Best Management Practices For West Alabama Catfish Production: Creating Profitability Through Efficiency, Consistency, and Quality

by

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A dissertation submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

Auburn, Alabama
December 14, 2013

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Abstract

The U.S. catfish industry is in a time of transition. In the last several years feed prices have been at historically high levels as fish prices have fluctuated wildly. Furthermore, in recent years the industry has experienced increased competition from foreign imports as well as alternative products from domestic producers. Now more than ever producing a quality product is of paramount importance to compete for market share. Now is the time for the U.S. catfish industry to modernize. They must consistently produce a high quality. In order to continue the process of increasing product quality and consistency in U.S. farm raised catfish this study looks at the development of best management practices from a farm level. Surveys were sent to every farm producing food size catfish in Alabama. Information was gathered on the complete range of farm management practices and paired with production and profitability data in order to produce regression models predicting farm production (on a per acre basis) as well as profitability (Chapter 3). Issues of quality are also addressed focusing on yellow fillet (Chapter 2) and off-flavor (Chapter 4). Regression equations were developed to examine the relationship between farm management practices and yellow fillet as well as off-flavor. These regression equations provide farm managers a tool to predict the outcome of a management change on the quality and quantity of catfish that their farm will produce.

This study ends with a chapter updating best management practices from the literature Chapter 5) as well as a chapter outlining a system where fish are sold under a merit based marketing system where the price paid to producers rewards higher quality fish (Chapter 6). Such a system can serve as a catalyst for change in the industry.

Acknowledgments

I would first and foremost like to thank God for bringing me to this PhD program, as well as getting me through it. I also would like to thank my wife, Bethany Courtwright, for your support through this process as well as my parents, Ernest and Pat Courtwright, for your constant encouragement. I would like to thank Luke Roy, Lisa Bott, and Bill Hemstreet for all your help in getting data and access to farms, and Alice Moore for all the patience and help at Harvest Select. Also, I would like to thank the catfish farmers of West Alabama for cooperating with this study. Finally, I would like to thank my committee Dr. Hanson, Dr. Rouse, Dr. Chappell, and Dr. Terhune for this opportunity as well as Dr. Abebe for guiding me through the statistics, and Dr. Witte for serving as the university reader.

Table of Contents

List of Tables

List of Figures

Chapter 1. Introduction

This is a time of transition for the United States catfish industry. In recent years input prices have increased and at the same time competition for market share from other products has greatly intensified (Hanson and Sites, 2011). It is more important now than ever for the industry to produce a consistently high quality product and to produce it as efficiently as possible. A clear concise set of best management practices (BMPs) and standard operating procedures (SOPs) for production of catfish is essential for producers to have established guidelines to increase farm profitability and economic efficiency. Standardized production systems will also enable farms to produce fish in similar and consistent ways in order to deliver high quality products to the market.

Production systems used to produce catfish are extremely complex systems with many variables that interact forming a constantly changing environment. Because of the complexity and variety of systems used to grow catfish the literature on BMPs and SOPs is confusing at best, and in many cases somewhat contradictory. Furthermore, many of the publications (especially extension publications) addressing the issue of BMPs for catfish production are outdated or essentially re-publications of dated material. In recent years new technologies have emerged and economic conditions have changed creating the need to re-visit BMPs for growing catfish. This study seeks to define the management practices that maximize profitability and produce the highest quality product. In addition it seeks to better understand how and why producers make the management decisions that they do in order to better facilitate continuous improvement in the industry.

This study uses a framework of industry surveys to match farm production practices with measures of outcomes (both quantity and quality) arriving at the processing plant. From enterprise budgets, determinations are made about the patterns of production that result in the highest profits per water acre per year for producers. Furthermore, the same survey is used in order to better understand how information is disseminated throughout the West Alabama catfish producing community as well as evaluate farm owner's and farm manager's ability and willingness to bear risk.

Goals

The main goals of this study are to:

1. Develop best management practices that can guide the Alabama catfish industry toward improved production efficiency, increased economic efficiency, improved product quality, and improved product consistency.

2. Better understand farm technology adoption factors, producer's willingness to bear and take risks, and social mechanisms for information transfer through the catfish producer community in West Alabama.

3. Begin the process of transferring appropriate BMPs and SOPs to the catfish producers and processors in West Alabama based on the findings of the study through extension workshops, fact sheets, articles, and/or mailings.

Objectives

In order to accomplish these goals the following objectives were identified:

1. Summarize the range of current management practices for producing catfish in West Alabama.

2. Analyze current farm management practices for production, economic efficiencies and profitability.

3. Analyze producer's willingness to take risks, such as in adopting new technologies or intensifying production.

4. Group farms and farmers into appropriate clusters, based on production intensity level, financial profitability, willingness to bear risk, and/ or socioeconomics/ demographics.

5. Review current management practices and identify those that most effectively help farmers in each cluster accomplish Goal 1 above, that is, matching farm management to goals of production/economic efficiency and product quality/consistency.

6. Analyze the similarities and differences in the most effective current production methods and the current BMPs from the literature.

7. Develop a new set of BMPs based on objectives 4 and 5 above that are appropriate for each cluster classification. This may confirm existing practices, modify existing practices, or develop completely new BMPs. Using the agreements and discrepancies established in the prior objectives for each cluster, will help the whole industry better accomplish the goals stated above.

Accomplishing these objectives has the potential to help producers increase their profitability and provide a higher quality product. By better understanding the complex interaction of variables at work in their production systems, farmers can produce a more consistently high quality product at a lower price which would result in a more sustainable livelihood for producers and a better quality product for processors. These changes will provide a better chance for the industry to compete with other meat and seafood products in the U.S. and world markets.

Limitations

This study is being conducted only using farms in West Alabama. It is not necessarily generalizable to catfish farms across the country due to regional differences in water quality, pond construction, as well as input and transportation costs. The principles discussed in this study are generalizable to catfish production as a whole and with proper understanding of the interactions of the variables in a catfish production system, the specific BMPs can be modified to different production settings. Furthermore, this study is limited to the establishment of BMPs for food fish production. Separate BMPs need to be developed for hatchery/brood stock management, harvest and transport of fingerlings, harvest and transport of food fish, and processing. These areas are outside the scope of this study. The BMPs established in this study may have applicability to some of these other areas; however they are not intended to address the specific industry settings mentioned above.

The majority of the data used in the following chapters were developed from the production years 2011 and 2012. These two years are distinctive in the history of the U.S. catfish industry as feed prices reached all-time highs and in 2011 fish prices were also at an all-time high followed in 2012 with a crash in pond bank prices paid for fish. These two years present unique opportunity into looking at changes in management practices that helped farms survive the low fish prices and high feed prices of 2012. However, the data from these two years also presents many challenges for analysis in that many farms were actually trying to limit production in 2012. Considering that catfish are often a multi-year crop, management decisions during the high pond bank prices of 2011 likely affected production during the low prices of 2012.

Definitions

Best Management Practices: Techniques and culture methods based on the current technologies available and the most reliable, and testable data that have the highest probability of producing a product that meets all the stated goals.

Standard Operating Procedures: Techniques and culture methods that are standardized industry wide in order to produce consistency in the output industry wide.

Organization of the study:

Chapter 1 is an introduction to the study, discussing the problems addressed by the study as well as the goals and objectives of the study, followed by the limitations of the study and the definition of terms. Chapter 1 ends with a review of the literature (both academic journals as well as extension literature) to serve as a basis for the later discussion of established BMPs. Chapter 2 begins the detailed discussion of the issue of yellow fillet, beginning with a review of the literature on the subject followed the methods, results, and discussion of the yellow fillet survey conducted as part of this study. Chapter 3 deals with the best management practices for production focusing on not only quantity but also profitability. Data from the second survey will be used in order to highlight the production practices that produce the most fish per acre per year. By using enterprise budgets constructed from the survey data the most efficient and profitable methods of growing catfish will be defined. Chapter 4 examines the issue of off-flavor in catfish. Off-flavor is a problem that has had significant research done in order to identify its principle causes. In this study farm management plans producing the most consistently on-flavor fish were identified in order to provide practical information intended for direct dissemination to farmers. Chapter 5 is a discussion of the findings from the previous chapters, including disagreements that may arise in the best management practices, as well as a comparison of these studies to the current BMP's for catfish production in order to highlight potential differences or discrepancies. Chapter 6 is a discussion of a framework for establishing a system where fish are sold under a merit-based pricing system where premium prices are paid to farms consistently producing premium products. Following Chapter 6 are appendices, including equations for economic analysis used, the survey instruments themselves, as well as the scores given by the expert panel for validity testing of the BMP survey.

Literature Review

The following review includes both literature from peer reviewed journals as well as extension publications. Extension publications are not a primary source of research data and would not normally be weighted as heavily in a literature review as they are below. However, it is appropriate in this case as the focus of this study is an extension focus and one of the major outcomes should be to verify or modify existing BMPs in the extension literature and add new BMPs where necessary. Also, the following literature review addresses broad catfish farm management topics. As this dissertation is focused on extension and information transfer it is appropriate to include a basic explanation of the principles of catfish farming to be used as a framework for future extension publications including established BMPs as well as new or modified BMPs resulting from this study. With that in mind the following brief review of the literature will serve as the basis for discussion and comparison for the entire study with each chapter having a more concise review of pertinent literature.

STOCKING

The BMPs for stocking are hard to define as there are several methods for growing catfish in ponds. There are single and multiple batch systems and each have variations. Though single batch systems have been shown to be more profitable if fish can be sold without constraint, most producers use a multiple batch system largely due to issues of off-flavor. The advantage of multiple batch systems is that more ponds will have marketable size fish at any one time (Tucker and van der Ploeg, 1999). However, regardless of the type of system used, a producer must first determine what is their intended market size and the frame they want to harvest their fish before determining the density of fish to stock in their pond. The stocking rate is determined by the carrying capacity of the particular pond which is strongly influenced by the inputs into the pond (feed, aeration, water exchange etc.). Currently, processors are demanding a fish between 1.5 and 3.0 pounds. An older extension publication suggests a stocking density for experienced producers could be up to 6,000 fish per acre to produce 6,000 pounds per acre per year (Jensen, 1997). In the "Catfish Farmer's Handbook," Wellborn (N.D.) stated that, when available, stockers of 6-8 inches long should be stocked as they can reach a size of 1.5 pounds in approximately 210 feeding days with water temperature above 70 degrees F. Here one can begin to note the difficulty in using the literature to pick a perfect number of fingerlings to stock per acre. It appears that Jensen's publication was predicting a harvest size of approximately 1 pound (if low mortality is assumed). Wellborn was calculating based on 1.5 pounds which would make the total number of fish different when thinking of the total carrying capacity of the pond. Also, one pound fish are smaller than the processors demand so the producer would likely receive a penalty for selling fish that are too small, if they were accepted at all (unless they were intended for a specific small niche market and not to be sold to processors for the mass market). Gregory Whitis (Extension agent) suggests stocking 6850; 9-inch stockers per acre in order to raise a 2 pound fish in one growing season (personal communication, Gregory Whitis, 2009). Similarly, Auburn University's Yield

Verification Project protocol recommends stocking 6750, 8-inch fingerlings to reach an average market size of 2 pounds and total pond production of 13,000 to 14,000 pounds per acre per year. As for the timing of stocking, fingerlings can be stocked anytime in the year but are able to deal with the stresses of transport better when water temperatures are low in late winter or early spring (Jensen 1997). Timing of harvesting/market should be considered as well when stocking if the fish are to go to a special or niche market where timing of harvest is important.

When producing with a multiple batch production scheme the same principles of carrying capacity apply for initial stocking and producers should attempt to re-stock (after harvest) the same number of fish lost from the system (number of fish harvested plus mortalities), in an attempt to keep the pond producing at its maximum potential without over stocking.

FEEDING

Feed is one of the most important inputs in catfish production. Feed not only represents the biggest variable production cost, it is the main determining factor in fish growth and water quality. At high densities a nutritionally complete feed is required. According to Jensen (1997), feed containing 32% protein plus all essential vitamins and minerals is adequate and the most economical feed for catfish production. It should be noted that Wellborn (N.D.) recommended protein content in feed is slightly higher, 35%. Cacho (1984) shows no difference in weight gain, feed consumption or conversion between 26% and 32% protein diets. To complicate matters even more Li et al. (2008) found no significant difference in the growth of channel catfish fed 24%, 28%, 32%, and 36% protein diets, however in the same study there were significant differences in carcass, fillet, and total meat yield across the protein range (fish fed higher proteins had better yield). The most recent recommendation from the National Research Council for the nutrition requirements of Channel Catfish is that fish receive a minimum of 29% protein (National Research Council, 2011). This protein level has actually been decreased from 32% which they recommended in 1993 (Subcommittee on fish Nutrition, 1993).

While discussing feed quality it is important to not only look at growth of the fish but also specifically address the issues of increasing yield and improving feed conversion ratios (FCRs). Increasing yield and improving FCR are two of the most important aspects to making the U.S. catfish industry profitable in the long run. Slight improvement in yield of fish arriving at the processing plant over the large volumes processed in a year represent significant increases in profits for the processors. These profits could be partially passed to producers in the form of incentives for producing a higher quality product. This is known as selling fish on a merit-based marketing system (see chapter 5 for a more thorough discussion of merit-based marketing). Likewise, even a small change in FCR on the farm can have huge impacts on profitability, especially when considering the high feed costs paid by farmers recently.

Li et al (2008) found that increasing protein levels of feed fed from 24% to 36% increased dress-out yield. In another study, Li et al. (2000) found a positive linear relationship in fillet yield as feed protein levels increased from 24% to 26%. In a subsequent study Li et al. (2001b) found that fish fed a 32% protein feed had a higher fillet yield than did fish fed 26% protein feed and a higher carcass yield than fish fed a 28% protein diet. In a study examining higher protein levels (28, 32, 36, and 40%) it was found that yield increased as dietary protein increased to 36% (Robinson et al., 2004). However, Li et al. (2003) found no changes in yield between fish fed 28% and 32% protein feeds. This result is supported by Li et al. (2001a) which showed no difference in yield between groups fed 26, 28 and 32% protein feeds.

Increasing protein content of the feed has resulted in lower FCRs in some studies but not others. In the study mentioned above Li et al. (2000) found FCR was lower for fish fed a 28% diet than for fish fed either the 24% or 32% protein diets but similar to fish fed a 36% protein diet (Li et al., 2000). These results are contradicted by a study conducted by the same researcher a few years later where it was found that fish fed a 28% diet had a higher FCR than fish fed either a 32% or 35% diet (Li et al. 2004). Of the other studies mentioned above, Li et al. 2001a, 2001b, 2003 as well as Robinson et al. 2004, found no differences in FCR between protein groups.

One might speculate that these differences in the literature could be due to the fish in each trial using different amounts of natural productivity as a supplement to the feed fed, but there are many other variables that affect growth, yield, and feed conversion (especially water quality parameters).

The common practice of culturing hybrid channel x blue catfish further complicates the question of feed protein level. Li et al. (2007) found hybrid channel x blue catfish had higher yields when fed 36% protein feed but there was no difference in consumption, weight gain, or FCR for hybrids fed 28, 32, or 36% protein diets (Li et al., 2007).

Feed comes in various sizes; crumbles (for fingerlings less than 3 inches), 3/16 inch pellet (for fish larger than 3 inches), and ¼ to 3/8 inch pellets (for grow-out size fish greater than ½ pound). Jensen (1997) found that catfish grow most efficiently when fed about 90% of all they will voluntarily eat in 5-10 minutes (Jensen 1997). Dr. Jesse Chappell (personal communication, Aquaculture Extension Specialist, Auburn University) recommends allowing 10-15 minutes instead of 5-10 minutes and says that this satiation amount should be adjusted once a month in the winter, every 2 weeks when water temperatures are between 60 and 73 F, and every 7-10 days during the core feeding season (2010). Following a similar satiation regime, Auburn University's yield verification protocol gave a maximum feeding rate of 150 pounds per acre per day (assuming aeration rates are sufficient, see Oxygen Management discussion, page 23). Another method of calculating feeding rates is to sample fish every two weeks (or estimate body weight based on historical feed conversion ratios for that pond) and adjust feed according to the table in the Extension publication "Channel Catfish Production In Ponds" (Jensen 1997).

Wellborn (N.D.) reported that feeding twice daily usually improves feed consumption and feed conversion. It is best to wait to feed the morning part of the ration until after dissolved oxygen concentrations increase (usually after 8 or 9 a.m.) and feed again in the early afternoon. By feeding in early afternoon as opposed to late afternoon a producer can prevent the increased oxygen requirement of fish after feeding from coinciding with the decreasing oxygen concentrations in the evening (Wellborn, N.D.). However, in a more recent study Li et al. (2010) found that feeding twice daily actually resulted in higher feed conversions. Wu et al. (2004) found that there was no difference in FCR, weight gain, survival, or percent dress-out between fish fed once per day and those fed twice per day. And in a study published in 2005, Li et al. found that feed conversion ratios decreased when fish were fed once daily in the morning compared to once daily in the afternoon or twice daily. However, almost all catfish farmers when factoring labor costs and time typically feed once daily after dissolved oxygen increases in the morning and before it is late enough in the afternoon to cause additional stress as described above. Also, Wellborn (N.D.) notes that feeding 7 days a week as opposed to only 6 days per week can reduce production time by four weeks. However, Wu, et al. (2004) found no difference in weight gain between fish fed seven days a week and those fed six days per week.

Another major issue of feed management is that of winter feeding. According to Hatch et al. (1998), partial feeding in the winter months (maintaining feeding regimes based on temperature in November, March, and April and not feeding from December through February) results in higher profitability than maintaining a full feed regime or not feeding at all in the winter. In a study looking at overwintering channel catfish, blue catfish, and hybrid channel x blue catfish, it was found that winter feeding at a rate of 2% of initial body weight, twice per week, improved growth and fillet yield when compared to fish not fed the duration of the 14 week study (Bosworth, 2012). It also should be noted that fish should not be fed for at least 24 hours before harvest and shipping because fish wastes and regurgitated feed consume large quantities of oxygen in live haul tanks and can cause ammonia and carbon dioxide problems (Jensen, 1997).

FEED'S INFLUENCE ON WATER QUALITY

Protein in the feed entering the pond system has nitrogen as one of its components. Therefore more feed brings more ammonia (and potentially nitrite under certain conditions). This can be deadly to fish, but also the process of nitrification of the nitrogen in the feed adds acidity to the water increasing the liming requirement in the ponds (Boyd personal communication, 2010). Alkalinity in catfish ponds in different areas of the country vary greatly and, therefore, their ability to buffer this change in pH varies greatly as well (for further discussion of alkalinity and pH buffering capacity see water quality section). Also, the nutrients in the feed (nitrogen, phosphorus, potassium and others) stimulate the primary production in the pond driving the whole aquatic ecosystem, and greatly influencing oxygen production and management in the pond. The more feed added to the pond, the higher the oxygen demand to break down those nutrients, and the lower night time dissolved oxygen concentrations will drop. Therefore, feeding the highest quality feed available, with all essential vitamins and minerals is extremely important. When being fed an inferior diet fish must take in more feed than they would on a high quality diet in order to maintain the same growth rate (in order to get all the nutrients necessary, a greater volume of a lower quality feed must be ingested). Therefore, when low quality feeds are fed, water quality variables suffer because of the increased volume of feed entering the pond. It stands to reason that FCR will be higher as well (meaning the farmer has to buy more pounds of feed to grow his fish to market size). Since feed is one of the most significant variable costs in fish production as well as an influential factor in oxygen cycles, and strongly influences water quality parameters like ammonia, nitrite, alkalinity, and pH, it is essential that the feed used in catfish production be as high quality as possible. It should have the most digestible sources of protein, and the appropriate essential vitamins and minerals in order to lower feed conversion ratios and increase feed utilization by the fish causing less detrimental effects on water quality.

For a complete list of the nutrient requirements of catfish see the National Research Council's book Nutrient Requirements of Fish and Shrimp pages 327 and 328 (2011).

WATER QUALITY

The water quality in an aquaculture enterprise is the controlling factor in all production variables. Unlike most other livestock production, all the inputs (feed, chemicals for disease control etc.) in a closed pond aquaculture system remain in the system. Furthermore, under a closed pond management regime all wastes remain in the pond and must be processed biochemically in the same growing environment as the culture species. This presents serious challenges to the catfish producer. The maintenance of proper water quality for not only survival but optimum growth of the catfish is essential to a successful operation. The following discussion will break the water quality issues into 3 main classes: 1) water temperature, 2) water chemistry, and 3) oxygen management, though these three categories in actuality are in constant interaction and cannot be separated because of their effect on each other.

Water Temperature:

Water temperature plays an essential role in many aspects of channel catfish culture. For optimum growth of channel catfish water temperature should remain between 25°C and 32°C and growth decreases rapidly when water temperature decreases below 20°C and when it exceeds 35°C (Tucker and Hargreaves 2004). To obtain marketable size catfish, pond temperatures should remain above 20°C for at least 180 days per year and above 25°C for at least 125 of those days. It should be noted that while catfish in grow-out ponds perform better under warm water conditions, a time of cool water is necessary for brood stock as channel catfish are a temperate climate fish (Tucker and Hargreaves 2004). The cool months in Alabama are sufficient to stimulate egg development in brood stock if fingerling production is planned.

Water temperature also plays an important role in dissolved oxygen concentrations. Dissolved oxygen concentration at saturation varies inversely with temperature, thus at lower temperatures the saturation concentration is much higher. Temperature is also an important consideration in other management factors such as disease control and treatment, presence of toxic nitrogen compounds in the water, and fish transport (as fingerlings and stockers have higher survivals when moved in cooler water).

Water chemistry

The main aspects of water chemistry that catfish producers should be concerned with are alkalinity, hardness, pH, carbon dioxide, ammonia, nitrite, and chloride (Jensen 1997). Alkalinity is "the total concentration of titratable bases in water expressed as equivalent calcium carbonate" (Boyd, 1990, page 44) including bicarbonate, carbonate, ammonia, hydroxide, phosphate, silicate, and some organic acids. Alkalinity acts as a buffer to absorb hydrogen ions (which cause acidity). Therefore a high alkalinity helps resist pH change (Boyd, 1990). As a standard rule, alkalinity has traditionally been considered adequate for catfish ponds if it was above 20-30 mg/L (Tucker and Hargreaves 2004). However, more recent information shows that for commercial fish grow-out ponds, 50 mg/L should be considered a minimum for alkalinity, and that 80-

100 mg/L is preferred (Claude Boyd, personal communication, 2010). Alkalinity can be adjusted by the addition of one or a combination of several compounds (agricultural lime, hydrated lime, quick lime, sodium bicarbonate, or sodium hydroxide). Agriculture lime is the least expensive, most predictable, and least risky chemical to adjust alkalinity (Jensen, 1997). When thinking of a BMP for liming rates in West Alabama one must consider the highly variable alkalinities from region to region as well as differing soil types by location (and subsequently different lime requirements of pond bottom soils). Farmers should first test the alkalinity in the water on their farm and if it is lacking the best practice is to send a soil sample for analysis to determine the lime requirement specific for that pond. In practice it is not uncommon however to add a quantity of lime and then re-test alkalinity after 10-14 days, then re-apply if necessary.

Hardness is the measure of divalent (+2) alkaline earth ions, which in most waters is calcium and magnesium, and is measured in calcium carbonate ($CaCO_3$) equivalence (Boyd, 1990). Hardness benefits fish in osmoregulation and stress resistance and it is generally considered that hardness should be maintained at or above 20-30 mg/L for aquaculture ponds (Tucker and Hargreaves 2004). It should be noted that in most waters hardness and alkalinity have very similar values, though not always. Also, the most common method of adjusting alkalinity, agriculture lime, is an acceptable way to raise hardness; as agricultural lime usually is made of calcitic or dolomitic limestone containing calcium and sometimes magnesium. The best management practice for hardness modification is the same as that of alkalinity, and typically the application of lime to adjust alkalinity will result in hardness within the acceptable range.

