else
LcolumnarisP = 0;
If LcolumnarisT > 0 then LcolumnarisD = 1;
              else LcolumnarisD = 0;

Lent_septicemiaT = (sum(Lent_septicemiaA, Lent_septicemiaB, Lent_septicemiaC));
EPent_septicemiaT = (sum(EPent_septicemiaA, EPent_septicemiaB,
EPent_septicemiaC));
If EPent_septicemiaT > 0 then Lent_septicemiaP = Lent_septicemiaT /
EPent_septicemiaT;          else Lent_septicemiaP = 0;
If Lent_septicemiaT > 0 then Lent_septicemiaD = 1;
                                        else Lent_septicemiaD = 0;

Lesc_columnarisT = (sum(Lesc_columnarisA, Lesc_columnarisB, Lesc_columnarisC));
EPesc_columnarisT = (sum(EPesc_columnarisA, EPesc_columnarisB,
EPesc_columnarisC));
If EPesc_columnarisT > 0 then Lesc_columnarisP = Lesc_columnarisT /
EPesc_columnarisT;          else Lesc_columnarisP = 0;
If Lesc_columnarisT > 0 then Lesc_columnarisD = 1;
                                        else Lesc_columnarisD = 0;

Lchannel_catT = (sum(Lchannel_catA, Lchannel_catB, Lchannel_catC));
EPchannel_catT = (sum(EPchannel_catA, EPchannel_catB, EPchannel_catC));
If EPchannel_catT > 0 then Lchannel_catP = Lchannel_catT / EPchannel_catT;
       else Lchannel_catP = 0;
If Lchannel_catT > 0 then Lchannel_catD = 1;
                     else Lchannel_catD = 0;

Lgill_diseaseT = (sum(Lgill_diseaseA, Lgill_diseaseB, Lgill_diseaseC));
EPgill_diseaseT = (sum(EPgill_diseaseA, EPgill_diseaseB, EPgill_diseaseC));
If EPgill_diseaseT > 0 then Lgill_diseaseP = Lgill_diseaseT / EPgill_diseaseT;    else
Lgill_diseaseP = 0;
If Lgill_diseaseT > 0 then Lgill_diseaseD = 1;
                     else Lgill_diseaseD = 0;

Ltoxic_algaeT = (sum(Ltoxic_algaeA, Ltoxic_algaeB, Ltoxic_algaeC));
```

```
EPtoxic_algaeT = (sum(EPtoxic_algaeA, EPtoxic_algaeB, EPtoxic_algaeC));
If EPtoxic_algaeT > 0 then Ltoxic_algaeP = Ltoxic_algaeT / EPtoxic_algaeT;
        else Ltoxic_algaeP = 0;
If Ltoxic_algaeT > 0 then Ltoxic_algaeD = 1;
                        else Ltoxic_algaeD = 0;

Lvisceral_toxT = (sum(Lvisceral_toxA, Lvisceral_toxB, Lvisceral_toxC));
EPvisceral_toxT = (sum(EPvisceral_toxA, EPvisceral_toxB, EPvisceral_toxC));
If EPvisceral_toxT > 0 then Lvisceral_toxP = Lvisceral_toxT / EPvisceral_toxT;   else
Lviscera_toxP = 0;
If Lvisceral_toxT > 0 then Lvisceral_toxD = 1;
                        else Lvisceral_toxD = 0;

Lwinter_fungusT = (sum(Lwinter_fungusA, Lwinter_fungusB, Lwinter_fungusC));
EPwinter_fungusT = (sum(EPwinter_fungusA, EPwinter_fungusB, EPwinter_fungusC));
If EPwinter_fungusT > 0 then Lwinter_fungusP = Lwinter_fungusT / EPwinter_fungusT;
        else Lwinter_fungusP = 0;
If Lwinter_fungusT > 0 then Lwinter_fungusD = 1;
                        else Lwinter_fungusD = 0;

Lich_diseaseT = (sum(Lich_diseaseA, Lich_diseaseB, Lich_diseaseC));
EPich_diseaseT = (sum(EPich_diseaseA, EPich_diseaseB, EPich_diseaseC));
If EPich_diseaseT > 0 then Lich_diseaseP = Lich_diseaseT / EPich_diseaseT;
        else Lich_diseaseP = 0;
If Lich_diseaseT > 0 then Lich_diseaseD = 1;
                        else Lich_diseaseD = 0;