The next two water chemistry parameters, pH and carbon dioxide, are discussed together. Changes in the pH occur on a daily cycle driven by photosynthesis in the pond (Boyd, 1990). At night when there is no photosynthesis occurring, carbon dioxide is released from respiration of the bacteria breaking down organic matter in the pond as well as algae and the culture species. This carbon dioxide then reacts with the water to form carbonic acid driving the pH downward through the night. Once the sun rises and the algae in the pond begin to photosynthesize pH begins to move upward again, because carbon dioxide is used in photosynthesis. Optimum pH for catfish ponds is 6.5-8.5 (neutral to slightly basic), but can vary from 6.0-9.5 without severely stressing fish (Jensen 1997). This diurnal swing in pH is buffered by alkalinity making the difference between night time low and afternoon high less drastic and therefore less stressful on the fish. This illustrates the importance of the best management practice of maintaining appropriate alkalinity levels, based on soil and water analyses to determine proper liming rates.

Also significant in the discussion of ammonia is the pH of the water. Ammonia is released as a waste product from fish, and from bacterial decomposition of proteins in uneaten feed. Approximately 53.8 pounds of ammonia-nitrogen is produced for each ton of 28% protein feed fed. Ammonia in the water dissolves into two different compounds, ionized ($NH4+$) and un-ionized ammonia ($NH3$) depending on the pH and temperature of the water. Ionized ammonia is only slightly toxic to fish, but un-ionized ammonia is extremely toxic (Boyd, 1990). Un-ionized ammonia levels as low as 0.12 ppm can cause reduced growth in Channel Catfish (Robinette, 1976), and the 96 hour

TC50 for channel catfish is between 1.50 and 3.10 mg/L (Boyd, 1990). As water temperature rises and as pH raises the portion of total ammonia nitrogen present in the water in the form of un-ionized ammonia increases with pH having the most drastic effects on the presence of un-ionized ammonia (Jensen, 1997). The daily swing in pH (and the importance of buffering this swing with adequate alkalinity levels) is extremely important in managing toxic un-ionized ammonia in the pond. Throughout the day as temperature increases pH also increases (especially in un-buffered waters) due to increased photosynthesis, making the percentage of ammonia in the water that is un-ionized potentially toxic in catfish ponds receiving a high feeding rate. There is no cost effective means of treating high ammonia levels in ponds (Tucker and Hargreaves 2004). Withholding feeds results in a decline of ammonia concentrations but this decline usually takes several days after feeding is stopped. Therefore, the best way to manage high ammonia concentrations is prevention. By manipulation of stocking, feeding and harvesting rates one can attempt to keep the ammonia inputs into the water below the assimilation capacity of the pond system (Tucker and Hargreaves 2004). When un-ionized ammonia levels become dangerously high pond water should be flushed; fresh water and extra aeration should be added in an attempt to minimize mortality as ammonia damages the gills of the fish (Jensen 1997). It should be noted that though flushing ponds is the only practical way to eliminate ammonia from the culture environment, in many cases it is not always possible due to limited water availability. Furthermore, adoption of management practices that limit the nutrient or chemical rich effluents entering receiving streams is an environmentally responsible a goal for catfish producers.

Ammonia can be absorbed by bacteria in the pond that use ammonia as a nutrient. These oxygen requiring bacteria use ammonia in a process called nitrification. Bacteria from the genus *Nitrosomonas* convert ammonia to nitrite and bacteria from the genus *Nitrobacter* convert nitrite to nitrate (Jensen 1997). In this process of breaking down the ammonia, hydrogen ions are released increasing the acidity of the water and causing an increased lime requirement to buffer this change in acidity. The exact amount of extra lime required is dependent on the quantity of nitrogen (protein) in the feed (making use of a quality feed very important) and the feed conversion efficiency of the culture animal (Claude Boyd, Auburn University, personal communication, 2010).

Another water chemistry component of concern is nitrite. As stated above nitrite is a compound produced in the breakdown of ammonia. It is important to catfish production because it is very toxic to catfish. Nitrite concentrations can reach dangerous levels if the process of nitrification is disrupted. Most commonly nitrite problems occur in fall and winter, when sudden changes in water temperature disrupt bacterial decomposition (Jensen, 1997). Nitrite in the pond is taken up by the fish and oxidizes the hemoglobin in the blood (the oxygen transport cells) forming methemoglobin which cannot carry oxygen efficiently. Fish under stress from nitrite toxicity appear to be under oxygen stress though there is ample oxygen in the water, but their blood cannot properly carry it. The blood and gills of a fish suffering from nitrite toxicity will appear brown from the presence of the methemoglobin (Noga, 2010). Nitrite levels as low as 0.5 ppm can cause stress (Jensen 1997).

It is difficult to determine the highest acceptable nitrite concentration (without causing mortality) because nitrite is so closely related to dissolved oxygen and presence of chloride ions in the water (Boyd, 1998). As the other variables change the effect on the fish of the same concentration of nitrite can be vastly different. To prevent nitrite toxicity in catfish ponds, salt (NaCl) is typically added. The chloride ion from the salt once in solution binds with the chloride cells on the gill epithelium blocking the binding and uptake of nitrite by gill cells. If the ratio of environmental chloride to nitrite-nitrogen is 30:1 or greater little nitrite will enter the blood stream of catfish even if environmental nitrite is high. Therefore it is a good practice to maintain 100-150 mg/L of chloride in production ponds to prevent nitrite toxicosis (Tucker and Hargreaves 2004).

Oxygen management

Dissolved oxygen management in catfish ponds is one of the pivotal factors that make the difference between success and failure of the aquaculture enterprise. Oxygen levels (along with a few other factors like ammonia discussed above) dictate the amount of feed that can be fed into the pond and therefore dictate appropriate fish stocking rates. Oxygen is often one of the limiting factors that determine stocking density, growth, and final harvest weight. This effect can be both direct and indirect. Some of the direct effects of low dissolved oxygen are; stress on the fish, decreased feed intake, slowed growth, increased vulnerability to disease. The indirect effect of oxygen levels include restricting feed to the level that fish will not grow to their maximum growth potential. Oxygen in ponds is transferred across the water-air barrier and dependent on the partial pressure of oxygen in the water relative to the partial pressure in the air. In most catfish ponds the amount of oxygen that can be transferred in this manner is relatively low when looking at the complete oxygen budget because of the high biomass of bacteria, plants, and animals. A much larger portion of the total oxygen budget in aquaculture ponds is dictated by the interaction of respiration and photosynthesis (Boyd and Tucker 1998).

The processes of respiration and photosynthesis drive most of the oxygen budgets in pond environments. Respiration (of culture organisms, algae, and bacteria) uses oxygen 24 hours per day whereas photosynthesis only produces oxygen when sunlight is present. This interaction can cause large swings in oxygen on a daily cycle. High biological activity in catfish ponds can result in highly supersaturated oxygen conditions in the afternoon and highly unsaturated conditions at night. In many cases supplemental aeration is needed to keep oxygen levels from dropping too low for the fish in the pond to survive and grow well. Mechanical aeration should be supplied to attempt to maintain dissolved oxygen above 4 mg/L. According to Jensen as a general rule 1 to 1.5 horsepower per water acre is sufficient for supplemental aeration purposes, but additional emergency aeration should be available for extreme cases (Jensen 1997). This however shows the need to update extension materials. Masser et al. (2005) suggests 2-3 hp/ac. Furthermore, using a standard equation for aeration requirement, taking into account the biological oxygen demand of the feed, pond feeding rate, and the aerator's efficiency (using approximate average industry values such as 140 kg/ha feeding rate) one would need to aerate above 6 hp/acre to reach maximum efficiency, which is well above current industry standards (Claude Boyd personal communication, 2010).

Some of the most current ways of thinking about aeration are actually looking at aeration rates on a horsepower per acre-foot basis (Jesse Chappell, personal communication, 2010). The goal is to maintain dissolved oxygen concentrations above 3 mg/L throughout the water column, allowing fish to utilize the whole volume of the pond, and allowing for oxidation of wastes throughout the water column. When looking at aeration per ac-ft it is recommended that at least 1.25 hp/ac-ft is provided in channel catfish ponds. However, this recommendation is still being tested and tried but it is consistent with the above mentioned recommendation of 5-6 hp/acre considering many ponds have an average depth of 4 to 5 feet (Jesse Chappell personal communication, 2010).

In a study with ponds stocked at a rate of 4047 fish/acre (10,000 fish/ha) and receiving a maximum daily feeding rate of 47.3 pounds/acre (53 kg/ha); supplemental aeration was shown to increase feed efficiencies (FCRs of 1.32 versus 1.75 for aerated and un-aerated ponds, respectively). Providing supplemental aeration also increased total fish production (4,813 Kg/ha versus 3,659 Kg/ha for aerated and un-aerated ponds, respectively (Boyd and Tucker 1998). In another study it was reported that providing 6 hours of aeration every night, i.e. not allowing D.O. to drop below 4 mg/L, compared to providing aeration on an emergency basis only (when D.O. fell below 1 mg/L) resulted in significantly better feed conversion and greater weight gain (Lai-Fa and Boyd, 1988). A similar study conducted in Mississippi did not show better feed conversion (though fish were fed in a different way) but did result in very high net production values in ponds with a high aeration treatment (Torrans, 2005). It seems that increasing aeration well above the normally suggested rates could have positive effects on both growth and production efficiencies. Producers should be aware that the fish in a pond may utilize as little as 10% of the total oxygen used in a day depending on stocking and feeding rates. The other 90% goes to other biological and chemical factors in the pond (Boyd and Tucker, 1998). This microbial action is essential for the breakdown of organic waste into non-toxic forms. Therefore, farmers should consider increasing aeration rates to better provide appropriate growing conditions for their fish, whereby potentially increasing harvest by increased growth rates (and decreasing FCR) without increasing stocking rates (and feeding rates). If feeding rates are increased other water quality parameters, such as ammonia and nitrite, become increasingly more problematic.

Table 1.1 was updated from Jensen (1997) adding the research discussed above and the column for the BMP for achieving these goals. This table summarizes the best management practices from the literature for water quality parameters.

Table 1.1. A summary of BMPs for water quality for growing catfish from both peer reviewed and extension literature.

Component	Recommendation	BMP
Dissolved oxygen	4 ppm or more	Aeration of at least 3 hp/ac possibly 5 + hp/ac
Carbon dioxide	Less than 20 ppm	Addressed with aeration and appropriate alkalinity
pH	6 to 9.5	Maintain proper alkalinity
Total alkalinity	80 ppm or higher	Maintain alkalinity at least 20-30 ppm, and possibly as high as 80-100 ppm would be better
Total hardness	20 ppm or higher	Liming
Un-ionized ammonia	Less than 0.05 ppm	Do not feed more than 150 pounds/ac/day
Nitrite	Less than 0.05 ppm	Maintain 100-150 mg/L of chloride
Temperature change	Less than 5 degrees F as rapid change	Acclimate fish to temperature change before stocking

Arana (1999) demonstrated that the interaction of these water quality variables can be quite significant on daily feed intake levels by the fish (and therefore one could assume growth as well). The research showed that when morning dissolved oxygen concentrations were low along with high afternoon un-ionized ammonia levels the fish's feed intake was greatly reduced (though both parameters remained at sub-lethal levels). Also, the same study showed that when un-ionized ammonia levels were lower in the morning (even when D.O. concentrations were low and afternoon un-ionized ammonia levels were high) the fish were able to recover and feed well apparently due to the temporarily lower morning un-ionized ammonia levels (Arana, 1999).

Algae Control

Algal populations play major roles in water quality issues in catfish ponds. Therefore, it is important to manage algal populations properly. In fed ponds algae can become overly abundant causing night-time dissolved oxygen depletion (Boyd, 2006). Also, dense blooms of predominantly one species of algae (especially a single species of blue green algae) create conditions favorable for a sudden die-off of the algal bloom which can cause sudden oxygen depletion. Furthermore, some species of algae are responsible for producing compounds that when absorbed by catfish cause off-flavor (for more detail see chapter 4), as well as potentially toxic compounds (Boyd, 2009). Therefore, it is often desirable to control algae blooms in catfish ponds. Of the approximately 200 herbicides registered by the EPA only 6 are labeled for use in aquaculture (Avery, 2003), however there are others with special local needs registration, or emergency exemptions (American Fisheries Society, 2011). One of the most commonly used herbicides and most effective in controlling algae populations (especially blue-green algae populations) is copper sulfate. The cupric ion released from copper sulfate in water is toxic to plants and only slightly less toxic to aquatic animals. The concentration of copper considered sufficient for phytoplankton control is 0.06-0.50 mg/L and the maximum recommended for fish in low alkalinity waters is 0.02 mg/L and in high alkalinity, high pH waters 0.2 mg/L (Boyd, 2005). In order to control algal populations, weekly applications of copper sulfate at a rate of 1.25 pounds of copper sulfate pentahydrate per acre foot is recommended in ponds with alkalinity and hardness between 100 and 300 mg/L as $CaCO_3$ when water temperatures are above 70 °F (Tucker and van der Ploeg, 1999). In a focused pond study weekly applications of copper sulfate at a rate of 0.12 mg Cu/L was effective at controlling algal populations (Tucker et al., 2001). The Fish Farming Center in Greensboro, AL recommends applying copper weekly at a rate of half the maximum dose of copper for the pond. This half dose can be figured using the following equation (alkalinity / 100) X 2.7 X 0.5 which yields pounds of crystal copper sulfate pentahydrate to apply to the pond when water temperatures are above 70° F (Bill Hemstreet, personal communication, 2012).

A second, and very important algaecide commonly used in the U.S. catfish industry is diuron, which is registered under special local needs approval. Diuron is predominately used to control blue-green algae. Zimba et al. (2002) found that weekly applications of 0.01 mg/L of diuron to catfish ponds significantly lowered the biomass of filamentous blue-green algae without significantly affecting overall phytoplankton biomass because the blue-green algae that was removed was replaced with diatoms, accomplishing the goal of lowering the off-flavor causing compound 2-methylisoborneol (for more information on off-flavor see chapter 4).

Another commonly practiced method of controlling algae in catfish ponds is stocking a filter feeding fish with the catfish in order to control phytoplankton blooms. One of the most commonly stocked filter feeders is threadfin shad. Giudice et al. (2004) found that threadfin shad had positive effects on the algal community, as well as water quality, and catfish survival when stocked into catfish ponds at rates of approximately 700/acre. Other fish that are also commonly stocked with catfish in order to control algae populations are gizzard shad, paddlefish, and tilapia.

Intensive Systems

Aside from traditional pond culture of catfish new technologies for more intensive culture are being developed that should be considered BMPs as well. For instance in-pond raceway systems (IPRS) (and less intensive but similar, partitioned aquaculture systems/split pond systems) are intensive systems where fish are grown throughout the production cycle in fixed or floating enclosures within the pond. IPRS are utilized to culture catfish in the raceways with tilapia and paddlefish loose in the pond to help control plankton populations as well as providing extra fish production from the ponds (Brown et al., 2010). Increases in catfish production per acre on are also possible in the IPRS when compared to traditional pond culture (Brown et al., 2011). IPRS can also increase profitability of the pond (Brown et al., 2010). Another advantage of the IPRS is at harvest when the fish can be crowded and scooped out of the system using a boom truck and a basket making harvest easier and much less stressful on the fish. With an IPRS is it is possible to have a staggered harvest from a single pond (like multiple batch systems) but with each size class cultured separately (like single batch systems) since multiple raceways are built in each pond. IPRS can provide several size classes of fish in each pond (giving farmers options when dealing with off-flavor problems and keeping a more steady revenue stream to the farm) as well offering increased size uniformity and inventory control while lowering losses from cannibalism and big fish out competing small fish for feed. IPRSs allow for complete harvesting which facilitates more accurate re-stocking. From a fish health perspective it is easier and more cost effective to treat fish disease problems in a raceway as opposed to the entire pond. Another potential benefit of the IPRS is being able to feed specialized diets to individual size class fish. Robinson et al. found that feeding a 24% protein diet is sufficient for maximum growth and feed efficiency of catfish in ponds but that yield is reduced when compared to fish fed a higher protein diet. However, when fish were grown out on a 24% protein diet and then fed a finishing diet with 32 or 35% protein yield was increased (Robinson et al., 2006). This is a common practice in other modern livestock industries where inventory control is possible and animals are fed different quality feeds at different life stages in order to maximize growth, FCR, and processing yield but keeping costs as low as possible.

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Chapter 2: Best Management Practices To Reduce The Occurrence of Yellow Fillet In Farm Raised Catfish In The Southeastern United States

Abstract:

Yellow pigment in catfish fillets has been a growing concern for several years, especially in fresh markets. This study uses survey data to investigate linkages between on-farm production practices and the occurrence of yellow fillet at the processing plant. A survey of catfish farmer production practices was conducted for individual ponds in West Alabama, Mississippi, and Arkansas from December 2009 through December 2011. The survey consisted of 25 questions containing 126 variables. In total, 154 ponds were surveyed spanning 28 farms in three states. Correlation analysis was used to identify management practice variables significantly correlated to the occurrence of yellow fillet. Then those variables were used to produce regression models of management practices responsible for the occurrence of yellow fillet. The best regression models included the variables; “days off feed before harvest,” “presence of snails,” “number of harvests in the last year,” and “presence of threadfin shad.” Other variables, such as “method of copper sulfate application,” “fillet size,” and “season” were also statistically significant. These significant variables make a case that catfish consuming natural productivity (algae, shad, etc.) have a higher incidence of producing yellow color in processed fillets. The results of this study demonstrated that feeding strategies where catfish receive all of their nutritional requirements from commercial rations instead of natural

productivity as well as management plans which control algal blooms could significantly reduce the occurrence of yellow fillet in U.S. farm raised catfish. The regression model in this study predicts the percent of fillets from a pond that will exhibit yellow coloration. Being able to predict the occurrence of yellow fillet is a powerful tool for farm managers. Using the equation developed in this study farm managers can predict the effect of a management change on the quality of the fillets that they produce.

Introduction:

Fillet color has become an important concern in the United States farm raised catfish industry due to certain consumer groups rejecting fillets with a yellow or red color. The pigment causing the yellow coloration has no adverse effects on the taste or shelf life of the fillet (Lovell, 1984); however consumers perceive fillets with yellow coloration to be low quality or not fresh. Several large buyers of catfish fillets have rejected U.S. Farm Raised Catfish in recent years due to the yellow coloration in the fillets. Considering the strong competition from imported fish into the United States (especially pangasius catfish species from Asia and tilapia species from Asia and Latin America) as well as competition from other economical protein sources like chicken, U.S. consumers today have more choices than ever when deciding what meats to buy. Therefore, it is imperative that the U.S. catfish industry produce a consistently high quality product that is appealing not only to the taste buds but also to the eye. Recent higher prices for U.S. farm raised catfish have pushed it into a premium price category. It is essential that it also be a premium product where quality is concerned.

Meat color characteristics have long been a concern in many livestock industries. In aquaculture the color of fish fillets has long been a concern especially in salmon. However, in the salmon industry the focus is adding color to the fillets whereas in catfish the desired product is devoid of pigment (Lovell, 1984).

Multiple studies have been conducted analyzing the type of pigment causing yellow fillet in catfish. Lee (1987) found lutein and zeaxanthin to be the only carotenoid pigments in catfish fillets. However, in a more recent study Liu et al. (2012) found alloxanthin and diatoxanthin in addition to the carotenoids found by Lee. As catfish cannot synthesize carotenoids these pigments must be present in catfish feed or other food sources (Liu et al., 2012). Lee (1987) found 11 mg/ kg of diet to be the maximum carotenoid concentration in the diet for channel catfish in ponds in order to not produce objectionable pigmentation in the flesh. More recently Li et al. (2009) found 7 ppm to be a threshold level and 10 ppm seemed to be the concentration where yellow pigmentation increased to a more intense level. Li states that the difference in the results of the 2009 study and Lee's study in 1987 are likely due to different analysis methods (Li, et al., 2009). Furthermore, a different study by Li et al. (2007b) confirms that the typical dietary ingredients commonly used in catfish feed do not have high enough levels of carotenoids to be solely responsible for the occurrence of yellow fillet, except in a rare case of yellow corn and by-products used at high levels. In those cases where high levels of corn gluten are used there is a possibility that yellow fillet problems could occur. However, in a study conducted by Hu et al. (2012) found that diets containing 20% corn gluten feed showed no incidence of yellow fillet. Robinson et al. (2001) used up to 50% corn gluten feed and reported no differences in fillet or skin color. The carotenoids appear to accumulate in the fillets from natural food sources or a combination of feed and natural food consumed by the catfish. This is supported by a study seeking to identify the source of yellow pigment causing a similar problem in trout flesh that found fish from farms without yellow pigment were fed feed with at least as high of concentrations carotenoids in the feed as fish from farms with problems of yellow pigment in the flesh. (Welker et al., 2001).

Though the body of research does seem to agree that threshold levels of yellow pigments are reached not from feed but from consumption of natural food items, there is only limited research in channel catfish aimed at identifying which of the host of in-pond natural food items could be the source of the carotenoids. Lovell (1984) suggests green algae, including filamentous types, are possible candidates because of their high concentrations of carotenoids. Li et al. (2009) analyzed several possible natural food sources available to catfish in many (but not all) ponds and found that on a wet-tissue basis gizzard shad had yellow pigment levels of 0.9 ppm and threadfin shad had 4.9 ppm. Green sunfish were a little higher with 9.7 ppm. However, snails and filamentous algae were the highest potential sources analyzed with 54 and 158 ppm, respectively. It should be noted that these findings are just the levels of yellow pigment found in these potential natural food sources. This study did not make any attempt to tie the occurrence of yellow fillet with the consumption of any of these potential food sources. Hu et al. (2012a) in a study examining high levels of xanthophyll (calculated as a sum of lutein, zeaxanthin, and alloxanthin) in potential natural food sources in catfish ponds and the relationship to the presence of yellow pigment in fillets found smaller amounts of pigment in the potential food sources but still on the same order of magnitude. Levels of xanthophyll in gizzard shad ranged from 0.024 ppm to 0.439 ppm. Two different size classes of plankton were examined in this study. Plankton within the 20-75 micron range had xanthophyll levels of 0.009 ppm-0.127 ppm while plankton larger than 75 microns had levels of 0.002 ppm-0.159 ppm. Snails were the only other potential natural food source analyzed in the Hu et al. study and they were found to have xanthophyll levels ranging from 9.949 ppm to 18.215 ppm (2012a). A linear relationship between xanthophyll concentration in catfish fillets and concentrations in plankton above 75 microns was found as well as a correlation between xanthophyll concentrations in catfish fillets and concentrations in shad (Hu et al., 2012a). In a study seeking to resolve a similar yellow pigment problem in trout flesh it was observed that green algae Caldophora glomerata was present in the ponds where trout exhibited the yellow pigment in the flesh and the stomachs of yellow fleshed fish contained vegetable matter especially C. glomerata (Welker et al., 2001). Though this study was conducted in Europe with trout it is worth noting as the situation of unexplained yellow pigmentation in the fillets was correlated with stomach content containing a filamentous algae, even though trout are considered to be a carnivorous fish (Welker et al., 2001). Thus pond algae species should be considered when analyzing the yellow fillet issue in the U.S. catfish industry because catfish are considered to omnivorous (Cannamela et al., 1978).

As noted above a few attempts have been made to analyze the pigment levels in possible natural food sources in channel catfish ponds as well as one study seeking correlations between yellow pigmentation in catfish fillets and that of certain possible food sources. This study takes a much broader approach than what has been attempted in previous studies concerning yellow fillet in catfish. Instead of focusing on certain possible food sources this study uses a survey of many farm management variables seeking to correlate production practices at the farm level with the occurrence of the yellow coloration in the fillets in order to reduce or eliminate the number of fish arriving at the processing plant with yellow pigment as well as reduce the strength of the yellow pigment when it does occur. The hypotheses of this observational study are as follows:

Ho1: The occurrence of yellow pigment in catfish fillets is the result of a cumulative effect of pigmentation found in feeds as well as management practices (environmental factors) on the farm specifically the presence of shad in the production ponds.

Ho2: The occurrence of yellow pigment in catfish fillets is partially caused by not using or mis-using methods of algal control in ponds, specifically copper sulfate and diuron.

Materials and Methods:

In order to identify linkages between on farm management practices and the occurrence of yellow pigment in fillets; data from individual ponds on a farm by farm basis was collected from two Alabama processing plants (Harvest Select, Uniontown, AL and Southfresh, Eutaw, AL). The occurrence of yellow pigmentation in fillets was monitored by size class of fillets for the first pond processed in the respective plants each morning. Originally the study was conducted with the plants collecting samples from ponds exhibiting strong yellow pigmentation but the protocol was changed to taking the first pond through the plant each morning (no matter if there were yellow fillets or not) in order to insure that the fillets being sampled were in fact from the pond that they were attributed to because the processors informed the researchers that as the processing day goes on sometimes it is difficult to distinguish which fillets came from which ponds by the time they reach the end of the processing line where the yellow grading was typically done. Furthermore, this change in protocol allowed for a more randomized sample of the ponds coming into the plants, giving data on ponds that exhibited the yellow coloration as well as those that did not. After this change the processors typically reported the occurrence of yellow fillets as a percentage of a sample from each size class though analyses of yellow fillet by size were conducted an overall average (numbers of yellow fillets in all size groups divided by the total number of fillets sampled) was used for most of the comparisons discussed in the results section.

The data from each pond provided by the processing plant were then linked to a production practice survey that was conducted with the individual producer concerning the particular environmental factors (production practices) in that specific pond. The producer survey consisted of questions examining a broad range of management practices on the farm (see appendix 3). The survey consisted of 25 questions divided into 126 variables. The survey was conducted for two years (December, 2009-December, 2011). In total, 154 ponds were surveyed spanning 28 farms in Alabama, Mississippi, and Arkansas. Summary statistics were produced and a correlation analysis was conducted using SAS 9.2. After seeing which variables were most closely correlated to the presence of yellow pigment regression models were developed using stepwise regression, forward selection, backward selection, Akaike's Information Criteria (AIC), and Sawa's Bayesian Information Criteria (BIC) analysis in order to form models that best explain the variation in the occurrence of yellow fillet (see appendix 1 for a description of each of these procedures).

Results:

The correlation analysis resulted in 27 variables correlated to the presence of yellow fillet with p-values less than 0.05. Of these variables several had very few responses on the survey, the question was repetitive, or the question itself was a question of more of a demographic nature making it not relevant to the occurrence of yellow pigment in the fillets, therefore these variables were dropped from consideration. See Table 2.1 for a list of the variables that upon an initial run of the correlation analysis were significantly correlated, and table 2.2 for the mean and range of variables in table 2.1.

Table 2.1: Variables significantly correlated (alpha < 0.05) with the occurrence of yellow pigment in catfish fillets and their respective correlation coefficients and p-values. Variables are listed in the same order that they appear on the survey.

Variable	Correlation Coefficient	p-value
Processor	0.415	<0.0001
Year	*-0.283*	*0.0009*
Season	-0.221	0.0105
City (farm location)	-0.351	<0.0001
State	-0.312	0.0003
Days off feed before harvest	0.601	<0.0001
Average feeding rate in the summer (pounds/acre/day)	0.212	0.0247
Secondary feed source (n=18)	0.642	0.0099
Other fish stocked in the pond	0.187	0.0308
Presence of Threadfin shad	0.303	0.0004
Presence of other secondary species (not gizzard shad, threadfin shad, or fathead minnows)	-0.199	0.0256
Copper applied in the form of liquid or crystal	-0.565	<0.0001
Use of automated D.O. monitoring system	0.375	<0.0001
Calculated pond vol. (ac-ft)	0.273	0.0015
Aeration rate (hp/ac-ft)	-0.224	0.0096
Alkalinity	-0.401	<0.0001
Salinity	0.315	0.0009
Presence of snails in the pond	-0.252	0.0034
noticeable blue green algae mats	-0.202	0.0236
Number of harvests in the last year	-0.193	0.0294
Is the pond on track or behind track for harvests	0.188	0.0385
Secondary disease (n=4)	0.982	0.0177
Low D.O. (below 1.5 ppm in the last 60 days)	-0.216	0.0154
Number of times D.O. fell below 1.5 ppm	-0.196	0.0327
Report of incidence of red fillet	0.271	0.0022
Report of incidence of yellow fillet	0.307	0.0005

Table 2.2. Descriptive statistics for variables found to be correlated with the occurrence of yellow fillet in the initial correlation analysis.

Variable	N	Mean	Range
Processor	153	1.36	1 to 2
Year	153	2010	2009 to 2011
Season	153	1.81	1 to 4
City (farm location)	150	4.36	1 to 8
State	150	1.34	1 to 3
Days off feed before harvest	123	12.4	1 to 165
Average feeding rate in the summer (pounds/acre/day)	131	141.8	45.5 to 495.0
Secondary feed source	18	2.34	1 to 5
Other fish stocked in the pond	153	0.73	0 to 1
Presence of Threadfin shad	152	0.52	0 to 1
Presence of other species (not gizzard shad, threadfin shad, or fathead minnows)	146	0.27	0 to 1
Copper applied in the form of liquid or crystal	77	0.99	0 to 2
Use of automated D.O. monitoring system	148	0.31	0 to 1
Number of batches of fish in the pond before harvest	130	2.5	1 to 15
Calculated pond volume (ac-ft)	153	59.3	16.3 to 144.5
Aeration rate (hp/ac-ft)	153	0.56	0 to 2.0
Alkalinity	115	150.3	60 to 310
Salinity	124	270	0 to 2500
Presence of snails in the pond	153	0.16	0 to 1
Noticeable blue green algae mats	146	0.25	0 to 1
Number of harvests in the last year	148	2.4	0 to 7
Is the pond on track or behind track for harvests	141	0.67	0 to 1
Secondary disease	4	2	0 to 4
Low D.O. (below 1.5 ppm in the last 60 days)	145	0.19	0 to 1
Number of times D.O. fell below 1.5 ppm	139	6.19	0 to 60
Report of incidence of red fillet	144	0.41	0 to 2
Report of incidence of yellow fillet	142	0.48	0 to 2

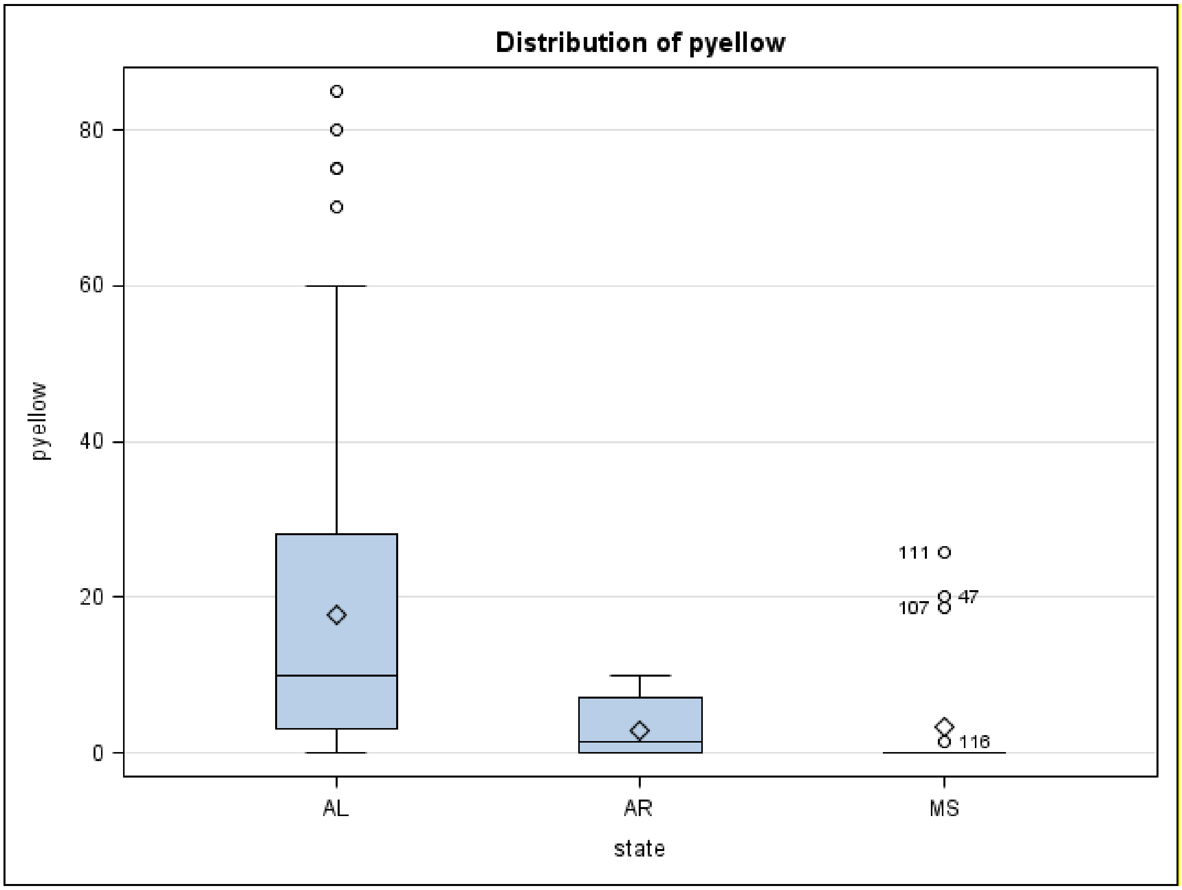
As noted above several variables were found to be significantly correlated with the incidence of yellow fillet yet were not included in further statistical procedures. The justifications for those decisions are as follows. The variable named "processor" was removed in part because the processor is not related to on-farm management practices also the processors involved were randomly assigned a number code making a correlation to this "value" of the processor arbitrary. However correlation and single regressions were calculated separating the data by processing plant (see later in the results section). The variable "Year" was not considered for further analysis because though there maybe variation over time in the presence of the yellow pigment; in this particular study this data is potentially misleading. At the beginning of the study the processors were reporting only those ponds with severe yellow problems making this variable biased. Also, as there was no question asked about changes in management style from year to year and only a limited number of individual ponds that were sampled over multiple years therefore this variable is not informative about what particular management practices are leading to the occurrence of yellow fillet. Both the variables "city" and "state," documenting where the farm is located, were removed because the cities and the states were randomly assigned numbers in place of their names and therefore correlating a higher "value" for the city or state with presence of yellow fillet is meaningless though it is very possible that there is a geographical component to the yellow fillet problem. Because of this problem of data labeling separate ANOVA analysis were used in order to examine the geographical components of the occurrence of yellow fillet (see later in this section). The variable "secondary feed source" was removed because there were only 18 respondents using more than one feed mill and it was random as to which feed mill they listed first and which they listed second. Therefore no discernible pattern can really be traced to the occurrence of yellow fillet especially considering that the main feed source was not significantly correlated. The variable “other fish stocked in the pond” was removed because it was followed up with more specific questions about individual species therefore this question didn’t add specific information to the data. However it is worth noting that there was a significant, all be it weak, correlation showing that the farms with only catfish in their ponds had less incidence of yellow pigment in the fillets. “Presence of other secondary species” was removed because it was a yes no question that was then followed up by a question detailing what species and those more specific answers were non-significant therefore it didn’t seem that this question would add much to the model only complicate it and make it harder to get a significant result with a final model. The variable noting whether farms used liquid or crystal copper sulfate was removed from the list though a strong correlation existed because there was a choice on the question for those that mix crystal copper sulfate with water themselves and apply it as a liquid and these choices were randomly given numerical values that don’t necessarily justify being inputted into a correlation analysis. However, it should be noted that there was a strong correlation with the form of copper used therefore a separate ANOVA procedure was conducted (see later in this section). The variable “noticeable blue green algae mats” was removed because the question was too subjective and when producers were asked it was clear that they were unsure of how to answer. Therefore this variable was deemed to be one that would complicate the model more than help it especially since the cause of blue green mats or lack thereof is addressed in other variables like copper usage and feed quantity input. "Harvest track" was removed because this question is extremely subjective. Some farms may want to harvest 6 times a year and others only 2 or 3 and therefore if both ponds were harvested 3 times one farm would answer "behind track" and the other "on track" when in reality the number of harvests were the same. The variable "secondary disease" was removed because the number of farms reporting more than one disease in the pond in question was only 4 and it was random what disease they listed first and which was listed second. Both the variables "low D.O." as well as "number of times D.O. dropped below 1.5" were considered unreliable because few people, if any, looked at records to verify their answer, they just tried to remember. Also, these variables overlap with amount of aeration and feeding rates which are more easily quantifiable. The variable "incidence of red fillet" comes from a question on the survey that attempted to quantify from the producer's knowledge if there had been any incidences of red fillet reported from that particular pond recently and was removed from the analysis because it is subjective in that there could have been red fillet problems that were not reported to the producer. Also, the answers were coded with a zero for "no" a one for "yes" and a two for "I don't know" therefore a correlation really has little bearing on the actual significance of that scale. However, it is still an important variable to be considered when looking at feedback from the processor to the producers and the general flow of information in the industry, but it is not an explanatory variable for the yellow fillet. Finally the variable "report of incidence of yellow fillet" was removed because obviously this should be correlated with presence of yellow fillet and is more of a question designed to see how much feedback producers get from processors.

The correlation values indicate that the variable “days off feed before harvest” accounts for a large portion of the variation in the occurrence of yellow fillet. It should be noted that with closer scrutiny the variable “days off feed before harvest” does have a very wide range of reported values (1 to 165 days) and only a few of these values are near the upper end. Therefore, a second correlation analysis was conducted removing these potential outliers and the variable was still significantly correlated to the occurrence of yellow fillet (correlation coefficient=0.40578 p-value<0.0001 without extreme values). Furthermore, this correlation coefficient was still one of the highest values reported for any variable therefore it was determined that as there was no reason to believe that the extreme values were invalid and since the result remained significant all statistical analyses were conducted with all the possible data values included.

After the general correlation analysis using all the variables possible from the data set, the data was divided by processor and a second correlation analysis was conducted. Though a common protocol had been established at the beginning of the study it became apparent that the different processors were using somewhat different protocols for sampling the fillets in their plants due to several factors such as availability of workers, convenience, or just their own personal preference. Therefore, in order to check to see if that difference in sampling protocol was affecting the results, the second correlation analysis was run with the data divided by processing plant. This second analysis resulted in many of the variables no longer being correlated at significant levels probably due to the much lower sample size. Therefore, it was determined that the original correlation analysis with data from all processing plants grouped together was the most reliable on which to base further analyses.

Though the variables of city and state did not fit well into a correlation as discussed above, separate ANOVA procedures were conducted to compare these variables to the percent of fillets with yellow pigment and the results were statistically significant for both variables (p-values of <0.0001 and 0.0006 respectively). In order to establish which cities and states were statistically significant from the others a Tukey-Kramer analysis was conducted to determine significance at the familywise level. The results of the Tukey-Kramer analysis by state showed that Alabama had a statistically significantly higher incidence of yellow fillet than either Mississippi or Arkansas. However, it should be noted that there were very few farms sampled in Mississippi or Arkansas so this information could be biased. Furthermore, when comparing cities Forkland, Al had significantly higher incidence of yellow fillet when compared to every other town with the exception of Marion, AL and there the incidence was higher but not statistically significant. Eutaw, AL only had statistically higher differences in percent of fillets exhibiting yellow pigmentation when compared with Hollandale, MS and Lake Village, AR. All other differences in mean occurrence of yellow fillet between cities were not statistically significant. However, it is difficult to know how fine to break down the cities as most farms are located somewhere around the actual municipality and this variable was treated more like a region. If the “cities”/regions were further broken down it is possible that other differences would appear however the intent of this variable is to look at geographical differences in soil and water quality and too fine of a division would yield only on farm practices and be broken down too much to see regional differences. Figure 2.1 show the occurrence of yellow fillet by state and figure 2.2 shows the occurrence of yellow fillet by city.

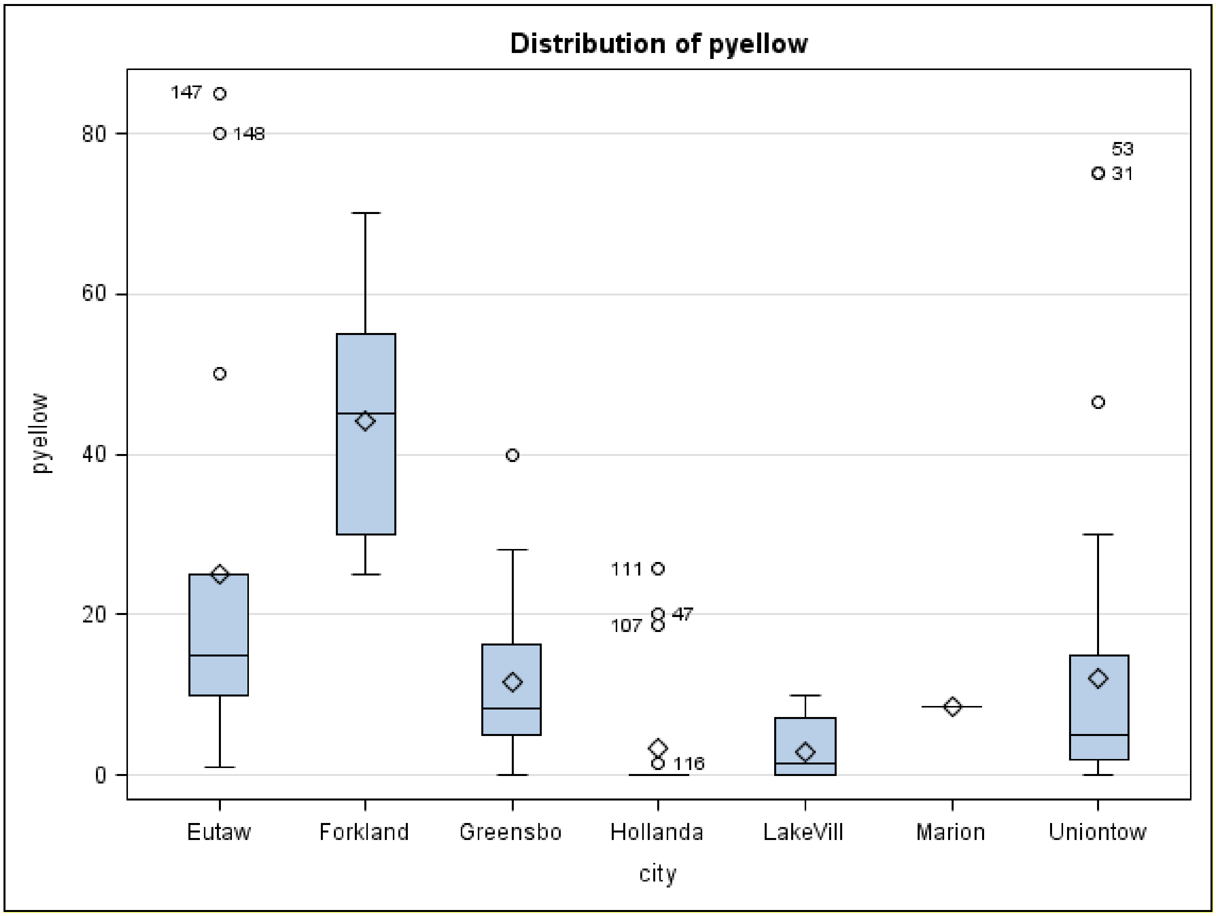
Figure 2.1. A box plot showing the variation in the occurrence of yellow fillet between states.



[1] pyellow = percent of fillet with yellow pigmentation.

[2] In this box and whisker plot the top and bottom edges of the box represent the 75th and 25th quartile respectively and the line in the box is the median. The mean is represented by the diamond shape. The whiskers reach as far as the data with a maximum length of 1.5 times the interquartile range. Data points outside this range are marked with circles.

Figure 2.2. Variation of occurrence of yellow fillet among cities where farms are located.

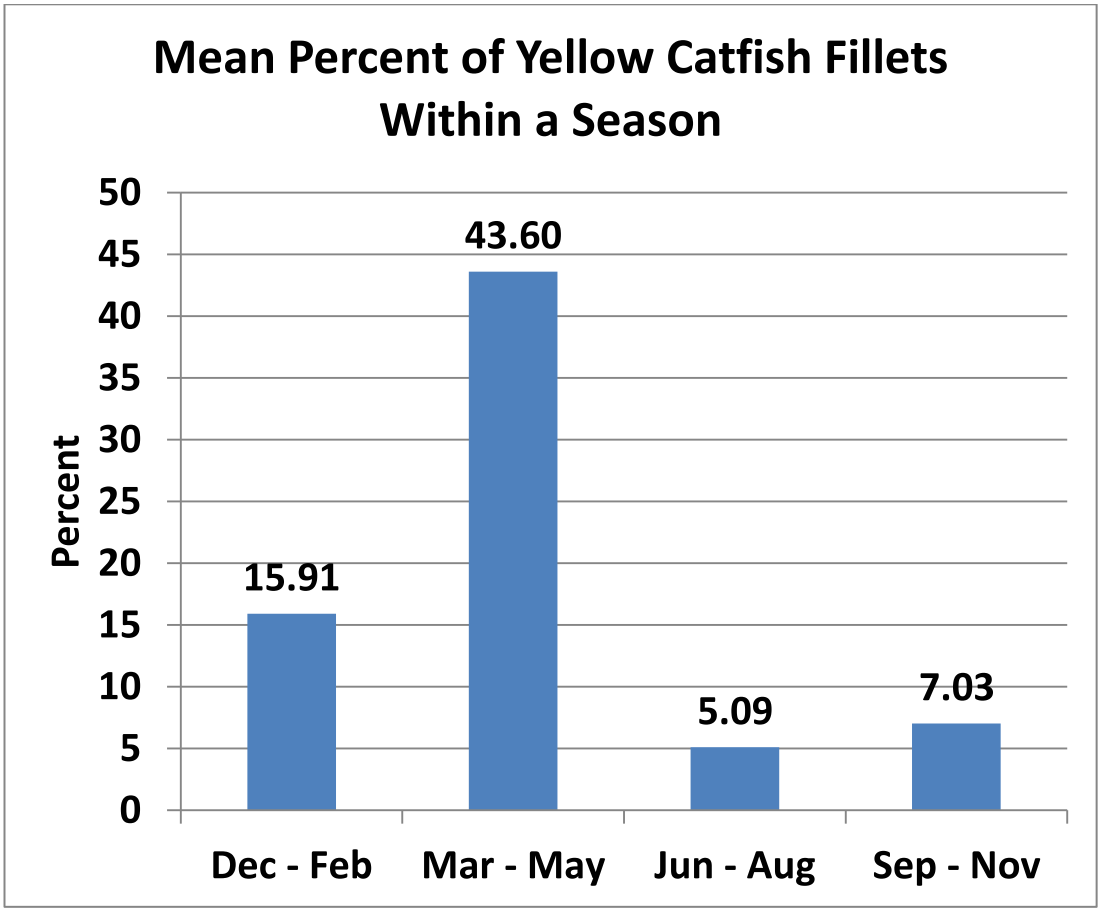


[1] Eutaw = Eutaw, AL; Forkland = Forkland, AL; Greensbo = Greensboro, AL; Hollanda = Hollandale, MS; LakeVill = Lake Village, AR; Marion = Marion, AL; Uniontow = Uniontown, AL.

[2] In this box and whisker plot the top and bottom edges of the box represent the 75th and 25th quartile respectively and the line in the box is the median. The mean is represented by the diamond shape. The whiskers reach as far as the data with a maximum length of 1.5 times the interquartile range. Data points outside this range are marked with circles.