LotherT = (sum(LotherA, LotherB, LotherC));
EPotherT = (sum(EPotherA, EPotherB, EPotherC));
If EPotherT > 0 then LotherP = LotherT / EPotherT;              else LotherP = 0;
If LotherT > 0 then LotherD = 1;                                        else
LotherD = 0;

/* combining columnaris, esc, and esc & columnaris*/
Lcolumnaris_escT = (sum(LcolumnarisT, Lent_septicemiaT, Lesc_columnarisT));
EPcolumnaris_escT = (sum(EPcolumnarisT, EPent_septicemiaT, EPesc_columnarisT));
If Lcolumnaris_escT > 0 then Lcolumnaris_escD = 1;
                else Lcolumnaris_escD = 0;

run;
quit;

data Losses2;
set Losses1;
```

```
LweatherT = (sum(LfreezingT, LfloodT, LdroughtT, Lsevere_weatherT));
EPweatherT = (sum(EPfreezingT, EPfloodT, EPdroughtT, EPsevere_weatherT));
If EPweatherT > 0 then LweatherP = LweatherT / EPweatherT;                 else
LweatherP = 0;

Lfall_springT = (sum(Lcolumnaris_escT, Lchannel_catT, Lgill_diseaseT,
Lich_diseaseT));
EPfall_springT = (sum(EPcolumnaris_escT , EPchannel_catT, EPgill_diseaseT,
EPich_diseaseT));
If EPfall_springT > 0 then Lfall_springP = Lfall_springT / EPfall_springT;
        else Lfall_springP = 0;

LweatherP = LweatherP /10;

Lfall_springP = Lfall_springP /10;

/*scaling number of ponds on an operation*/
ic2102M = ic2102 / 10;

/*scaling average stocking rate of fry*/
ic2321M = ic2321 / 1000;

/*scaling H2O water acres*/
ic2121M = ic2121 / 10;

/*scaling average stocking rate for stockers*/
ic2323M = ic2323 / 1000;

/*scaling electrical horse power*/
ic2327M = ic2327 / 100;

/*scaling average stocking rate of fingerlings 2006*/
ic2322M = ic2322/1000;

/*Dummy variable creation for multiple category variables:
  ic1169 becomes edu with HS or less equaling 1 and above HS equaling 0;
  ic2324 becomes Production System type where multiple batch = 1 and single batch
      plus modular equal 0;
 */
 if ic1169 = 1 or ic1169 = 2 then edu = 1; else edu = 0;
 if ic2324 = 2 then psystem = 1; else psystem = 0;
 psys_2322 = psystem * ic2322;
run;
quit;
```

```
/*descriptive statistics for weather*/

data losses2W ;
 set losses2 ;
  if LweatherP = . or ic2117 = . or ic2122 = . or ic2102 = . then delete ;
run;

ods html;
proc means data=Losses2W ;
 var  LweatherP edu ic2102M  psystem ic2122 Loxygen_depD Lcolumnaris_escD South
;
  WEIGHT EF3 ;
  output out=summaryW ;
run;quit;

proc QLIM data = Losses2w;
 model LweatherP = edu ic2102M  psystem ic2122 Loxygen_depD Lcolumnaris_escD
South ;
 endogenous LweatherP~censored(lb =0 ub=1); weight EF3;
 ODS OUTPUT ParameterEstimates=par_LweatherP ; output out=marg_LweatherP
PREDICTED marginal;
run; quit;

proc means data=marg_LweatherP N mean ;
 var Meff_edu Meff_ic2102M Meff_psystem Meff_ic2122 Meff_Loxygen_depD
Meff_Lcolumnaris_escD Meff_South ;
  WEIGHT EF3 ;
  output out=Meff_LweatherP
         mean (Meff_edu Meff_ic2102M Meff_psystem Meff_ic2122
Meff_Loxygen_depD Meff_Lcolumnaris_escD Meff_South)=
                        Meff_edu Meff_ic2102M Meff_psystem Meff_ic2122
Meff_Loxygen_depD Meff_Lcolumnaris_escD Meff_South ;
run;
quit;