In order to analyze the seasonality of the occurrence of yellow fillet, seasons were given a numerical value to be processed with a correlation procedure. One was assigned to any pond harvested in December, January, or February (the winter months when water temperatures are the coldest and most farms feed only limited amounts if at all). March, April, and May were assigned the number two as the spring category. Category three is June, July, and August, leaving September, October, and November to be category four. It should be noted however that one might assume that fish processed in one season were highly affected by the production practices of the season before especially the colder months when the fish's metabolism is slow and changes in physiology come slowly. As shown in table 2.1 the variable "season" was significantly correlated to the occurrence of yellow pigment in the fillets. In order to further understand this phenomenon an ANOVA analysis was conducted confirming that there is a significant difference between seasons (F-value = 15.23, p-value = <0.0001) (see figure 2.3).

Figure 2.3. Percentage of fillets with yellow pigmentation by season.



[1] December through February is season 1; March through May is season 2; June through August is season 3; and September through November is season 4.

In order to distinguish which seasons' means were different from the others statistically a tukey-kramer analysis was used showing that season 2 had higher incidences of yellow fillet when compared to all other seasons, and also season 1 had higher incidence than season 3 (see table 2.3).

Table 2.3. Familywise comparison of incidence of yellow fillet by season.

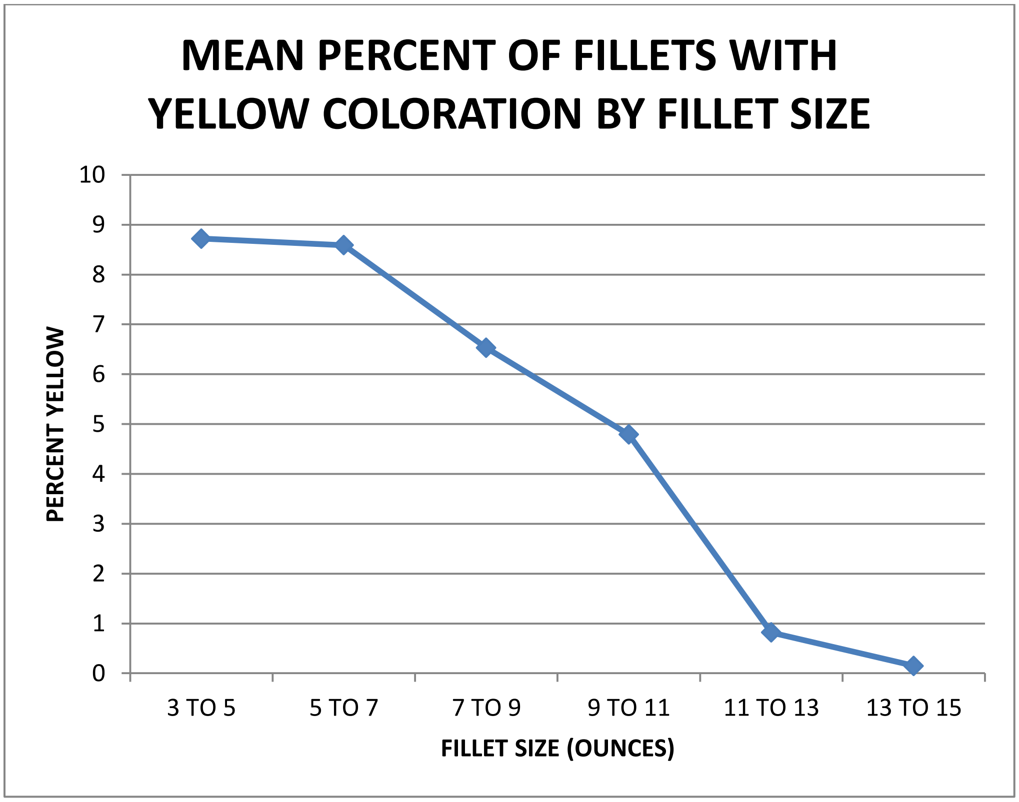
Season comparison	Difference between Means
2-1	27.7***
2-4	36.6***
2-3	38.5***
1-4	8.9
1-3	10.8***
4-3	1.9

Comparisons significant at the 0.05 level are indicated by ***.

These results seem to support anecdotal evidence that the colder months are the most problematic for yellow fillet. However it is unclear if this difference is because of different management practices used in the winter or because of the fishes' slower metabolism (see discussion section).

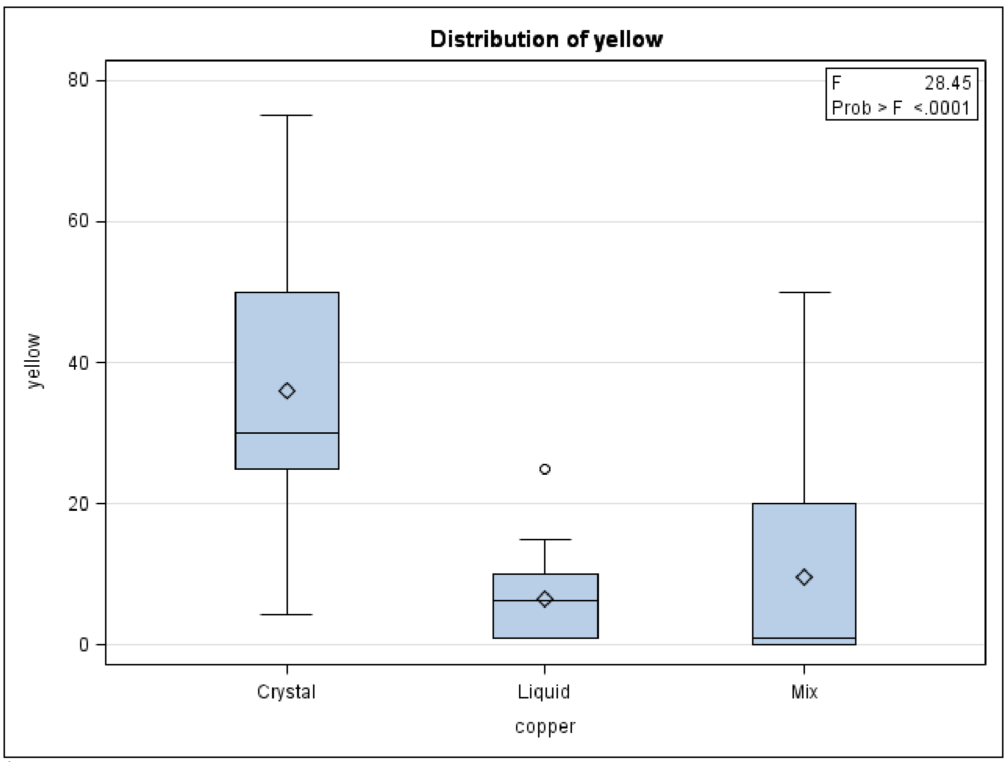
An analysis of variance test was conducted to test the difference in the occurrence of yellow fillet between fillet size classes. The ANOVA procedure produced results showing that there are significant differences in yellow between size classes (F value = 4.71 p-value = 0.0001). For further analysis a Tukey-Kramer test was conducted showing that both the 2-3 ounce fillets as well as the 3-5 ounce fillets had significantly higher occurrence of yellow fillet when compared to 11-13 and 13-15 ounce fillets. All other differences between groups were non-significant (see figure 2.4).

Figure 2.4. Occurrence of yellow pigment by fillet size.



As noted above the variable "copper applied in the form of liquid or crystal" was removed from the correlation results and not included in any of the model selection methods because the three categories (liquid, crystal, and crystal mixed in water and applied as a liquid) were randomly assigned numbers (1, 0, and 2), respectively, making any correlation with these numbers not justifiable. However, an ANOVA analysis of the data based on the groups themselves produced significant results showing that there is, in fact, a difference in the rate of the occurrence of yellow fillet based on the form of copper used (F-value = 28.45 p-value = <0.0001). Therefore, a Tukey-Kramer analysis was conducted showing that when copper is applied in crystal form there is a significantly higher incidence of yellow fillet than when it is applied in either liquid or mixed (purchased as crystal and mixed to form a liquid). And though the mixed method did have a higher mean occurrence of yellow fillet than the liquid form it was not a significant difference (see figure 2.5 and table 2.4).

Figure 2.5. A box plot of the occurrence of yellow pigmentation in catfish fillets (reported as percent of fillets with yellow pigmentation) plotted against the method of applying copper.



[1] "Mix" is used to describe the method of applying copper where crystal copper sulfate is mixed with water to form a slurry and applied to the pond as a liquid slurry.

[2] In this box and whisker plot the top and bottom edges of the box represent the 75th and 25th quartile respectively and the line in the box is the median. The mean is represented by the diamond shape. The whiskers reach as far as the data with a maximum length of 1.5 times the interquartile range. Data points outside this range are marked with circles.

Table 2.4. Tukey-Kramer pairwise comparisons for the occurrence of yellow pigmentation based on the copper application method.

Copper application method	Difference Between Means
Crystal-Mix	26.4***
Crystal-Liquid	29.5***
Mix-Liquid	3.1

Comparisons significant at the 0.05 level are indicated by ***

After conducting the correlation an attempt was made to incorporate all the significantly correlated variables (except those discussed above) into a single regression model in order to explain the occurrence of the yellow pigmentation in fillets, however the results were not significant using all the variables selected from the correlation analysis. Therefore, several model selection methods were used in order to find the best model to explain the occurrence of yellow fillet. The model selection methods used were; Stepwise Regression, Forward Selection Method, Backward Selection Method, AIC (Akaike's Information Criteria), and BIC (Sawa's Bayesian Information Criteria). The following is a summary of the results of these model selection procedures and the ways that they agree as well as disagree.

Before conducting the analyses listed above the data for percent yellow was transformed using the arcsine transformation because in reality the percent of fillets showing yellow pigmentation cannot be normally distributed because there are constraints that are put on the data as no data point can be less than zero and no point can be greater than 1 because each data point is a percentage. Therefore, in order to produce an equation from the regression model that has power to predict (and not allow any predicted value to fall above 1 or below 0) the arcsine transformation was necessary.

After the data were transformed the model selection methods listed above were used in order to select the variables forming a single model to explain the largest portion of the variation in the occurrence of yellow as possible. Running a stepwise regression with a 0.2 significance level (because of the lack of precision in how producers answered some of the questions) a four variable model was created using the variables; days off feed before harvest, presence of snails, number of harvests in the last year, presence of threadfin shad with individual R-Square values of 0.3247, 0.0726, 0.0548, and 0.0167 respectively, for a total model R-Square of 0.4689. Running an analysis using Forward Selection Method with an alpha value of 0.2 generated the same prediction model as did the stepwise regression at the same significance level incorporating the same variables into the model (days off feed before harvest, presence of snails, number of harvests in the last year, and presence of threadfin shad) and generated a the same R-Square value for the model (0.4689). AIC also selected the same variables to incorporate into the final regression model (AIC = -241.4980). The ANOVA results for the entire model are f-value = 14.57 p-value = <0.0001.

Though the Stepwise Regression, Forward Selection, and AIC model selection methods generated the same model retaining the same variables the other two methods of model selection used did not. The Backwards Elimination Method (again using an alpha value of 0.2) and BIC methods only selected 3 variables to incorporate into the model instead of 4 as in the previous model. These methods produced a model incorporating the variables; days off feed before harvest, presence of snails in the pond, and number of harvests in the last year; leaving out the presence of threadfin shad. The R-squared value for this model was 0.4522 with an f-value of 18.43 and p-value of <0.0001 (BIC = -238.4213). Table 2.5 shows the variables selected by the various methods.

Table 2.5. Variables selected by several model selection methods producing regression equations in order to explain the occurrence of yellow fillet (using arcsine transformed data).

Method	Variables selected	R-Squared	p-value
Stepwise Regression	Days Off Feed Before Harvest Presence of Threadfin Shad Presence of Snails Number of Harvests	0.4689	<0.0001
Forward Selection	Days Off Feed Before Harvest Presence of Threadfin Shad Presence of Snails Number of Harvests	0.4689	<0.0001
Backward Elimination	Days Off Feed Before Harvest Presence of Snails Number of Harvests	.4522	<0.0001
AIC	Days Off Feed Before Harvest Presence of Threadfin Shad Presence of Snails Number of Harvests	0.4689	<0.0001
BIC	Days Off Feed Before Harvest Presence of Snails Number of Harvests	0.4522	<0.0001

There is some disagreement between the various methods for model selection as to which variables should be incorporated into a final model. Therefore there is a need to select which model is really the most appropriate in this case. First, consideration should be given to the ways that the methods select the variables incorporated into the models. Stepwise Selection, forward selection, and backward selection are all dependent on an alpha value chosen by the researcher, whereas AIC and BIC are not and the best fit model is determined only from an equation based solely on the data and the model with the lowest AIC (or BIC) is the best fit model. Secondly, both the AIC and BIC methods incorporate a penalty term which increases the AIC (or BIC) when more variables are incorporated into the model making the ability to explain the amount of yellow pigment in the fillets of each additional variable incorporated into the model very important so that variables explaining only a small amount of the variation actually are a detriment to the AIC value and therefore making models with several variables that only slightly raise the R-squared value more likely to be eliminated. In this case AIC and BIC do not produce the same model and the model produced by AIC was also generated by forward selection and stepwise regression whereas the model produced by BIC was only confirmed with backward selection. Furthermore, the model produced with the AIC method has a slightly higher R-Square value therefore all further analysis in this study will use the model produced by AIC, as shown in table 2.6.

Table 2.6. Regression model selected for prediction of the occurrence of yellow fillet.

Variable	Coefficient	Standard error	p-value
Intercept	0.32437	0.06116	<0.0001
Days off feed before harvest	0.00408	0.00074	<0.0001
Presence of threadfin shad	0.06316	0.04381	0.1541
Presence of snails	-0.15036	0.0554	0.0085
Number of harvests	-0.04726	0.01873	0.0141

The equation produced from this regression models can be used for predicting the percent of fillets from a given pond that will exhibit yellow coloration because of the arcsine transformation, however in order to produce predicted values of percent of fillets exhibiting yellow coloration a back transformation must be conducted. The following equation represents the model produced by AIC, stepwise regression, and forward selection can predict the percentage of fillets from a given pond that will exhibit yellow coloration (percentage stated as a whole number not decimal proportion):

$$\text{Percent Yellow} = 100 * \sin^2(0.32437 + 0.00408 * D + 0.06316 * T - 0.15036 * S - 0.04726 * N) \quad (2.1)$$

where D is “days off feed before harvest,” S is “presence of snails” (yes = 1 no = 0), N is “number of harvests in the last year,” and T is “presence of threadfin shad” (yes = 1 no = 0).

Using this equation, rough estimates of the percentage of fillets from any given pond that have yellow pigmentation can be predicted. This is useful both for ponds with no historical records of presence or absence of yellow fillet and especially useful for managers seeking to lower the occurrence of yellow fillet from their ponds. Three individual ponds from the data set can be used as an example of using the regression equation above to predict the outcome of changes in management practices in order to reduce the occurrence of yellow fillet (see table 2.7) (note the three ponds below were chosen from the data set because they are examples where the equation was very successful in predicting the percentage of fillets that would be yellow). In pond A 60% of the fillets when harvested had yellow pigment. This particular pond was a March harvest and the fish had not been fed for 137 days (since November of the previous year). The pond has threadfin shad, there were no snails reported in the pond, and this pond had been harvested 3 times in the previous year. The equation above predicted that 51.9% of the fillets would have yellow pigment. Pond B was a January harvest and had not been fed for 85 days. It did have threadfin shad, there were no snails reported, and it had only been harvested 1 time in the previous year. The observed yellow fillet percentage was 40% and the predicted value is 40.2%. Pond C was a December harvest that had been fed 5 days prior to harvest there are threadfin shad, no snails were reported, and it had been harvested twice in the previous year. The observed yellow fillet percentage was 10% and the predicted value is 9.5%. Below is a table showing these original values from the data set for these three example ponds as well as changes that the pond managers could make attempting to reduce the occurrence of yellow fillet and the predicted percentage of fillets that would have yellow pigment based on the management change. For example in pond A if threadfin shad were removed from the system the predicted percentage of fillets with yellow pigment drops from 51.9% to 45.6%. If the pond were harvested 4 times per year instead of 3 (but still with threadfin shad in the system) the predicted percentage of yellow fillets drops only to 47.2%. If the winter feeding regime were changed to once per week feeding, making the days off feed before harvest a maximum of 7 instead of the observed value of 137 (but keeping all other factors the same) the occurrence of yellow fillets drops to 7.3%. Finally if all three of these management changes were made (threadfin shad eliminated, four harvests per year instead of three, and a maximum of 7 days off feed before harvest) the predicted percentage of fillets with yellow pigmentation drops from 51.9% to 2.7%.

Table 2.7. Predicted impact of management changes on the occurrence of yellow fillet, where lower predicted yellow fillet percentage is desired.

Pond	Management change	Predicted yellow fillet %	Observed yellow fillet %
A	Actual management	51.9	60
A	No threadfin shad	45.6	
A	4 harvest/year instead of 3	47.2	
A	Feed once/week in the winter (max. 7 days off feed before harvest)	7.3	
A	Once/week feeding, no threadfin, and 4 harvests per year	2.7	
B	Actual management	40.2	40
B	Once/week feeding in the winter	13.0	
B	4 harvests/year instead of 1	26.9	
B	No threadfin shad	34.1	
B	Once/week feeding, 4 harvests/year, and no threadfin	2.7	
C	Actual management	9.5	10
C	Only 3 days off feed before harvest	9.0	
C	4 harvests/year	4.7	
C	No threadfin shad	6.1	
C	3 days off feed, 4 harvests/year, no threadfin	2.2	

[1] See text above for description of "Actual Management."

As can be seen from table 6 making a few management changes can have huge impacts on the occurrence of yellow fillet, in the case of pond A the predicted value was reduced from 51.9 to 2.7 and from 40.2 to 2.7 and from 9.5 to 2.2 in ponds B and C respectively.

Discussion:

As stated in the results section the model that best fits the data to explain the occurrence of yellow fillet based on pond management practices is the model produced by the AIC, forward selection, and stepwise regression methods. This model incorporates the variables; days off feed before harvest, presence of threadfin shad, presence of snails, and number of harvests in the last year. However, it seems that the form of copper being used potentially deserves being a factor in the final analysis of how to stop yellow fillet from occurring which brings up the question of if form of copper was significantly related to the occurrence of yellow fillet, why was the total amount of copper not linked to the occurrence of yellow? The possible solution to this problem is that the survey asked for the amount of copper that was applied to the pond in the two months prior to harvest (see appendix 2, question 3). It did not ask with what frequency was that copper applied. In the process of interviewing the farm managers it became clear that some farms apply copper at regular intervals throughout the growing period hoping to maintain a more stable algae bloom, while other farm managers mostly use copper in an attempt to get fish on-flavor just before harvest and apply much higher doses all at once than do the farms applying at regular intervals. Therefore, the way that the question is stated allows for only a numerical answer of the amount of copper applied in the two months prior to harvest and therefore, for example, if two farms had ponds of the same surface area and volume and one applied 100 pounds of copper per week and another applied 800 pounds the week of the harvest to get fish on-flavor both farms would report 800 pounds applied in the two months prior to harvest and obviously these are two very different management styles and likely would have very different effects on the algal communities in the pond (and likely different effects on the amount of yellow pigment in the fillets). Also, one must consider water quality parameters when figuring copper application rates therefore these factors combine to suggest that though the amount of copper applied to the pond was not significantly correlated to the occurrence of yellow fillet there is a good possibility that the amount (as well as timing and method of application) of copper does play a significant role in the build-up of yellow pigment in catfish fillets, but to confirm this further research is needed.

The seasonality of the yellow pigmentation problem is another variable that needs further research to be properly understood. As reported above there is a strong relationship showing that the colder months have a higher occurrence of yellow fillet however the cause of that phenomenon is unclear. Lee (1987) noted this same pattern of an increase in the occurrence of yellow fillet in late winter and early spring and suggested that it may be due to fat being metabolized through periods of fasting in the winter and the carotenoids stored in the fat metabolizing at a slower rate than the fat itself. Lovell (1984) also considered this possibility; however he added the possibility of increased foraging during periods of fasting in the winter. Considering the study on yellow pigment in trout that found a filamentous algae to be largely responsible (Welker et al., 2001), it stands to reason that as fish are often held on restricted diets (or a complete fast) through the winter they would likely be foraging more and in the winter and early spring pond water is typically clearer allowing for more filamentous algae growth. From the data in this study it should be noted that one of the variables that every model selection method agreed on including in the final regression model was the number of days off feed before harvest and fish harvested in the winter are more likely to have been off feed for a longer period because of the lower water temperatures. Therefore, the question arises is the seasonality of yellow fillet more a question of the temperature of the water and the slower metabolism of the fish, and the subsequent reduced ability to metabolize carotenoid pigments in the flesh paired with increased fat metabolism and release of stored carotenoids from that fat, or is it a factor of the different management practices used in the winter when fish are commonly left off feed for weeks if not months at a time?

The significance of the variable of the “number of days off feed before harvest” (as well as the seasonality of the occurrence of yellow fillet) is probably best explained simply by assuming that when fish are not fed a commercially prepared ration they begin to forage for natural food items in the pond whereby ingesting more algae etc. that have the carotenoid pigments. Furthermore, the strong relationship between size of the fillet and the occurrence of yellow flesh could come into play in this discussion. It is possible that the reason that smaller fish seem to have more problems with yellow fillets could be that the bigger fish are more aggressive or dominate when being fed. Thus decreasing access to feed for the smaller fish in the pond and essentially causing smaller fish to be in a partial fast because of limited access to the commercial diet (most farms are using a multiple batch production system and therefore have a wide range of sizes of fish in their pond at any one time). Therefore the variables of seasonality, number of days off feed before harvest, and size of fillet exhibiting the yellow coloration need further investigation to explain the mechanisms by which they affect the color of the fillets.

Also, these results show that the region around Forkland, AL has a higher occurrence of yellow fillet than other regions in this study. A possible explanation for this geographical difference is salinity. Though not selected in the regression model, one of the variables highly correlated to the occurrence of yellow fillet was salinity. Farms near Forkland, AL have pond chloride levels reaching 2500 ppm because they fill their ponds with well water coming from a saline aquifer in the region. High chloride levels could affect the algal community whereby affecting the production of carotenoid pigments in the pond system.

The regression models produced along with other correlated variables seem to strongly point to two main management principles for the elimination of yellow fillet; management of algal populations and feed management. Three of the four variables in the regression model (“average feeding rate in the summer”, “presence of threadfin shad" and "presence of snails") all could strongly influence algal populations. Other significant variables that include: "type of copper sulfate applied to the pond," "salinity," "average feeding rate in the summer," "pond volume," "alkalinity," and "aeration rate" could also have a significant effects on algal populations. As discussed above, copper sulfate usage is designed to manage algae populations. The variables of pond volume as well as aeration rates both can have significant effects on algal communities, especially when mixing of pond water is a consideration. Pond volume was positively correlated to the occurrence of yellow fillets; the bigger the pond (by volume) the higher the occurrence of yellow fillet. Aeration rates were negatively correlated meaning that higher aeration rates reduced the frequency of yellow fillet. Huisman et al. (2004) reported that turbulent mixing of lakes favor algal populations dominated by sinking diatoms and green algae rather than cyanobacterium. It stands to reason that higher aeration rates and smaller ponds where aerators more effectively mix the water would shift the algal populations to communities with less blue-green algae.

The other management principle strongly associated with the reduction of yellow fillet is feed management. The variables "days off feed before harvest" and "number of harvests in the last year," plus data from the processors showing that the occurrence of yellow fillet is significantly higher in smaller fish than larger ones suggest that when fish are not receiving enough of a prepared diet, be it because of pre-harvest fasting, a limited feed regime, or competition between size classes, suggest that the hungry fish would begin to forage on natural pond organisms. Foraging on natural foods seems to greatly increase the occurrence of the yellow pigments in the fillets.