/*calculation of marginal effects for the 5 dummy variables in the weather loss model
Note d1=education dummy; d2=psystem dummy; d3=LoxygenD dummy;
d4=Lcolumnmaris_escD dummy;
d5=South dummy */

data dum_ME_weather;
set Losses2d;
pred1_0we = cdf('Normal',(-0.069139 + 0.021838*ic2102M + 0.057646*ic2122 -
0.026180*psystem
```

```
                        -0.058429*Loxygen_depD -0.056249*Lcolumnaris_escD -
0.072495*south)/0.073476);
pred1_1we = cdf('Normal',(-0.069139 -0.037043 + 0.021838*ic2102M +
0.057646*ic2122 - 0.026180*psystem
                        -0.058429*Loxygen_depD -0.056249*Lcolumnaris_escD -
0.072495*south)/0.073476);
pred2_0we = cdf('Normal',(-0.069139 - 0.037043*edu + 0.021838*ic2102M +
0.057646*ic2122
                        -0.058429*Loxygen_depD -0.056249*Lcolumnaris_escD -
0.072495*south)/0.073476);
pred2_1we = cdf('Normal',(-0.069139 -0.037043*edu + 0.021838*ic2102M +
0.057646*ic2122 - 0.026180
                        -0.058429*Loxygen_depD -0.056249*Lcolumnaris_escD -
0.072495*south)/0.073476);
pred3_0we = cdf('Normal',(-0.069139 - 0.037043*edu + 0.021838*ic2102M +
0.057646*ic2122
                        -0.026180*psystem -0.056249*Lcolumnaris_escD -
0.072495*south)/0.073476);
pred3_1we = cdf('Normal',(-0.069139 -0.037043*edu + 0.021838*ic2102M +
0.057646*ic2122 - 0.026180
                        -0.058429*Loxygen_depD -0.056249*Lcolumnaris_escD -
0.072495*south)/0.073476);
pred4_0we = cdf('Normal',(-0.069139 - 0.037043*edu + 0.021838*ic2102M +
0.057646*ic2122
                        -0.026180*psystem -0.058429*Loxygen_depD -
0.072495*south)/0.073476);
pred4_1we = cdf('Normal',(-0.069139 -0.037043*edu + 0.021838*ic2102M +
0.057646*ic2122 - 0.026180*psystem
                        -0.058429*Loxygen_depD -0.056249 -
0.072495*south)/0.073476);
pred5_0we = cdf('Normal',(-0.069139 - 0.037043*edu + 0.021838*ic2102M +
0.057646*ic2122
                        -0.026180*psystem -0.058429*Loxygen_depD -
0.056249*Lcolumnaris_escD)/0.073476);
pred5_1we = cdf('Normal',(-0.069139 -0.037043*edu + 0.021838*ic2102M +
0.057646*ic2122 - 0.026180*psystem
                        -0.058429*Loxygen_depD -0.056249*Lcolumnaris_escD -
0.072495)/0.073476);
run;
/*Means for the above dummy variable cdf's are estimated here*/
proc means data=dum_ME_weather;
var pred1_0we pred1_1we pred2_0we pred2_1we pred3_0we pred3_1we pred4_0we
pred4_1we pred5_0we pred5_1we;
output out=dum1 mean=;
run;
```

```
/* The dummy variable marginal effect is calculated by subtracting the mean cdf for d=0
from
the mean cdf for d=1 and this difference is multiplied by the dummy variable coefficient
estimated in the above PROC QLIM procedure for this weather loss model.
Note: these marginal effects are different from those calculated by the canned PROC
QLIM procedure.
*/
data dum2;
set dum1;
margeffd1we = (pred1_1we - pred1_0we)*(-0.037043);
margeffd2we = (pred2_1we - pred2_0we)*(-0.026180);
margeffd3we = (pred3_1we - pred3_0we)*(-0.058429);
margeffd4we = (pred4_1we - pred4_0we)*(-0.056249);
margeffd5we = (pred5_1we - pred5_0we)*(-0.072495);
run;

proc print;
run;
/*descriptive statistics for diseases*/
data losses2D ;
 set losses2 ;
  if Lfall_springP = . or ic2101 = . or edu = . or ic2105 = . or
                         ic2122 = . or ic2102M = . then delete ;
run;

proc means data=Losses2D ;
 var Lfall_springP ic2101 edu ic2105 ic2122 ic2102M  ;
  WEIGHT EF3 ;
  output out=summaryD ;
run;quit;

proc QLIM data = Losses2d;
 model Lfall_springP = ic2101  edu ic2105 ic2122 ic2102M;
 endogenous Lfall_springP~censored(lb =0 ub=1); weight EF3;
 ODS OUTPUT ParameterEstimates=par_Lfall_springP ; output out=marg_Lfall_springP
PREDICTED marginal;
run; quit;

proc means data=marg_Lfall_springP N mean ;
 var Meff_ic2101 Meff_edu
            Meff_ic2105 Meff_ic2122 Meff_ic2102M ;
  WEIGHT EF3 ;
  output out=Meff_Lfall_springP
          mean (Meff_ic2101 Meff_edu
            Meff_ic2105 Meff_ic2122 Meff_ic2102M)=
```

```
                    Meff_ic2101 Meff_edu
            Meff_ic2105 Meff_ic2122 Meff_ic2102M;
run;
quit;

/*calculation of marginal effects for the ONE dummy variable in the disease loss model
Note d1=education dummy
*/
data dum_ME_disease;
set Losses2d;
*pred1_0 = cdf('Normal',(0.017623 - 0.000600*13.7034911 - 0.000009401*19.4187536 -
0.000431*11.8113642
                                        -0.004485*5.4984991)/0.035800);
*pred1_1 = cdf('Normal',(0.017623 - 0.000600*13.7034911 - 0.001577 -
0.000009401*19.4187536 -0.000431*11.8113642
                                        -0.004485*5.4984991)/0.035800);
pred1_0 = cdf('Normal',(0.017623 - 0.000600*ic2101 - 0.000009401*ic2102m -
0.000431*ic2105
                                        -0.004485*ic2122)/0.035800);
pred1_1 = cdf('Normal',(0.017623 - 0.000600*ic2101 - 0.000009401*ic2102m -
0.000431*ic2105
                                        -0.004485*ic2122 - 0.001577)/0.035800);
run;
/*Means for the above dummy variable cdf's are estimated here*/
proc means data=dum_ME_disease;
var pred1_0 pred1_1;
output out=dum3 mean=;
run;
/* The dummy variable marginal effect is calculated by subtracting the mean cdf for d=0
from
the mean cdf for d=1 and this difference is multiplied by the dummy variable coefficient
estimated in the above PROC QLIM procedure for this disease loss model.
Note: these marginal effects are different from those calculated by the canned PROC
QLIM procedure.
*/
data dum4;
set dum3;
margeff = (pred1_1 - pred1_0)*(-0.001577);
run;

proc print;
run;
 ods html;
```

```
/*declaration of variables for FCR model*/
data efficiencyfcr;
set Losses2;
ic1168 = ic1168 * 1;
ic2101 = ic2101 * 1;
ic2109 = ic2109 * 1;
ic2121M = ic2121M * 1;
ic2308 = ic2308 * 1;
ic2321M = ic2321M * 1;
ic2322M = ic2322M *1;
ic2323M = ic2323M * 1;
ic2325 = ic2325 *  1;
ic2327M = ic2327M * 1;
ic2328 = ic2328 * 1;
ic1168_01 = ic1168 * ic2101;

/*Dummy variable creation for multiple category variables:
  ic1169 becomes edu with HS or less equaling 1 and above HS equaling 0;
  ic2324 becomes Production System type where multiple batch = 1 and single batch
        plus modular equal 0;
 */
 if ic1169 = 1 or ic1169 = 2 then edu = 1; else edu = 0;
if ic2324 = 2 then psystem = 1; else psystem = 0;
run;
quit;

proc reg data = efficiencyfcr;
model cat_fcr = ic1168 edu ic2101 ic2109
     ic2121M ic2308 ic2321M ic2322M ic2323M ic2325 ic2327M ic2328
          psystem ic1168_01;
title 'Regression Results for Cat FCR  Variables'  ;
run;
quit;

/*decriptive statistics*/
proc means data = efficiencyfcr n mean stddev median min max fw=-7 maxdec=2
          classdata = efficiencyfcr exclusive printalltypes;
          var cat_fcr ic1168 edu ic2101 ic2109
     ic2121M ic2308 ic2321M ic2322M ic2323M ic2325 ic2327M ic2328
          psystem ic1168_01;
                    *class cat_fcr;
                    title 'Descriptive Mean Statistics for Cat FCR  Variables'  ;
run;
quit;
ods html close ;
```