The original hypothesis of this study was that the occurrence of yellow pigment in catfish fillets is the result of a cumulative effect of pigmentation found in prepared feeds and natural foods. Management practices on the farm, especially the presence of shad in the production ponds as well as the lack of use of algal bloom control are involved. The basic hypothesis seems to be supported by the data of this study as well as a review of the literature. It should be noted that the principle feed mill where feed was purchased for each farm was not significantly correlated to the presence of yellow fillet therefore the feed component does not seem to be significantly different between feed mills. There is evidence in the literature that there are pigments that can cause yellow fillet in catfish feed but not at levels sufficient to cause the yellow fillet problem. Since several environmental/pond management variables (including presence of shad and lack of algal control) were correlated to the presence of yellow pigments in catfish fillets this hypothesis can be accepted. It can be speculated that the correlation between threadfin shad and yellow fillet is actually an algae issue as there is likely a bioaccumulation effect of the yellow pigments in the shad, which are filter feeders, and then serving as forage for the catfish. Future studies could examine stomach contents of catfish found to have especially pronounced problems with yellow fillet to determine the role of threadfin shad and direct consumption of algae on the presence of yellow fillet (Welker et al., 2001).

Though the data support the hypothesis the management implications of this study are really the most important outcome of the study. Algae populations should be better managed but it appears that feed management is also very important. Proper feed management keeps fish satiated on the feed fed therefore limiting the amount of foraging on natural food. Certain management factors, like not having threadfin shad in the pond as well as more frequent harvests, can also have a significant impact on the occurrence of yellow fillet. Though the equation developed in the results section of this study does not explain all of the occurrences of yellow fillet it does give farm managers tools to begin to manage against yellow fillets. It also provides a basis for predicting effects of management changes which will be necessary when making decisions about selling fish under a merit base pricing system (as discussed in chapter 5).

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Chapter 3. Best Management Practices for Efficiency and Profitability in the Alabama Farm Raised Catfish Industry

Abstract:

The Alabama farm raised catfish industry consists predominately of independent growers that sell their products to processors. These independent growers utilize a wide range of production practices to grow catfish. This study uses a comprehensive management practice survey to document the range of methods used for growing catfish in Alabama. These production parameters are then matched with output measures such as pounds of fish produced per acre per year as well as enterprise budgets in order to establish the most productive and economically efficient means of growing catfish. Regression models are developed for both production per acre and net returns per acre. These regression models can serve as tools for farm managers when considering a management change. They can be used to predict the impact of certain management changes to total production as well as net returns per acre.

Introduction: The U.S. catfish industry is composed of many independent growers and is not vertically integrated like most modern livestock industries. Because of the diversity in growing conditions and differing management schemes, fish are produced in many different ways. The scientific and extension literature available on best management practices (BMPs) is somewhat dated. In some cases the literature is not in agreement about the most efficient ways to grow catfish. Increasing imports and feed prices have greatly affected economics. It is clear that the best management practices for growing catfish need to be adjusted for today's industry situation with tomorrow's goals in mind. This study uses a framework of an industry survey to match farm production practices with measures of outcomes arriving at the processing plant. Utilizing enterprise budgets, determinations are made about the patterns of production that result in the highest profits per water acre per year for producers.

The following is a review of peer reviewed and extension literature. Extension literature is important, though not peer reviewed, because this project seeks to update and revise established BMPs for catfish producers. This review serves as both a framework for this chapter and a basis for comparison and discussion to follow in chapter 5. Due to the complexity of the culture systems and the number of variables that interact in those systems, the following review will focus on stocking, feeding, and aeration as the majority of the hypotheses are centered on these variables. Chapter 1 provided a more in-depth discussion of these variables and others, their interactions and best management practices.

STOCKING

BMPs for stocking are hard to define as there are several methods for growing catfish in ponds. The stocking rate is determined by the carrying capacity of the pond which is strongly influenced by the inputs into the pond (feed, aeration, water exchange etc.). Currently processors are demanding a fish between 1.5 and 3.0 pounds. An older extension publication suggests a stocking density for experienced producers could be up to 6,000 fish per acre to produce 6,000 pounds per acre per year (Jensen, 1997). Wellborn (N.D.) states when available, stockers of 6-8 inches should be stocked as they can reach a size of 1.5 pounds in approximately 210 feeding days with water temperature above 70 degrees F. In a current effort to verify extension recommendations, Auburn University's Yield Verification Project protocol mandates stocking 6750, 8-inch fingerlings to reach an average market size of 2 pounds and total pond production of 13,000 to 14,000 pounds per acre per year. As for the timing of stocking, fingerlings can be stocked anytime in the year but are able to deal with the stresses of transport better when water temperatures are low in late winter or early spring (Jensen 1997).

When using a multiple batch production scheme, producers should attempt to re-stock (after harvest) the same number of fish lost from the system (number of fish harvested plus mortalities). This is in an attempt to keep the pond producing at its maximum potential without over-stocking.

FEEDING

Feed is one of the most important inputs in catfish production. Feed not only represents the highest variable production cost, it is also the main determining factor in fish growth and water quality. At high densities a nutritionally complete feed is required. There is no consensus in the literature on the most productive and economical protein level to use in catfish ponds. According to Jensen (1997), feed containing 32% protein plus all essential vitamins and minerals is adequate and the most economical feed for catfish production. However, the Catfish Farmer's Handbook recommends 35% protein feed (Wellborn, N.D.). Conversely, several studies show no difference in growth between 32% and lower protein. Cacho (1984) showed no difference in weight gain, feed consumption or conversion between 26% and 32% protein diets. Li et al. (2008) found no significant difference in the growth of channel catfish fed 24%, 28%, 32%, and 36% protein diets. However in the same study there were significant differences in carcass, fillet, and total meat yield across the protein range (fish fed higher proteins had better yield). The most recent recommendation from the National Research Council for the nutrition requirements of Channel Catfish is that fish receive a minimum of 29% protein (National Research Council, 2011). This protein level was a decrease from 32% which the council recommended in 1993 (Subcommittee on fish Nutrition, 1993).

While discussing feed quality it is important to not only look at growth of the fish but also address the issues of increasing yield and lowering feed conversion ratios (FCRs).

Increasing yield and improving FCR are two of the most important aspects for making the U.S. catfish industry profitable in the long run. Slight improvement in yield of fish which arrive at the processing plant, over the large volumes processed in a year, represent significant increases in profits for the processors. This in turn can be partially passed to producers in the form of incentives for producing a higher quality product. This is known as selling fish on a grade/yield or merit basis (see chapter 6 for a more thorough discussion of merit based marketing). Likewise even a small change in FCR on the farm can have huge impacts on profitability, especially at the high feed costs paid by farmers recently.

Oxygen management

Dissolved oxygen management in catfish ponds is one of the pivotal factors that contribute to the difference between success and failure of the aquaculture enterprise. Oxygen levels are crucial in determining the amount of feed that can be fed into the pond and therefore dictate appropriate fish stocking rates as well. Oxygen is a primary limiting factor that determines stocking density, growth, and final harvest weight.

Oxygen in ponds is transferred across the water-air barrier and is dependent on the partial pressure of oxygen in the water relative to the partial pressure in the air. However, in most catfish ponds the amount that can be transferred in this manner is relatively low when looking at the complete oxygen budget because of the high biomass of bacteria, plants, and animals. A much larger portion of the total oxygen budget in aquaculture ponds is dictated by the interaction of respiration and photosynthesis (Boyd and Tucker 1998).

The processes of respiration and photosynthesis drive most of the oxygen budgets in pond environments. Respiration (of culture organisms, algae, and bacteria) uses oxygen 24 hours per day whereas photosynthesis only produces oxygen when sunlight is present. This interaction can cause large swings in oxygen on a daily cycle. High biological activity in catfish ponds can result in highly supersaturated oxygen conditions in the afternoon and highly unsaturated conditions at night. In most cases supplemental aeration is needed to keep oxygen levels from dropping too low for the fish in the pond to survive and grow well. Mechanical aeration should be supplied in an attempt to maintain dissolved oxygen above 4 mg/L. A general rule of 1 to 1.5 hp/water acre is sufficient for supplemental aeration purposes, but additional emergency aeration should be available for extreme cases (Jensen 1997). Masser et al. suggests 2-3 hp/acre (2005). Whereas, in Auburn University's Yield Verification Protocol 5-6 hp/ surface acre is recommended, which is more consistent with up to date aeration research and more appropriate for a best management practice. This shows the need to update extension materials. Using a standard equation for aeration requirement that takes into account the biological oxygen demand of the feed, feeding rate, and the aerator's efficiency (using approximate average industry values such as 140 kg/ha feeding rate) one would need to aerate above 6 hp/acre to reach maximum efficiency, which is well above industry standards (Boyd personal communication, 2010).

Some of the current ways of thinking about aeration are actually looking at aeration rates on a hp/acre-foot basis. This seems appropriate as the goal is to maintain dissolved oxygen concentrations above 3 mg/L throughout the water column. This allows fish to utilize the whole volume of the pond, and allows for oxidation of wastes throughout the water column. When looking at aeration per ac-ft it is recommended that at least 1.25 hp/ac-ft is provided in channel catfish ponds (Jesse Chappell personal communication, 2010). However, this recommendation is still being tested but it is consistent with the above mentioned recommendation of 5-6 hp/surface acre considering many ponds have an average depth of 4 to 5 feet.

Supplemental aeration has been shown to increase feed efficiencies and total fish production in ponds stocked with 4047 fish/acre (10,000 fish/ha) and receiving a maximum daily feeding rate of 47.3 pounds/acre (53 kg/ha) (Boyd and Tucker 1998). In another study it was reported that providing 6 hours of aeration every night, i.e. not allowing D.O. to drop below 4 mg/L, compared to providing aeration on an emergency basis only (when D.O. fell below 1 mg/L) resulted in significantly better feed conversion and greater weight gain (Lai-Fa and Boyd, 1988). A similar study conducted in Mississippi did not show better feed conversion (though fish were fed in a different way) but did result in very high net production values from ponds in a high aeration treatment (Torrans 2005). Therefore it seems that increasing aeration well above the normally suggested rates could have positive effects on both growth and production efficiencies. Producers should be aware that depending on stocking and feeding rates the fish in a pond may utilize as little as 10% of the total oxygen with the other 90%

going to other biological and chemical factors in the pond (Boyd and Tucker, 1998). This microbial action is essential for the breakdown of organic waste into non-toxic forms. Therefore, farmers should consider increasing aeration rates to better provide appropriate growing conditions for their fish, whereby potentially increasing harvest by increased growth rates (and decreasing FCR) without increasing stocking rates (and feeding rates). If feeding rates are increased other water quality parameters (such as ammonia and nitrite) become increasingly more problematic.

Arana (1999) demonstrated that the interaction of water quality variables can be quite significant on daily feed intake levels (and therefore one could assume growth as well). The research showed that when morning dissolved oxygen concentrations were low, and afternoon levels of un-ionized ammonia were high the fish's feed intake was greatly reduced (though both parameters remained at sub-lethal levels). The same study showed that when un-ionized ammonia levels were lower in the morning (even when D.O. concentrations were low and afternoon un-ionized ammonia levels were high) the fish were able to recover and feed well apparently due to the temporarily lower morning un-ionized ammonia levels (Arana 1999).

This current study attempts to verify or modify the above discussed BMP's for catfish production through the testing of the following hypotheses.

Hypotheses:

Ho1: Farms managed with a multiple batch production system that harvest each pond at least 3 times per year will have a higher net return than farms harvesting less frequently.

Ho2: Farms with aeration rates greater than or equal to 6 hp/ac will have a higher net return than farms with lower aeration rates.

Ho3: Farms with higher aeration (per acre foot) will have a higher net return per water acre per year than do farms with lower aeration rates.

Ho4: Farms stocking between 1500 and 1800 fish per acre for every one horsepower per acre of fixed paddle wheel aeration will have a higher net return than farms stocking at higher densities.

Ho5: Farms feeding 32% protein feed have higher net returns than farms feeding lower protein feeds.

Ho6: Farms with higher aeration rates (per acre foot) will have higher production rates (per water acre per year) than do farms with lower aeration rates.

Ho7: Farms stocking less than or equal to 8000 fish per acre will have a higher net return on a per acre-year basis than farms stocking more than 8,000 fish per acre.

Ho8: Farms that feed less than or equal to 30 pounds per acre per day for every 1 horsepower of fixed paddle wheel aeration (on a hp/ac basis) will have a higher net return per water acre per year than farms feeding over 30 pounds.

Ho9: Farms with medium production intensity levels will have a higher propensity to adopt new technology than farms with either low or high production intensity levels.

Ho10: Medium intensity farms have higher net returns per acre of water per year of production than do either low or high intensity farms.

Ho11: Farms with aeration rates greater than or equal to 6 hp/ac have lower FCR's than farms with lower aeration rates.

Ho12: Farms stocking between 1500 and 1800 fish per acre for every one horsepower per acre of fixed paddle wheel aeration have lower FCR's than farms stocking at higher densities.

Materials and Methods

A comprehensive industry wide management practices survey was conducted. The survey incorporated questions necessary to find the range of production practices utilized to produce catfish in Alabama as well as methods of information transfer and adoption rates of new technologies. The survey instrument was 70 questions and typically took about one half hour to complete.

Estimates of instrument validity and reliability were created using panel review. (See appendix 4). The five member panel was asked to evaluate the instrument in terms of clarity and conciseness. On a scale of 1-5, 1 = low and 5 = high, the mean score for clarity was, m = 4.5 and the mean score for conciseness was m = 4.7. Reliability estimate was provided by using a Cronbach's Alpha technique. The resultant $\alpha = 0.72$ was determined to be sufficient for continuing the research project. This procedure is as described in Wiersma and Jurs, (2009).

The survey was sent to every catfish framer in Alabama which, at the time was thought to be 95. Two weeks after the initial mailing of the survey, farms that had not replied received a reminder card in the mail. After another two weeks, farms that still had not replied received a reminder letter with a second copy of the survey. This procedure follows the survey methodology established in Dillman (2007). After another 3 weeks had passed attempts were made to conduct the survey over the phone or in person with farms that still had not completed the survey.

Analysis of the survey data was accomplished in several steps. In the results section below statewide averages and general production practices are examined first. In order to associate management practices with profitability, enterprise budgets were developed for each farm participating in the survey based on their answers to survey questions. These enterprise budgets were calculated for each farm for the years 2011 and 2012 as well as an average of the two years. Each year was calculated separately for comparison purposes and the average was calculated to smooth over spikes in the production cycle. This was done because farms (especially those operating with multiple batch production systems) do not necessarily begin and end production cycles on a calendar year basis, and expenses in one year are often incurred for fish sold in the next. Prices used for inputs and fish pond bank prices were obtained from various sources as seen in Table 3.1. Budget lines were calculated as described in Table 3.2.

Table 3.1. Prices used for partial budgets, and the source of the prices.

Item	2011	2012	Source
Pond bank fish price ($/pound)	1.17	0.98	NASS processing report (average per year)
Feed 32% ($/pound)	0.2105	0.2345	Catfish database (Hanson and Sites, 2011)
Feed 28% ($/pound)	0.201	0.223	Catfish database (Hanson and Sites, 2011)
Labor			
Management	45,000	45,000	Auburn University yield verification project
Non-management ($/year)	18,000	18,000	$9.00 per hour for a 40 hour work week 50 weeks per year
Channel catfish fingerlings ($/inch)	0.015	0.015	Need More Fisheries (a fingerling supplier)
Hybrid catfish fingerlings ($/inch)	0.025	0.025	Need More Fisheries (a fingerling supplier
Harvest and transport ($/pound)	0.05	0.05	Auburn University yield verification project
Fuel- diesel ($/gallon)	3.33	3.62	Auburn University yield verification project-average prices paid by producers
Electricity-aeration ($/kwh)	0.09	0.09	Auburn University yield verification project-average prices paid by producers
Chemicals			
Copper ($/pound)	1.52	1.42	Auburn University yield verification project-average prices paid by producers
Diuron ($/oz.)	0.47	0.47	Auburn University yield verification project-average prices paid by producers
Salt ($/ton)	110	110	Gregory Whitis extension agent
Interest on operating capital (%)	0.07	0.07	Auburn University yield verification project-average prices paid by producers
Machinery depreciation ($/yr/acre)	187.74	184.74	Hanson et al., 2002
Pond depreciation ($/yr/ acre)	103.24	103.24	Hanson et al., 2002
Taxes ($/acre)	11.74	11.74	Auburn University yield verification project-average prices paid by producers
Interest on total capital costs ($/acre)	50.19	50.19	Hanson et al., 2002
Interest on machinery purchases ($/acre)	47.37	47.37	Hanson et al., 2002

Table 3.2. Method of calculating items in partial budgets.

Variable	Method of Calculation
Gross receipts	Pounds sold*average price for that year
Receipts per acre	Gross receipts/# of acres
28% protein feed costs	Amount of 28% protein feed fed*price for that year
32% protein feed costs	Amount of 32% protein feed fed*price for that year
Average feed costs	Average of the 2 year's total feed costs
Labor	
Management	(# full-time managers +(0.5*#part-time managers)*salary from price table
Non-management	(# full-time workers +(0.5*#part-time workers)*salary from price table
Channel catfish fingerlings	Total number of channel fingerling inches stocked *price for that year per inch
Hybrid catfish fingerlings	Total number of hybrid fingerling inches stocked*price for that year per inch
Fuel costs	# of tractor hours *3.4 gallons per hour*price per gallon of diesel fuel
Electricity	((31*aeration hours per day in July)*(hp/ac*number of acres/10)*8.47*price per kw-hr
Chemical costs	See written explanation
Interest on operating capital	Total variable costs not including interest on operating capital*0.07
Total variable costs	Sum of all costs above
Total variable costs per acre	Total variable costs/# of acres
Machinery depreciation	# of acres*amount from price table
Pond depreciation	# of acres*amount from price table
Taxes	# of acres*amount from price table
Interest on total infrastructure costs	# of acres*amount from price table
Interest on total equipment and machinery costs	# of acres*amount from price table
Total fixed costs	Sum of all costs in this table after the total variable costs line
Total expenses	Total fixed costs + total variable costs
Returns above variable costs	Gross receipts – variable costs
Returns above total costs	Gross receipts – total costs
Breakeven price to cover variable costs	Total variable costs/total pounds of fish produced
Breakeven price to cover total costs	Total expenses/total pounds of fish produced

Along with the information presented in the tables above, a few variables need more explanation of how they were calculated. The electrical usage was assumed to mostly be for aeration. The fixed paddlewheel aeration electrical usage was estimated in the following way: average nightly hours of aeration in July was used to predict total aeration usage for the year. In order to establish a prediction factor, the number of kilowatt hours necessary for aeration on 3 ponds on each of 3 different farms (Auburn University yield verification data) was taken as a percentage of the total power consumption for each of the ponds for the entire year. This was done over 2 years producing 18 total observations. An ANOVA revealed no significant difference in the means of July's percentage of the total year's aeration for the three farms at the 0.05 alpha level. Therefore, the July aeration usage was used as a predictor of total usage for the year with July representing 18.4% of the total yearly aeration needs. The subsequent procedure used for figuring aeration costs was as follows: the number of aeration hours in July (question 57) was multiplied by 31 days in July, then divided by 0.184 (the mean percentage from above) to give the total number of aeration hours per year. The total number of aeration hours per year was then multiplied by the number of 10 hp aerators on the farm (which was found by multiplying the number of horsepower per acre (question 52) by the number of acres farmed (question 8) and dividing by 10). The result was then multiplied by 8.47 kw-hr per hour of 10 hp aerator operation (Hanson et al., 2002) and then multiplied by $0.091957/kw-hr (from Auburn University's yield verification project). This resulted in an estimate of total farm aeration costs for the entire year which when compared on a per acre basis to farms in the yield verification project shows that the result is reasonable.

The variable in the budget for total chemical costs was calculated by adding the cost of copper sulfate, diuron, and salt for each year. The cost of copper sulfate was found by multiplying question 37 (do you use copper sulfate) by the quantity used then by the price and adding it to the factor for diuron found in the same way (Q42 * Q44 * price). The cost of salt was calculated using a rule of thumb that Alabama Cooperative Extension recommends for an average farm (not using saline wells) which is 250 pounds of salt per acre-foot of water per year. Though lime is a common additive to catfish ponds in many areas of the country it is not common to add lime to catfish ponds in West Alabama (Gregory Whitis, personal communication, 2013) therefore there was no cost of liming added into the enterprise budgets for this study. Insurance costs were not included though a standard value could be applied for all farms. Without any information on types and amounts of coverage it seems to be extremely variable. It also should be noted that fuel costs are only for emergency tractor aeration and does not include feed trucks, mowing, or other fuel uses. However, emergency tractor aeration is likely the biggest burner of fuel on most farms.

Depreciation for ponds and machinery is included, though not an immediate and felt cost. In the long run of operating a catfish farm, equipment will need to be replaced and ponds will need to be renovated and therefore it is a cost that should be included in the budgets. Also, interest on operating capital, infrastructure, and machinery is included in the budgets even though some farms may not have loans to pay for these expenses. In the case of a farm that does not have debt for these expenses, this interest can be looked at as an opportunity cost for choosing to use the available capital for catfish farming instead of other ventures.

Several farms did not have, or did not report, records of amounts of certain inputs for variables needed to develop the enterprise budgets (amount of copper applied, amount of diuron applied, hours aerators ran per night and tractor hours) for those farms an estimate of the missing values was established by averaging all of the farms that reported a value for the variables listed above (on a per acre basis). Then any missing values were replaced with the statewide average in order to calculate complete budgets for those farms.

Assumptions for the enterprise budgets:

1. All acres reported as "actively farmed" in the BMP survey are for catfish grow-out not hatchery, fish-out operations, or production of other species.

2. For single year budget data it is assumed that production costs that may have been incurred in the previous year or production sold in the next year, and costs incurred in the year in question, will be equivalent in subsequent years. Therefore, a calendar year is used as a production cycle though it is actually just a frame of an ongoing production process under multiple batch systems (the two year average is used to smooth any peaks and valleys in this ongoing production scheme).

3. It is assumed that all farms use custom seining and hauling crews though some may actually have on farm labor.

4. As described above it is assumed that average nightly aeration hours in July are representative of a percentage of the total yearly aeration requirements for the entire farm.

5. In figuring total aeration on the farm it is assumed that all fixed electric paddlewheel aerators are 10 hp aerators and not another size. It is also assumed that an average power usage can be assumed though depending on farm maintenance practices draw from different aerators can be quite different.

6. The price of fish used is a yearly average some producers could have sold at lower or higher prices depending on timing of harvest due to fluctuations in the market.

7. Feed prices are also a yearly average and does not account for any advanced booking of feed or timing of feed deliveries.

8. Fuel prices are an average as well and do not account for timing of fuel purchases.

9. Electricity prices do not account for “peak” and “off-peak” rate plans. These plans are available in some areas however to standardize the cost data a standard rate was used for all calculations.

Following the development of state-wide average enterprise budgets the budgets from individual farms were used to test the hypotheses stated above. Clustering farms was necessary for testing hypotheses 9 and 10. Using principle components analysis then cluster analysis (proc fastclus in SAS) farms were divided into management clusters. Also, questions from the survey were utilized to assign a numerical ranking to farm managers based on their willingness/ability to adopt new technologies and take risks. Following the hypotheses tests regression models predicting production and farm profit were fit to the data.

In order to test the hypotheses and fit the regression models the following statistical procedures were used; ANOVA, regression analysis, stepwise regression, forward selection, backward elimination, AIC, BIC, logistic regression, principal components analysis, and cluster analysis were used to link production practices to the output measures. A brief description of each of these statistical procedures can be found in appendix 1.

RESULTS:

At the end of the data collection period of the total 95 surveys sent out, 68 farms had participated (71.6% participation). Of those 68 surveys returned, 11 farms did not produce food size catfish to be sold to a processing plant in 2011 or 2012. This makes these farms ineligible for the study (these farms were mostly out of business or fee fishing operations). There were also 2 farms that were ineligible because of one being a new farm and one under a new manager that did not have data from the previous years. In the case of four farms from the original survey mailing list, two of the farms were actually divisions of larger farms under the same manager therefore it was determined that the four farms were in actuality only 2 farms. These modifications to the original list of 95 farms resulted in a list of 80 farms eligible for participation. Of those 80 potential participants, 53 farms returned usable data (66.3%).

Table 3.3 below shows state wide averages for production variables from the survey data.

Table 3.3. Alabama state wide catfish production averages and ranges.

Variable	2011 Mean (range)	2012 Mean (range)	Both 2011 and 2012 (range)
Experience, years			20.9 (2-42)
Water acres, #	241.9 (15-1,387)	242.1 (15-1,387)	
Ponds, #	21 (1-121)	21 (1-121)	
Ponds depth (ft)	5.3 (3-10)	5.3 (3-10)	
Acres taken out of production	1 (0-50)	5 (0-100)	
Pounds sold (million pounds)	1.695 (0.035-13.0)	1.507 (0-10.0)	
Production pounds/acre	6,715 (1,768-22,308)	6,104 (0-16,176)	
Pounds ready to sell but unable to find a buyer	7,554 (0-200,000)	98,871 (0-1,500,000)	
Feed fed, pounds/ acre/year	14,941 (5,385-43,077)	13,667 (1,680-32,352)	
Stocking rate (fish/acre)	6932 (3,000-12,000)	6845 (3,000-12,000)	
Fingerling size (in)	6.2 (5-9.5)	6.1 (0-9.5)	
Production system			
Single batch			9.6%
Multiple batch			61.5%
Both			28.8%
Batches per pond			2.15 (1-3)
Farms growing:			
Channel catfish	64.2%	75.5%	
Hybrid catfish	3.8%	3.8%	
Both	32.1%	20.8%	
Harvests per year	2.1 (1-4)	1.9 (0-6)	
Farms using:			
Feeding cap	49%	47%	
Not using feed cap	51%	53%	
Farms feeding:			
28% protein feed	51%	62%	
32% protein feed	49%	38%	
Farms:			
Using copper sulfate	96%	94%	
Not using copper sulfate	4%	6%	

Table 3.3 Continued			
Variable	2011 Mean (range)	2012 Mean (range)	Both 2011 and 2012 (range)
Use copper sulfate in regular low doses to control algae	YES=40% NO=60%	YES=38% NO=62%	
Farms:			
Using diuron	77%	70%	
Not using diuron	23%	30%	
Using diuron in regular low doses	55%		
Average alkalinity			114 (7-200)
Salinity			144 (0-3,000)
Aeration (hp/ac)			3.25 (1-9)
Farms using automated oxygen monitoring systems			Yes=66% No=34%
FCR (pounds of feed fed/pounds of fish sold)	2.35 (1.37-4.41)	2.48 (1.12-5.83)	
FCR for the average of the two years of production (to account for continuous production cycle)			2.41 (1.62-4.08)
Total FCR (pounds of feed fed/pounds of fish sold + estimate of fish ready to sell but unable to find a buyer)	2.33 (1.37-4.41)	2.27 (0.67-3.80)	
Total FCR for the average of the two years of production (to account for continuous production cycle)			2.32 (1.62-3.72)

Enterprise budgets were developed for each farm using the prices and procedures described in the materials and methods section. The following budgets represent the mean value for each budget line by year. Table 3.4 is the budget for 2011, table 3.5 shows the budget for 2012, and table 3.6 is the budget for the average of the two years.

Table 3.4. Budget for an average Alabama farm in 2011.

Item	$	$/Acre	Range, $ Low	High
Gross receipts	1,983,544		41,371	15,210,000
Gross receipts per acre		7,825	2,069	26,100
Variable costs				
Feed	784,010	3,081	27,365	5,473,000
Labor				
Management	68,774	573	45,000	135,000
Hired labor	48,906	266	0	324,000
Fingerlings	183,654	732	7,200	1,497,960
Harvest and transport	84,767	334	1,768	650,000
Fuel	52,691	225	0	452,880
Electricity	84,385	353	787	546,022
Chemicals				
Copper sulfate	26,461	108	0	165,497
Diuron	1,205	4	0	22,962
Salt	16,640	73	1,375	95,356
Interest on operating capital	95,936	405	5,987	643,030
Total variable costs	**1,466,458**		**91,511**	**9,829,171**
Total variable costs per acre		**6,184**	**2,546**	**15,532**
Income above variable costs	**556,648**	**1,642**	**-180,441**	**5,380,829**
Fixed costs				
Machinery depreciation	44,691	185	2,771	256,234
Pond depreciation	24,974	103	1,549	143,188
Taxes on land	2,840	12	176	16,283
Interest on pond construction costs	12,142	50	753	69,614
Interest on equipment/machinery	11,460	47	711	65,702
Total fixed costs	**72,506**		**4,496**	**415,706**
Total of all specified expenses	**1,540,808**		**97,505**	**10,244,877**
Total of all specified expenses per acre		**6,484**	**2,845**	**15,832**
Net returns above all specified expenses	**482,297**		**-260,671**	**4,965,122**
Net returns above variable costs, $/acre		**1,642**	**-7,040**	**10,568**
Net returns above total costs, $/acre		**1,342**	**-7,341**	**10,268**
Breakeven price to cover specified variable costs, $/pound	**1.06**		**0.61**	**5.15**
Break even price to cover specified total costs, $/pound	**1.11**		**0.63**	**5.32**

[1] The number of acres used for per acre calculations varies by line item and associated number of survey observations and/or source of line item expense if not from the survey.

As can be seen from the table above, the average Alabama farm in 2011 had income of $1,642 per acre above their variable costs and $1,342 per acre above their total costs with a breakeven price to cover total costs of $1.11 per pound. However, the range around the mean is fairly wide with one farm losing $7,341 per acre (when considering total costs, and one farm profiting $10, 268 per acre above their total costs. The range around the breakeven price to cover total costs is quite wide as well. The figures below show the distribution of farms and their profits/losses above variable and total costs (figures 3.1 and 3.2 show profit/loss for 2011, figures 3.3 and 3.4 show profit/loss for 2012, and 3.5 and 3.6 show profit/losses for the average of the two years). Figure 3.7 is a box plot showing the distribution of farms and their breakeven price to cover total costs.

Figure 3.1. Income above variable costs per acre for 2011.

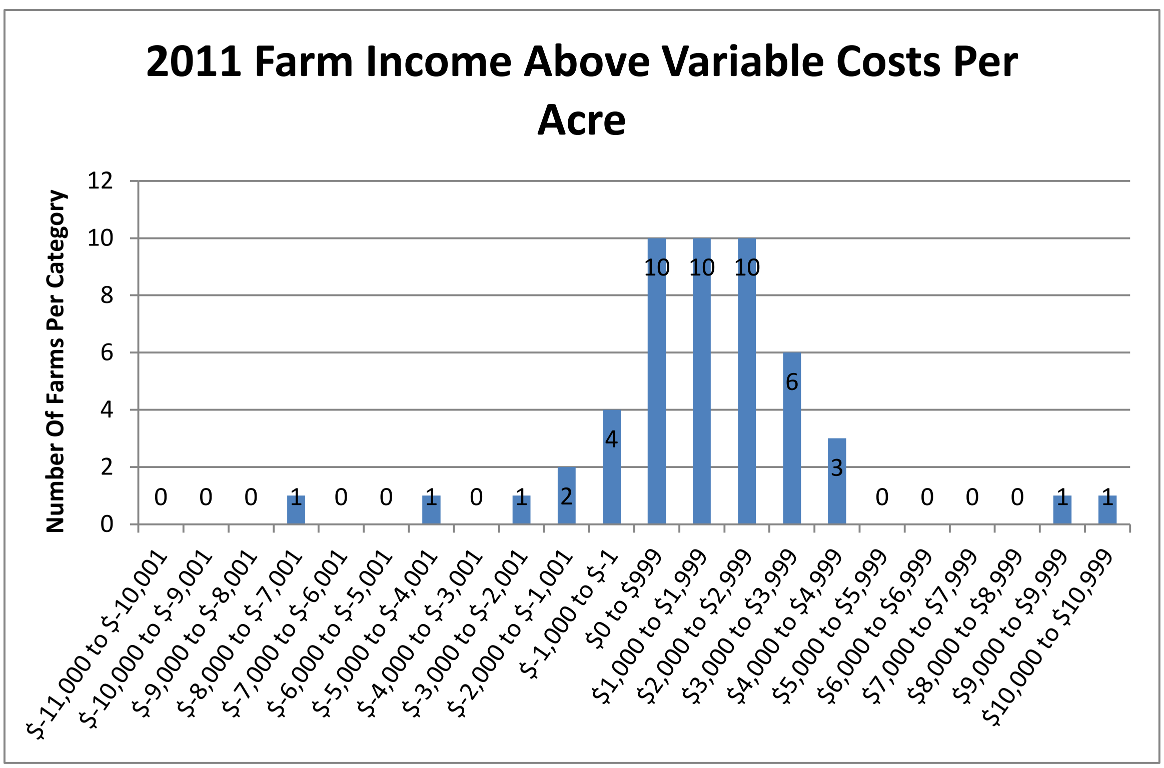
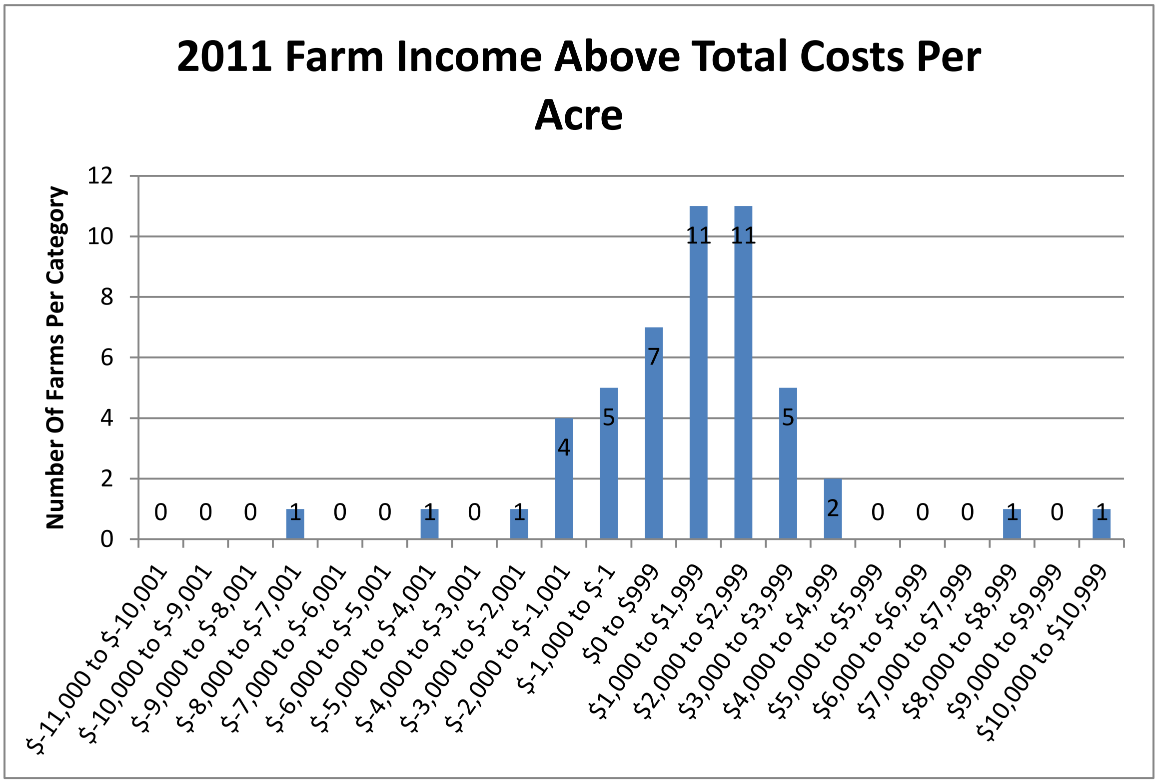


Figure 3.2. Income above total costs per acre for 2011.



As can be seen from the figures above, the majority of the farms (76%) were profitable in 2011. However, as feed prices increased and fish prices dropped in 2012 the average Alabama farm was no longer profitable. In 2012, the average farm actually lost $482 per acre when only considering variable costs and when total costs are considered the average farm lost $782 per acre. However, there were farms that remained profitable in 2012. The range around the mean for income above total costs was from a loss of $10,577 per acre to a profit of $5,624 per acre, as can be seen in table 3.5 below.

Table 3.5. Budget for average Alabama catfish farm in 2012, developed from BMP survey.

Item	$	$/Acre	Range, $ Low	High
Gross receipts	1,476,906		0	9,800,000
Gross receipts per acre		5,577	0	15,853
Variable costs				
Feed	798,470	3,105	19,698	4,690,000
Labor				
Management	68,774	621	45,000	135,000
Hired labor	48,906	267	0	324,000
Fingerlings	167,481	675	0	1,123,470
Harvest and transport	75,352	285	0	500,000
Fuel	48,889	185	0	492,320
Electricity	85,382	348	787	546,022
Chemicals				
Copper sulfate	25,145	103	0	161,502
Diuron	1,108	3	0	21,263
Salt	16,645	73	1,375	95,356
Interest on operating capital	94,445	397	6,752	547,204
Total variable costs	**1,443,656**		**103,204**	**8,364,396**
Total variable costs per acre		**6,070**	**2,781**	**10,865**
Income above variable costs	**55,484**	**-482**	**-835,969**	**2,014,242**
Fixed costs				
Machinery depreciation	44,733	185	2,771	256,234
Pond depreciation	24,998	103	1,549	143,188
Taxes on land	2,843	12	176	16,283
Interest on pond construction costs	12,153	50	753	69,614
Interest on equipment/machinery	11,470	47	711	65,702
Total fixed costs	**72,574**		**4,496**	**415,706**
Total of all specified expenses	**1,517,618**		**109,199**	**8,780,102**
Total of all specified expenses per acre		**6,370**	**3,081**	**11,165**
Net returns above all specified expenses	**-18,479**		**-955,856**	**1,912,339**
Net returns above variable costs, $/acre		**-482**	**-10,277**	**5,924**
Net returns above total costs, $/acre		**-782**	**-10,577**	**5,624**
Breakeven price to cover specified variable costs, $/pound	**1.15**		**0.61**	**3.16**
Break even price to cover specified total costs, $/pound	**1.22**		**0.63**	**3.43**

[1] The number of acres used for per acre calculations varies by line item and associated number of survey observations and/or source of line item expense if not from the survey.

Figure 3.3. Individual farm income above variable costs per acre 2012.

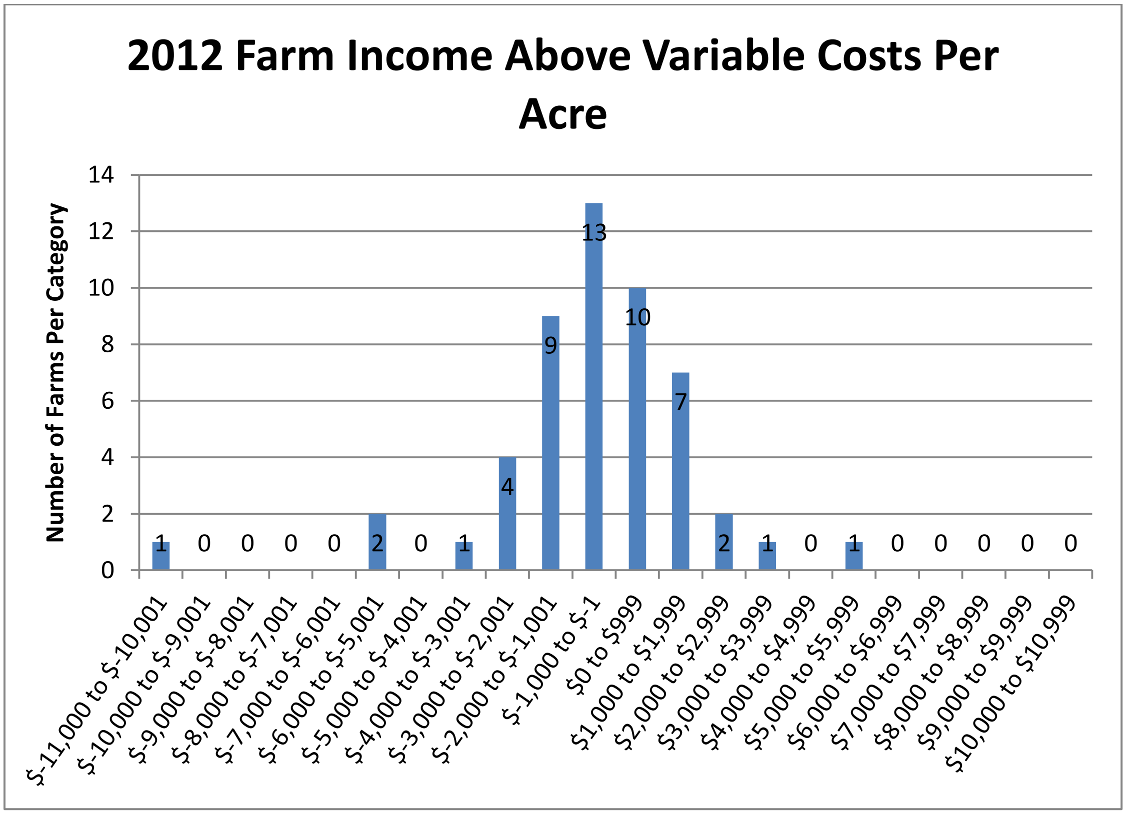
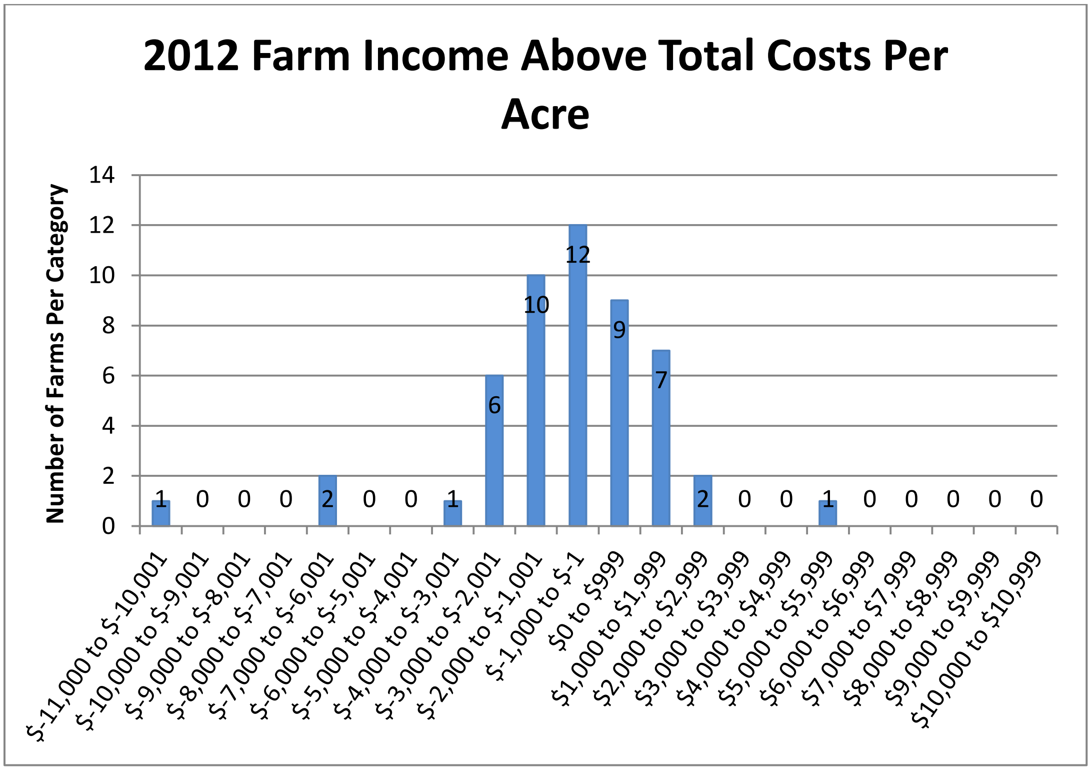


Figure 3.4. Farm income above total costs per acre 2012.



As in 2011, the farms seem to be fairly normally distributed around the mean. It should be noted that in 2012, only 37% of farms were profitable when considering total costs.

The following figures show the average budget for the combined data from the two years of production. It helps smooth any peaks and valleys in the production cycle (depending on stocking size and management intensity, catfish often are a multi-year crop). As can be seen from this budget and the subsequent graphs, most farms over the two year average were nominally profitable. With the average income above total costs being $360 per acre and the average breakeven price above total costs was $1.09

Table 3.6. Budget for an average Alabama farm using an average of the two production years.

Item	$	$/Acre	Range, $ Low	Range, $ High
Gross receipts	1,749,666		20,686	12,505,000
Gross receipts per acre		6,749	1,034	17,390
Variable costs				
Feed	798,875	3,085	32,443	5,081,500
Labor				
Management	68,774	581	45,000	135,000
Hired labor	48,906	263	0	324,000
Fingerlings	175,567	704	7,088	1,310,715
Harvest and transport	79,150	303	884	575,000
Fuel	50,790	199	0	472,600
Electricity	84,883	350	787	546,022
Chemicals				
Copper sulfate	25,803	106	0	163,500
Diuron	1,157	4	0	22,112
Salt	16,642	73	1,375	95,356
Interest on operating capital	96,015	398	6,369	595,117
Total variable costs	**1,467,672**		**97,358**	**9,096,784**
Total variable costs per acre		**6,088**	**2,818**	**11,095**
Income above variable costs	**307,707**	**660**	**-198,329**	**3,408,216**
Fixed costs				
Machinery depreciation	44,712	185	2,771	256,234
Pond depreciation	24,986	103	1,549	143,188
Taxes on land	2,841	12	176	16,283
Interest on pond construction costs	12,147	50	753	69,614
Interest on equipment/machinery	11,465	47	711	65,702
Total fixed costs	**72,540**		**4,496**	**415,706**
Total of all specified expenses	**1,542,418**		**103,352**	**9,512,490**
Total of all specified expenses per acre		**6,388**	**3,117**	**11,395**
Net returns above all specified expenses	**232,961**		**-318,216**	**2,992,510**
Net returns above variable costs, $/acre		**660**	**-8,659**	**7,583**
Net returns above total costs, $/acre		**360**	**-8,959**	**7,283**
Breakeven price to cover specified variable costs, $/pound	**1.03**		**0.61**	**10.97**
Break even price to cover specified total costs, $/pound	**1.09**		**0.63**	**11.30**

[1] The number of acres used for per acre calculations varies by line item and associated number of survey observations and/or source of line item expense if not from the survey.

[2] Note one farm that produced fish in 2012 but did not find a buyer was included in the budgets for 2012 and the average of the two years in the costs categories however it was removed from the calculations of breakeven price as it had expenses but sold no fish.

Figure 3.5. Two year average for individual farm income above variable costs per acre.

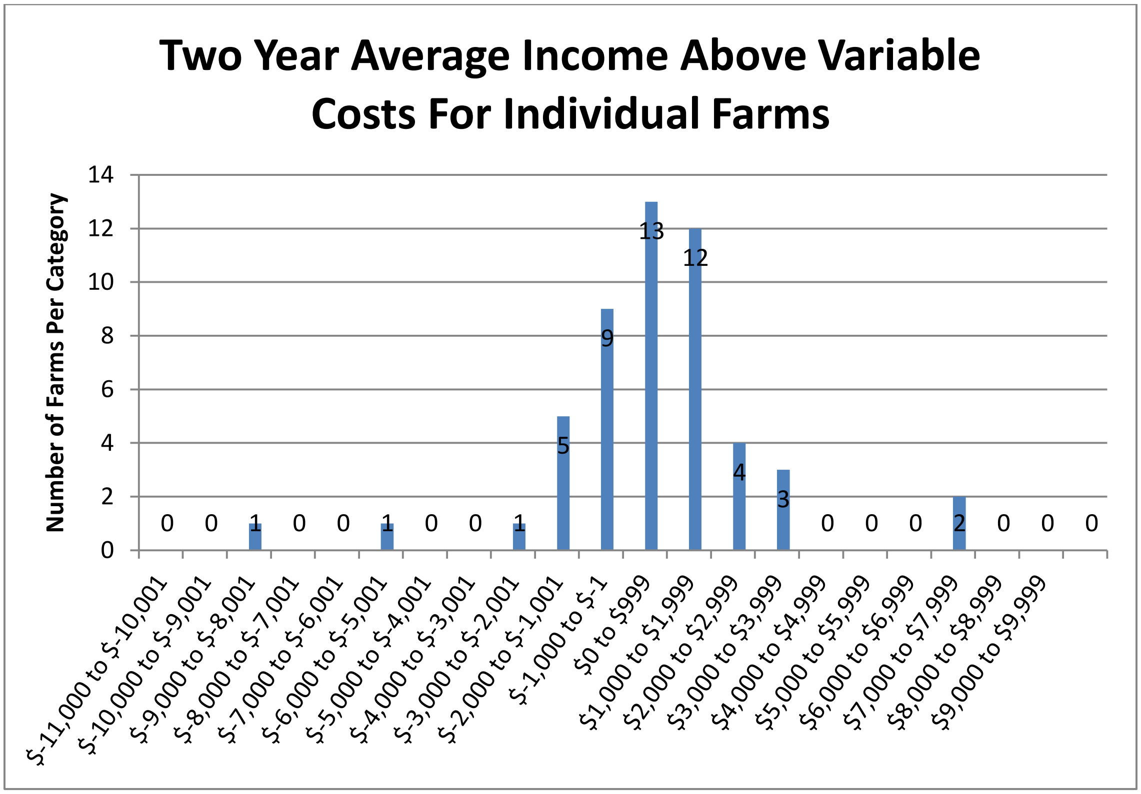
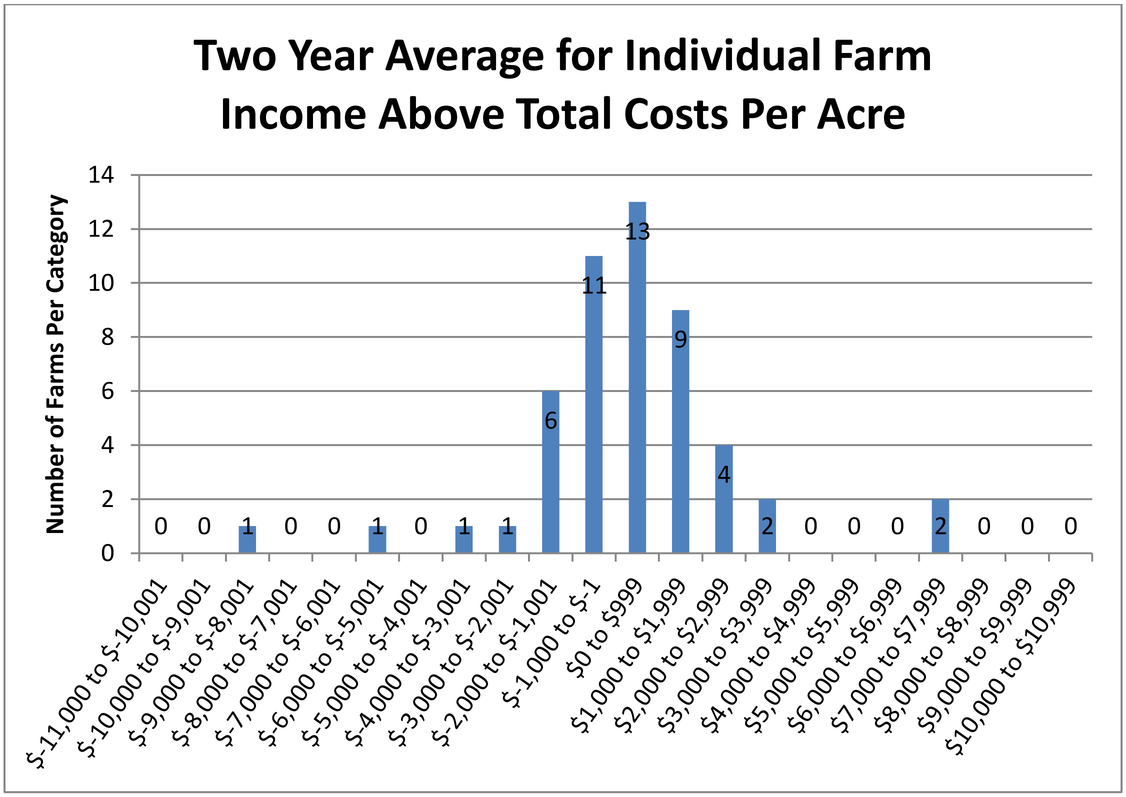


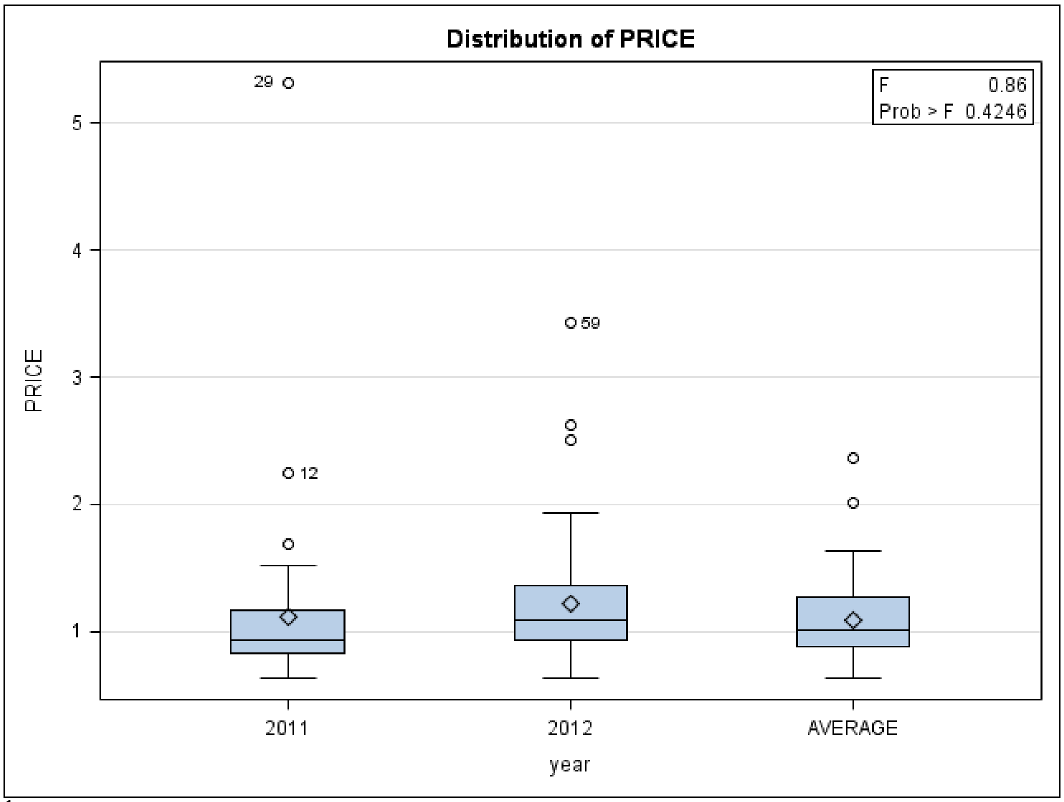
Figure 3.6. Two year average income above total costs per acre.



As can be seen in the figure above, 59% of Alabama farms were profitable over the two year average.

In these budgets the breakeven price to cover total costs is mentioned. This value is one that should be examined in a more in-depth way than just looking at the mean and the range. This value is really the number that must be used to look at possibilities of a merit-based pricing system that could be a catalyst for change in the catfish industry (see chapter 5). In 2012 when feed prices were high there were still farms that had low breakeven prices. Though the values above do represent the mean values for breakeven price, it should be noted that there are many farms well under that mean value (see figure3.7 below) and therefore increased efficiency in the industry is an obtainable goal.

Figure 3.7. Distribution of farms and their breakeven prices to cover total costs.



[1] Price is $/pound.

[2] In this box and whisker plot the top and bottom edges of the box represent the 75th and 25th quartile respectively and the line in the box is the median. The mean is represented by the diamond shape. The whiskers reach as far as the data with a maximum length of 1.5 times the interquartile range. Data points outside this range are marked with circles.

In every case (2011, 2012, and the average of the two years) the median is below the mean with many farms producing well below the median price (median and mean values for 2011, 2012, and the average of the two years are 2011 mean = $1.11 median = $0.93; 2012 mean = $1.22 median=$1.09, and the average of the two years mean = $1.09 median = $1.01) (figure 3.7). This difference in the mean and the median values shows that there are many farms that are producing fish more efficiently than the mean breakeven price which is evidence that there is room for significant improvement in efficiency on the other farms.

Clustering procedures:

In order to group farms by their management practices, first principal components analysis was conducted on the data set in order to narrow the list of variables to include in a clustering procedure. However, due to the variation in the data set and the number of variables included in order to explain 90% of the variation, the first 16 principal components were necessary for the 2011 data and 17 principal components were necessary for the 2012 data. The heaviest weighted variables from those principal components were selected. Due to the large number of principal components, the procedure only narrowed the possible variables to enter in a clustering procedure by 1 variable in 2011 and it did not narrow the variable set at all for 2012. After conducting the clustering procedure this yielded clusters with too much noise and variation to understand due to the long list of variables. Therefore, in order to group farms, three important management intensity variables were selected (stocking rate, aeration rate (hp/acre), feeding rate (pounds/acre/year). These variables were then used in a SAS proc fastclus procedure in order to find 3 disjoint clusters based on production intensity variables. This procedure produced 3 clusters (low, medium, and high intensity) with the means and standard deviations listed in table 3.7 below for each management variable. The overall R-squared values for the clustering procedures were 0.83904 and 0.81371 for 2011 and 2012, respectively.

Table 3.7. Means and standard deviations for each management variable by cluster.

Intensity	Number of farms	Stocking rate (fish/acre)	Aeration rate (hp/acre)	Feeding rate (pounds/acre/year)
2011 Low	18	5750 (+/- 1927)	2.6 (+/- 1.1)	8986 (+/- 2295)
2011 Medium	33	7545 (+/- 1483)	3.5 (+/-1.4)	16,448 (+/- 3270)
2011 High	2	7750 (+/- 354)	5.0 (+/-1.4)	37,315 (+/-7583)
2012 Low	15	5667 (+/- 2110)	2.5 (+/- 1.3)	7,632 (+/- 2429)
2012 Medium	36	7313 (+/- 1435)	3.5 (+/-1.4)	15,197 (+/- 2881)
2012 High	2	7500 (+/- 707)	4.5 (+/- 0.7)	28,376 (+/- 5624)

It should be noted that though proc fastclus was able to form disjoint clusters that do show significant differences in certain variables tested by ANOVA procedures below. The variables used to form these clusters were few and chosen by the researcher. When looking at enterprise budgets for farms in each cluster the variation is extreme and therefore inference past the ANOVA analyses conducted below would be questionable at best.

ANOVA procedures were conducted for net returns, breakeven price to cover total costs, and FCR by cluster for each year. For the 2011 data, only net returns returned significant differences between clusters. In the 2012 data, both net returns per acre as well as breakeven price to cover total costs showed significant differences between intensity cluster groups. Tables 3.8 and 3.9 show the results of the ANOVA procedures which returned significant results.

Table 3.8. ANOVA results for 2011 and 2012 analysis of net returns above the total costs by management clusters.

Intensity cluster	N	Mean ($/acre)	Standard deviation	f-value/p-value
2011 Low	16	$62	$2,231	18.18/<0.0001
2011 Medium	32	$1,473	$2,051	
2011 High	2	$9,489	$1,102	
2012 Low	14	-$1,612	$1,532	5.29/0.0084
2012 Medium	35	-$716	$2,445	
2012 High	2	$3,862	$2,493	

Following the ANOVA analyses, a Tukey-Kramer analysis was conducted to show that in 2011 there were significant differences in the mean of the high intensity cluster with both the low and medium intensity clusters, but no significant difference between the low and medium intensity clusters. The same holds true for the 2012 analysis. It is worth noting that there were only 2 farms in the high intensity cluster for both years; however only one of those farms was in the high intensity cluster both years. And though there are few farms producing in the high intensity level the results were still significantly different from the other clusters.

In the 2012 data, the ANOVA analysis for breakeven price to cover total costs also returned significant results with an F-statistic of 6.65, a p-value of 0.0029, and an R-squared value equal to 0.224409.

Table 3.9. Results of an ANOVA analysis of the breakeven price to cover total costs for 2012 by management intensity cluster.

Intensity cluster	N	Mean ($)	Standard deviation
Low	13	$1.60	$0.71
Medium	34	$1.10	$0.34
High	2	$0.71	$0.11

A Tukey-Kramer analysis followed the ANOVA procedure showing that the mean of the low intensity cluster was significantly higher than the mean for either the medium or high intensity clusters and that there was no significant difference between the means of the medium and high intensity clusters.

Hypotheses tests:

Below is a list restating the hypotheses of this study and the results found with each analysis. Included are other significant analyses that were conducted relating to each hypothesis though not necessarily testing the hypothesis as stated.

Ho1: Farms managed with a multiple batch production system that harvest each pond at least 3 times per year will have a higher net return than farms harvesting less frequently.

An ANOVA procedure was conducted comparing returns above total cost per acre for each year (profitability) by group (those harvesting at least 3 times per year and those harvesting less than 3 times per year). The results for 2011, 2012, and the average of the two years were non-significant. For 2011 F = 0.19, p = 0.6652, N = 45, for 2012 F = 0.82, p = 0.3694, and N = 50, and for the average of the two years F = 0.44, p = 0.5110, and N50 (see table 3.10).

Table 3.10. Summary of the results comparing net returns per acre for farms harvesting at least 3 times per year (group 1) and those harvesting less frequently (group 2).

Year	Group	N	Mean	p-value
2011	1	11	$1732.66 +/- 1038.24	0.6652
	2	34	$1349.83 +/- 2833.68	
2012	1	8	$-70.96 +/- 1327.69	0.3694
	2	42	-$927.00 +/- 2592.39	
Average	1	8	$884.17 +/- 1016.56	0.5110
	2	42	$233.82 +/- 2722.61	

Although the means of the group harvested at least 3 times per year is lower in 2011, 2012, and the average of the two years the difference between the means is not significant and therefore Ho1 cannot be accepted.

Ho2: Farms with aeration rates greater than or equal to 6 hp/ac will have a higher net return than farms with lower aeration rates.

An ANOVA analysis was conducted which compared the average net returns per acre (average of 2011 and 2012) for those farms with aeration rates at or above 6 hp/ac to those below 6 hp/ac. There was no significant difference found in the means of the two groups as shown in table 3.11.

Table 3.11. Comparison of the two year average net returns per acre for farms with aeration rates at or above 6 hp/ac (group 2) and those with aeration rates below 6 hp/ac (group 1).

Group	N	Mean profitability	p-value
1 (below 6 hp/ac)	47	$212.30 (+/- 2379.4)	0.2442
2 (at or above 6 hp/ac)	4	$1744.90 (+/- 3872.3)	

Since there is no difference between the two groups, Ho2 cannot be accepted. However, it should be noted that there were only 4 farms aerating at or above 6 hp/ac.

Ho3: Farms with higher aeration rates (per acre foot of pond water) will have a higher net return (per water acre per year) than do farms with lower aeration rates.

Ho3 is very similar to Ho2 however Ho3 considers aeration on a per acre-foot basis whereas Ho2 considers aeration on a surface acre basis. Also, Ho3 does not consider a breaking point or two aeration groups as Ho2 examines, Ho3 seeks to link a continuum of aeration rates to profitability therefore a regression analysis is appropriate for Ho3. Regression analyses were conducted for 2011 and 2012 net returns (as profitability) as well as the average for the two years. The results are presented in table 3.12 below.

Table 3.12. Results of regression analyses linking aeration on an acre-foot basis to farm profitability.

	2011	2012	Average of the two years
Intercept	82.70	-1544.86	-688.01
Aeration (hp/ac-ft)	1892.13	1162.01	1554.53
N	50	51	51
p-value	0.089	0.2349	0.1230
R-squared	0.0588	0.0287	0.479

The results are different for 2011 at a 0.1 alpha level (due to the variable nature of survey data this alpha level is appropriate) however for 2012 and the average of the two years, the results are not different even at a 0.1 level. This is understandable since in 2012 many producers were actually trying to limit production which would likely lower profitability and their aeration rates remained the same. Therefore, 2011 being the more “normal” year (though fish prices were extremely high, producers were not intentionally cutting production) it is appropriate that it be considered the more representative year allowing for a tentative acceptance of this hypothesis.

Having looked at aeration's effect on profitability by grouping farms based on their aeration on a horsepower per surface acre basis as in Ho2 and now looking at farms on a continuum in Ho3, but based on aeration on a horsepower per acre-foot basis, it seems appropriate to also conduct analyses examining the effect of aeration on a horsepower per surface acre basis on profitability without grouping farms as in Ho2. This is especially important considering that the aeration rate chosen to divide the groups in Ho2 (6 hp/ac) only allowed for 4 farms in the high aeration group. Table 3.13 shows the results of regression analyses of aeration rates (horsepower per surface acre) to farm profitability (net returns per acre) for 2011, 2012, and the average of the two years.

Table 3.13. Results of regression analyses of aeration rates (hp/ac) and farm profitability.

	2011 (+/-S.E)	2012 (+/- S.E.)	Average of the two years (+/- S.E.)
Intercept	-861.31 (923.40)	-1746.06 (847.59)	-1460.99 (846.35)
Aeration (hp/ac)	671.61 (258.47)	296.10 (238.86)	550.88 (238.51)
N	50	51	51
p-value	0.0124	0.2210	0.0252
R-squared	0.1233	0.0304	0.0982

For both 2011 and the average of the two years, aeration rates (hp/ac) did have a significant effect on the profitability of the farm. The regression equation below was generated by the 2011 analysis because of the farms limiting production in 2012 as discussed above.

Profitability = -861.30291 + 671.60653 * aeration rate (3.1)

Profitability = net returns
Aeration rate = hp/ac

Though Ho2 was not accepted and Ho3 was only accepted for the 2011 data, it is clear from these further analyses that aeration rate does significantly affect farm profitability. The higher the aeration rate the greater the farm's profitability.

Ho4: Farms stocking between 1500 and 1800 fish per acre for every one horsepower per acre of fixed paddle wheel aeration will have a higher net return than farms stocking at higher densities.

In order to test this hypothesis farms were assigned to groups based on their stocking rate (fish/acre per hp/ac of aeration) those farms stocking between 1500 and 1800 were assigned to group 1, farms above this stocking rate were assigned to group 2 and those below this target rate were assigned to group 3. ANOVA analyses were conducted for 2011, 2012, and the two year average. Though the means differed, there were no significant differences between any of the groups in any of the analyses. Therefore, Ho3 cannot be accepted (see table 3.14).

Table 3.14. Summary of the ANOVA procedures conducted analyzing the effect of stocking rate and aeration on farm profitability (net returns per acre) for 2011, 2012, and the average of the two production years.

Year	Group	N	Mean +/- standard dev.	p-value
2011	1	7	2008.36 +/- 1110.72	0.7689
2011	2	28	1158.45 +/- 2893.46	
2011	3	15	1374.00 +/- 3026.70	
2012	1	10	-606.23 +/- 3030.62	0.9345
2012	2	35	-867.90 +/- 2416.36	
2012	3	6	-574.18 +/- 1480.50	
AVERAGE	1	8	168.11 +/- 1414.10	0.3183
AVERAGE	2	37	130.27 +/- 2570.33	
AVERAGE	3	6	1798.70 +/- 3085.56	

Ho5: Farms feeding 32% protein feed have higher net returns than farms feeding lower protein feeds.

This hypothesis was analyzed in a similar way to those above; as farms only reported feeding either 28% or 32% protein feed, these were the two groups compared using ANOVA. In 2011, the means were significantly different at a 0.10 alpha level, but they were not for 2012 (see table 3.15).

Table 3.15. Results of ANOVA comparison of the profitability (net returns) of farms feeding 28% and 32% protein feed.

Year	Protein level	N	Mean +/- standard dev.	p-value
2011	28%	26	$658.75 +/- 2889.34	0.0650
2011	32%	24	$2082.41 +/- 2393.54	
2012	28%	32	-$828.16 +/- 2751.25	0.8619
2012	32%	19	-$704.36 +/- 1797.12	

This difference in significance between 2011 and 2012 is likely due to the difference in fish prices, feed prices, and significant changes in management practices (for instance every other day feeding to restrict production) that many farms used in 2012 due to the surplus of fish. It should be noted from the above table, several farms that fed 32% protein feed in 2011, changed to feeding 28% in 2012 (see the regression equation below for total production for an analysis of this management change). Ho5 can therefore be accepted as the data for 2011 when farm were feeding to maximize production showed a significant difference.

Ho6: Farms with higher aeration (per acre foot) will have higher production rates (per water acre per year) than do farms with lower aeration rates.

A regression analysis was conducted modeling an average of 2011 and 2012's production (pounds/acre) for each farm against the aeration rate on a horsepower *per acre foot* basis. The results were significant at a 0.05 level (n = 53, F = 9.12, p = 0.0039, R-squared = 0.1517). Therefore, Ho5 can be accepted. Farms with a higher aeration rate per acre foot do have higher production rates than farms with lower aeration rates. Furthermore, the same analysis was conducted using aeration on a horsepower *per surface water acre* basis and the results were also significant (n = 53, F = 16.76, p = 0.0002, R-squared = 0.2473). With the intercept being 2754.98 (S.E = 899.99) and the coefficient for the aeration term being 1043.90 (S.E. = 255.0). The following regression equation can be used to predict the effect of changes in aeration rates (hp/acre) and the effect that it will have on a farm's overall production.

$$\text{Production} = 2754.98 + 1043.90 * \text{aeration} \qquad \text{R-squared} = 0.2473 \qquad (3.2)$$

Note in this equation, production is on a per acre basis and aeration is horsepower per acre not per acre foot as the R-squared value was higher for the equation basing aeration on a horsepower per acre basis.

Whether aeration is measured on an acre-foot basis (pond volume) or on a pond surface area basis, it does have a significant effect on production, with higher aeration rates linked to higher production.

Ho7: Farms stocking less than or equal to 8000 fish per acre will have a higher net return on a per acre-year basis than farms stocking more than 8,000 fish per acre.

An ANOVA procedure was conducted testing the difference in mean net return for farms stocking greater than or equal to 8000 fish per acre and less than or equal to 8000 fish per acre. The average stocking rate and range for 2011 was 6,932 fish/acre and 3,000-12,000 fish/acre respectively, and for 2012 the average was 6,845 fish/acre with the same range as in 2011 (see table 3.3). This analysis was conducted for both 2011 and 2012, neither year had significantly different means for net return between the two groups, therefore Ho7 cannot be accepted (table 3.16).

Table 3.16. ANOVA results testing the difference in mean profitability for farms stocking no more than 8000 fish per acre (group 1) and those stocking more than 8000 fish per acre (group 2) for 2011 and 2012.

Year	Group	N	Mean +/- standard dev.	p-value
2011	1	40	$1384.09 +/- 2893.41	0.8305
2011	2	10	$1174.14 +/- 2079.36	
2012	1	42	-$759.79 +/- 2607.33	0.8889
2012	2	9	-$885.85 +/- 1328.73	

Conducting regression analyses of how stocking rates for 2011 and 2012 (not grouped as above) effect profitability also produced no statistical differences (p-values of 0.5032 and 0.2015 for 2011 and 2012, respectively). Therefore it cannot be concluded, according to this set of financial data, that stocking density has an effect on farm profitability (it should be noted here and throughout this study that in 2011 and 2012 fish and feed prices were extremely volatile reaching record highs).

Ho8: Farms that feed less than or equal to 30 pounds per acre per day for every 1 horsepower of fixed paddle wheel aeration (on a hp/ac basis) will have a higher net return per water acre per year than farms feeding over 30 pounds.

Farms were divided into two groups depending on their feeding rate per acre per day for every 1 horsepower of fixed paddlewheel aeration with group 1 feeding 30 pounds/ac/day/hp of aeration or less, and group 2 feeding over 30 pounds/ac/day/hp of aeration. Three separate ANOVA analyses were conducted testing for differences in the mean profitability between groups 1 and 2 for the data from 2011, 2012, and the two year average. The results for 2012 and the average show no significant difference between groups however the mean profitability for group 2 was higher than that for group 1 in 2011 ($2,656.44 and $927.05, respectively). Which is significant at the 0.1 alpha level. However, this is the opposite of what Ho8 predicts and therefore Ho8 cannot be accepted (see table 3.17).

Table 3.17. ANOVA results for tests of mean difference in profitability between farms feeding more than 30 pounds/ac/day for every 1 hp. of fixed paddlewheel aeration (group 2) and those feeding 30 or less pounds/ac/day/hp (group 1).

Year	Group	N	Means +/- standard dev.	p-value
2011	1	38	$927.05 +/- 2074.94	0.0550
2011	2	12	$2656.44 +/- 4036.12	
2012	1	43	-$800.24 +/-1842.16	0.9024
2012	2	8	-$684.17 +/- 4634.45	
Average	1	42	$294.49 +/- 2292.56	0.6770
Average	2	8	$706.04 +/- 3692.82	

Ho9: Farms with medium production intensity levels will have a higher propensity to adopt new technology than farms with either low or high production intensity levels.

In order to establish the propensity to adopt new technology, a coefficient of adoption was developed using questions 68, 69, and 70 from the management practice survey (appendix 3). The answers were coded in order with the first answer for each question being entered in the data set as a 1, the second as a 2 and so on. The answer from question 69 was then subtracted from the value of the sum of the answers from questions 68 and 70 producing the coefficient of adoption. Then an ANOVA analysis was conducted comparing the mean value for the coefficient of adoption by cluster for both the 2011 intensity clusters as well as the 2012 clusters. Neither the 2011 nor the 2012 returned significant results. For 2011 the F-statistic was 0.36 with a p-value of 0.7027 and for 2012 $F = 0.46$ and $p = 0.6322$. Therefore, according to this data set there is no difference in mean coefficient of adoption values based on management intensity clusters, and Ho9 cannot be accepted according to this data.

Ho10: Medium intensity farms have higher net returns per acre of water per year of production than do either low or high intensity farms.

An ANOVA procedure was conducted on net returns per acre for both 2011 and 2012 but intensity clusters (see discussion of clustering procedure above for ANOVA tables), and significant differences were found between cluster groups in both years. However, in both 2011 and 2012 the high intensity farms had higher profits per water acre than did the medium or low intensity farms. Therefore, Ho10 is not accepted.

Ho11: Farms with aeration rates greater than or equal to 6 hp/ac have lower FCR's than farms with lower aeration rates.

For this analysis farms were grouped into two groups those with aeration rates at or above 6 hp/ac and those below 6 hp/ac then an ANOVA was conducted the groups had mean FCRs of 2.28 (N = 4) and 2.34 (N = 46) respectively. However, the difference in these means was not statistically significant (p=0.7877). Therefore, according to this data Ho11 cannot be accepted. It should however be noted that there were only 4 farms participating in the study that aerated at or above 6 hp/ac.

Ho12: Farms stocking between 1500 and 1800 fish per acre for every one horsepower per acre of fixed paddle wheel aeration have lower FCR's than farms stocking at higher densities.

In order to analyze this hypothesis farms were split into two groups those with stocking densities between 1500 and 1800 fish per acre for every one horsepower per acre of fixed paddle wheel aeration, and those outside of that range. A separate ANOVA was ran for 2011, 2012, and an average of the two years. The data for 2011 and the average of the two years data returned non-significant results even at a 0.1 level (the 0.1 level is appropriate due to the imprecise nature of survey data). The ANOVA for 2012 was significant at a 0.1 level. However, the farms with stocking densities based on aeration that fell into the range of 1500-1800 actually had higher mean values than those that did not fall into that range (see table 18). Therefore, Ho12 cannot be accepted.

Table 3.18. Difference in means between groups of farms where group 1 represents farms with stocking densities between 1500 and 1800 fish per acre for every one horsepower of fixed paddlewheel aeration and group 2 represents farms outside of that range.

Year	Group	N	Mean FCR +/- standard dev.	p-value
2011	1	7	2.19 +/- 0.35	0.4340
2011	2	43	2.37 +/- 0.57	
2012	1	9	2.54 +/- 0.56	0.0917
2012	2	41	2.21 +/- 0.52	
Average	1	8	2.53 +/- 0.28	0.1554
Average	2	43	2.26 +/- 0.51	

This study has 12 different hypotheses. Table 3.19 is a summary of the hypotheses and the results of each hypotheses test. It should be noted however that the most important results of this study are in the regression analysis that follow.

Table 3.19. Summary of results of the stated hypotheses of this study.

Number	Summary of hypothesis	Accepted (yes/no)
Ho1	At least 3 harvests per year results in higher net returns	No
Ho2	Aeration rates greater than or equal to 6 hp/ac result in higher net returns	No (but very small number of observations for high aeration group
Ho3	Higher aeration rates result in higher net returns (as stated aeration was on a per acre foot basis, however analysis also considered hp/acre aeration rates as well)	Yes (especially when the analysis was conducted on a hp/ac basis)
Ho4	Stocking between 1500 and 1800 fish per water acre for every hp of fixed aeration results in higher net returns	No
Ho5	Feeding 32% protein feed results in higher net returns than lower protein feed	Yes
Ho6	Higher aeration rates result in higher production	Yes (both on a hp/ac basis as well as hp/ac-ft basis)
Ho7	Stocking no more than 8000 fish/acre results in higher net returns than higher stocking rates	No
Ho8	Feeding no more than 30 pounds per acre per day for every 1 hp of aeration per acre results in higher net returns	No
Ho9	Medium production farms have a higher propensity to adopt new technologies	No
Ho10	Medium production intensity farms have higher net returns than do either high or low intensity farms	No (high intensity farms had higher net returns)
Ho11	Aeration rates greater than or equal to 6 hp/ac have lower FCRs than farms with lower aeration rates	No (but only 4 farms were in the high aeration group)
Ho12	Stocking between 1500 and 1800 fish per acre for every 1 hp/ac of aeration results in lower FCRs than other stocking rates	No

Aside from the above described analyses for the stated hypotheses regression models were used in order to create equations predicting catfish production per acre per year and farm profitability based on management variables.

PRODUCTION MODEL:

In order to develop a regression equation for farm production in pounds per acre per year for the farm level, the above model selection methods were used for both the 2011 and 2012 data (with categorical variables with three or more categories not included). Using the 2012 data, the model selection methods showed little agreement on which variables to include in the final model and the R-squared was much lower for all the models than for the models using 2011 data (0.79 and 0.92 respectively). Also in 2012 many farms were actually trying to limit production due to an oversupply of fish and low pond bank prices which makes basing a production equation on 2012 data not logical. Therefore, the following discussion will focus on the 2011 data and regression models. It should be noted that proc reg in sas was used for the following analyses which does not allow for categorical variables with three or more categories to be included. For comparison purposes proc glmselect was used with stepwise selection in order to include the omitted categorical variables. This procedure produced a model including a single variable (amount of feed fed) with a lower R-squared than the models discussed below. As this variable was selected in the models produced from proc reg, it was decided that proc reg produced a more complete and appropriate regression model than did proc glmselect. Therefore the following results come from the proc reg analysis.

From the 2011 data three of the five methods (stepwise selection, AIC, and forward selection) produced the same regression model to explain production. The variables included in the model were: protein level of feed fed, copper sulfate used only before harvest, diuron use, and the amount of feed fed on the farm (pounds/acre/year). This model has an R-squared value of 0.9234 with the F-value, p-value and N being 111.49, <0.0001, and 42, respectively. The BIC selection method produced a model with the same variables listed above but not including protein level of feed fed. This model had an R-squared of 0.9100 and F = 148.37 p = <0.0001 N = 48. It should be noted that the model selected by the BIC procedure and the model selected by the three procedures listed above had nearly the same BIC value (598.1445 and 599.9243, respectively) therefore the model chosen by the three methods above is a close second in the BIC procedure. The backward elimination method produced the model with the fewest number of variables, only including two variables: copper sulfate used for snail control (yes/no) and amount of feed fed (pounds/acre/year). For this model the R-squared, F-value, p-value, and N were 0.7914, 72.10, <0.0001, and 41, respectively (table 3.20).

Table 3.20. Regression models produced from various model selection procedures explaining total production.

Method	Model		
Stepwise	1.	Protein level of feed	R-squared = 0.9234
	2.	Copper sulfate used only before harvest	F = 111.49 P = <0.0001
	3.	Diuron used (yes/no)	N = 42
	4.	Amount of feed fed (pounds/acre/year)	
AIC	1.	Protein level of feed	R-squared = 0.9234
	2.	Copper sulfate only used before harvest (yes/no)	F = 111.49 P = <0.0001 N = 42
	3.	Diuron used (yes/no)	
	4.	Amount of feed fed (pounds/acre/year)	
BIC	1.	Copper sulfate used only before harvest	R-squared = 0.9100 F = 148.37
	2.	Diuron used (yes/no)	P = <0.001
	3.	Amount of feed fed (pounds/acre/year)	N = 48
Forward selection	1.	Protein level of feed	R-squared = 0.9234
	2.	Copper sulfate used only before harvest	F = 111.49 P = <0.0001
	3.	Diuron used (yes/no)	N = 42
	4.	Amount of feed fed (pounds/acre/year)	
Backward elimination	1.	Copper sulfate for snail control	R-squared = 0.7914 F = 72.10
	2.	Amount of feed fed (pounds/acre/year)	P = <0.0001 N = 41

As three of the model selection methods produced the same model (and that model was a close second in the BIC procedure) the model produced by these three selection methods will be used in the following discussion. The selected model can be seen in table 3.21 and the regression equation produced follows (equation 3.3).

Table 3.21. Regression model predicting total production.

Variable	Coefficient	Standard Error	p-value
Intercept	-3524.61114	2576.22	0.1795
Protein level	123.55413	87.43	0.1659
Copper sulfate used only before harvest	-594.108	345.03	0.0934
Diuron used	-691.17768	384.13	0.0801
Total feed fed (pounds)	0.48847	0.026	<0.0001

F = 111.49 p = <0.0001 N = 42 R-squared = 0.9234

$$\text{Production} = -3524.61114 + 123.55413(P) - 594.108(C) - 691.17768(D) + 0.48847(F) \quad (3.3)$$

Where production is the total pounds of fish produced per acre per year for the entire farm. P is the level of protein used in the feed entered as a whole number (28% or 32%). It should be noted that no farm participating in the survey reported on question 33 having used higher than 32% protein or lower than 28% protein feed therefore this equation cannot be used to predict the outcome of a management change to a protein level outside the observed range. D is diuron use entered as 1 for yes and 0 for no. C is copper sulfate only used before harvest (killing algae with the result of getting fish on-flavor) entered as 1 for yes and 0 for no; and F is the total amount of feed fed in the entire year on a per acre basis entered as pounds. The standard errors for the variables included in the model above are; 87.43 for the protein variable, 345.03 for the copper sulfate variable, 384.13 for the diuron variable, and 0.026 for the total feed fed variable. Though this model does not perfectly predict the total production from a farm it does explain the majority of variation in the on-farm production (the R-squared for the entire model is 0.9234). However it should be noted that using this model to predict production from farms feeding extremely high rates per acre is dangerous as eventually other water quality factors such as dissolved oxygen and ammonia will become an issue as feed rate increases (as discussed in chapter 1). Probably the most interesting factor of this model is that of protein content in the feed.

Using as examples actual farms in the data set, the tables below show what the predicted change in production resulting from a change in protein level for four farms that span a wide range of actual pounds of fish produced per acre of water per year (actual production and amount of feed fed are data from 2011). Tables 3.22, 3.23, 3.24, and 3.25 below show how changing the protein level of the feed being fed would affect each farm's total yearly production as well as their profitability. The final two columns of the table show how the higher feed prices and lower pond bank prices paid to producers for fish sold in 2012 would affect the economic-based decision that each farm manager must make as feed prices rise and fish prices drop. The calculations in the 2012 columns were done using 2012 prices but the same feeding and production rates used for the 2011 calculations for comparison purposes (though these particular farms may have fed or produced different amounts in 2012 than they did in 2011 in actuality).

For the following examples, an assumption is made that, even with a change in protein level, the amount of feed fed (pounds/acre/year) will remain constant in order to focus on the effects of changes in protein level. As farmers often feed based on some combination of estimated fish biomass, historic records, a satiation regime, and a maximum feed cap, this assumption that feeding rates would remain fairly constant may not be too far from reality. For the purposes of this example in order to focus solely on the effects of protein level on production and profitability it is justifiable to keep the feeding rate constant.

Table 3.22. Example 1, actual, predicted, and simulated effects of changing feed protein level from 28% to 32% on farm production and profitability for a 400 acre farm producing 1,875 pounds of catfish per acre per year.

	2011 Actual[1]	2011 Predicted[2]	2012 Simulated[3]	2012 Predicted[2]
Protein level %	28	32	28	32
Copper usage	Yes	Yes	Yes	Yes
Diuron usage	Yes	Yes	Yes	Yes
Feed fed pounds/ac/year	6,000	6,000	6,000	6,000
Production pounds/ac/year				
Actual	1,875		1,875	
Predicted	1,580	2,075	1,580	2,075
Difference	295		295	
Expenses, $/acre				
Feed	$482,400	$505,200	$535,200	$562,800
Harvest and hauling	$37,500	$41,500	$37,500	$41,500
Difference		$26,800		$31,600
Sales	$877,500	$971,100	$735,000	$813,400
Price per pound	$1.17		$0.98	
Difference in sales		$93,600		$78,400
Profit or loss from change		$66,800		$46,800
Profit or loss from change/ acre		$167		$117

[1] Actual is from raw farm data

[2] Predicted uses the regression equation to predict production with a change in protein level of feed fed while keeping copper usage, diuron usage, and amount of feed fed constant.

[3] Simulated the 2011 actual values with 2012 fish and feed prices (feed prices used for the above calculations for 2011 were $0.201/pound and $0.2105/pound for 28% and 32% respectively, and for 2012; $0.223/pound and $0.2345/pound for 28% and 32% respectively).

Table 3.23. Example 2, actual, predicted, and simulated effects of changing feed protein level from 28% to 32% on farm production and profitability from a 100 acre farm producing 9,377 pounds of catfish per acre per year.

	2011 Actual[1]	2011 Predicted[2]	2012 Simulated[3]	2012 Predicted[2]
Protein level %	28	32	28	32
Copper usage	No	No	No	No
Diuron usage	Yes	Yes	Yes	Yes
Feed fed (pounds/ac/year)	20,700	20,700	20,700	20,700
Production pounds/ac/year				
Actual	9,377		9,377	
Predicted	9,355	9,849	9,355	9,849
Difference	22		22	
Expenses				
Feed	$416,070	$435,735	$461,610	$485,415
Harvest and hauling	$46,885	$49,245	$46,885	$49,245
Difference		$22,024		$26,165
Sales $/acre	$1,097,127	$1,152,333	$918,946	$965,202
Price per pound	$1.17		$0.98	
Difference in sales		$55,205		$46,265
Profit or loss from change		$33,181		$20,091
Profit or loss from change/ acre		$332		$201

[1] Actual is from raw farm data

[2] Predicted uses the regression equation to predict production with a change in protein level of feed fed while keeping copper usage, diuron usage, and amount of feed fed constant.

[3] Simulated the 2011 actual values with 2012 fish and feed prices (feed prices used for the above calculations for 2011 were $0.201/pound and $0.2105/pound for 28% and 32% respectively, and for 2012; $0.223/pound and $0.2345/pound for 28% and 32% respectively).

Table 3.24. Example 3, actual, predicted, and simulated effects of changing feed protein level from 28% to 32% on farm production and profitability from a 300 acre farm producing 5,333 pounds of catfish per acre per year.

	2011 Acutal[1]	2011 Predicted[2]	2012 Simulated[3]	2012 Predicted
Protein level %	28	32	28	32
Copper usage	No	No	No	No
Diuron usage	Yes	Yes	Yes	Yes
Feed fed (pounds/ac/year)	12,467	12,467	12,467	12,467
Production pounds/ac/year				
Actual	5,333		5,333	
Predicted	5,333	5,828	5,333	5,828
Difference	0		0	
Expenses				
Feed	$751,740	$787,270	$834,020	$877,030
Harvest and hauling	$80,000	$87,420	$80,000	$87,420
Difference		$42,950		$50,430
Sales $/acre	$1,872,000	$2,045,628	$1,568,000	$1,713,432
Price per pound	$1.17		$0.98	
Difference in sales		$173,628		$145,433
Profit or loss from change		$130,678		$95,003
Profit or loss from change/ acre		$436		$317

[1] Actual is from raw farm data

[2] Predicted uses the regression equation to predict production with a change in protein level of feed fed while keeping copper usage, diuron usage, and amount of feed fed constant.

[3] Simulated the 2011 actual values with 2012 fish and feed prices (feed prices used for the above calculations for 2011 were $0.201/pound and $0.2105/pound for 28% and 32% respectively, and for 2012; $0.223/pound and $0.2345/pound for 28% and 32% respectively).

Table 3.25. Example 4, actual, predicted, and simulated effects of changing feed protein level from 32% to 28% on farm production and profitability from a 65 acre farm producing 22,308 pounds of catfish per acre per year.

	2011 Actual[1]	2011 Predicted[2]	2012 Simulated[3]	2012 Predicted[2]
Protein level %	32	28	32	28
Copper usage	No	No	No	No
Diuron usage	No	No	No	No
Feed fed pounds/ac/year	43,077	43,077	43,077	43,077
Production pounds/ac/year				
Actual	22,308		22,308	
Production	21,471	20,977	21,434	20,977
Difference	837		874	
Expenses, $/acre				
Feed	$589,400	$562,800	$656,600	$624,400
Harvest and hauling	$72,500	$68,175	$72,500	$68,175
Difference		$-30,925		$-36,525
Sales, $/acre	$1,696,500	$1,595,301	$1,421,000	$1,336,235
Price per pound	$1.17		$0.98	
Difference in sales		-$101,199		-$84,765
Profit or loss from change		-$70,274		-$48,240
Profit or loss from change/ acre		-$1,081		-$742

[1] Actual is from raw farm data

[2] Predicted uses the regression equation to predict production with a change in protein level of feed fed while keeping copper usage, diuron usage, and amount of feed fed constant.

[3] Simulated the 2011 actual values with 2012 fish and feed prices(feed prices used for the above calculations for 2011 were $0.201/pound and $0.2105/pound for 28% and 32% respectively, and for 2012; $0.223/pound and $0.2345/pound for 28% and 32% respectively).

Net returns above all costs regression model:

Regression models predicting profit per acre were established. For this study net returns are used to represent profit though an argument could be made to use returns above variable costs as often that is what many producers are more concerned about, however it seems more appropriate to use net returns because if a farm is not covering its total costs it is not viable in the long run.

SAS proc glmselect was used with stepwise regression to attempt to fit a model to the profitability data using both categorical and continuous variables. This procedure returned a model with fairly strong R-Squared value (0.5020) but incorporating only a single variable, feed fed per acre. As it is obvious that the amount of feed fed will strongly effect farm profitability it was determined that a logistic regression would be more useful in fitting a regression model to the data. The logistic modeling procedure is not as straight forward as a simple regression model because it uses for its response variable an odds ratio. In this application the logistic model calculates the natural logarithm of the odds of a farm being profitable above a certain breaking point. A profitability breaking point of $1,000/acre was established using a 1 for farms that had at least $1,000 in net returns per acre and a 0 for those farms having less than $1,000 in net returns per acre. The same analysis was conducted but using a profitability breaking point of $0.00/acre as well. These analyses were run for the 2011 and 2012 data. All of the following discussion of logistic models will use only stepwise and forward selection model selection methods because AIC and BIC are not recognized by SAS in logistic modeling and backward selection consistently had problems with no maximum likelihood estimate making the validity of the model fit questionable. Also, it should be noted that though not necessarily common, an R-squared statistic was applied to these logistic models for comparison purposes with other models in this paper. The R-squared statistic used is actually the maximum rescaled R-squared because of the problems of fitting a traditional R-squared value to a logistic model as described in Nagelkerke (1991). Table 3.26 shows the models selected by the two methods for both 2011 and 2012 for each of the profit breaking points chosen. It should be noted that only profit greater than $1,000 per acre for 2012 is shown below because the other breaking points had too great a separation in the data putting the validity of the model in question.

Table 3.26. Logistic model variable selection using both the stepwise procedure and the forward selection methods with profit breaking points of $0.00 per acre and $1,000 per acre (for 2011 and 2012).

	Stepwise selection	Forward selection
Profit greater than $0.00 per acre, 2011	-average depth of ponds -target stocking rate -single or multiple batch -number of times per year each pond was harvested -copper sulfate used to treat disease (yes/no) -was diuron used (yes/no) -aeration rate (hp/acre) -feed fed (pounds/ac/yr) **Maximum rescaled R-squared = 0.7345**	-average depth of ponds -target stocking rate -single or multiple batch -number of times per year each pond was harvested -copper sulfate used to treat disease (yes/no) -was diuron used (yes/no) -aeration rate (hp/acre) -feed fed (pounds/ac/yr) **Maximum rescaled R-squared = 0.7345**
Profit greater than $1000 per acre, 2011	-copper sulfate used only before harvest to manage algae -aeration rate (hp/ac) **Maximum rescaled R-squared = 0.3260**	-copper sulfate used only before harvest to manage algae -aeration rate (hp/ac) -feed fed (pounds/ac/yr) -target stocking rate **Maximum rescaled R-squared = 0.4170**
Profit greater than $1000 per acre, 2012	-single or multiple batch -number of times per year each pond was harvested -was copper sulfate used on the farm (yes/no) -feed fed (pounds/ac/yr) **Maximum rescaled R-squared = 0.8252**	-single or multiple batch -number of times per year each pond was harvested -was copper sulfate used on the farm (yes/no) -feed fed (pounds/ac/yr) **Maximum rescaled R-squared = 0.8252**

As can be seen from table 3.26, there is disagreement in which variables to include in the logistic regression models for 2011 and 2012 and for the two different profit break points. The 2011 model produced for the data with a break point of $0.00 in net returns per acre has a higher rescaled R-squared value than does either model for the $1,000 per acre break point data. However with the break point at $0.00 per acre this allows for farms to be in this category and only be very nominally profitable. The $1,000 break point is more of a goal to strive for and therefore the following discussion will focus on the $1,000 break point making the results of the analysis and the tools for management change more useful to farm managers striving for a very successful farm. Comparing the stepwise model and the forward selection model for the 2011 data the forward selection model only adds additional explanatory variables to the stepwise model, it does not take any away and it has a much higher rescaled R-squared value. Therefore, the forward selection model will be used for the 2011 data. For the 2012 data the stepwise regression and forward selection agree on the variables selected to include in the model. Table 3.27 shows the model selected for each year as well as the variable coefficients which can be used to calculate an increase or decrease in the odds of a farm being having profits over $1,000 per acre per year.

Table 3.27. Variable coefficients for the 2011 and 2012 logistic regression models explaining the probability of a profit greater than $1,000 per acre.

2011 model	2011 model coefficient (+/- se)	p>Chi-sq	2012 model coefficient (+/- se)	p>Chi-sq
Intercept	-1.5019 (+/- 1.7041)	0.3781	-12.1465 (+/-5.6861)	0.0327
Target stocking rate (fish/acre)	-0.00035 (+/- 0.000236)	0.1378		
Copper sulfate used only before harvest	-1.1017 (+/- 0.7663)	0.1505		
Aeration rate (hp/ac)	0.7747 (+/- 0.5226)	0.1382		
Feed fed (pounds/ac/yr)	0.000201 (+/- 0.000129)	0.1192	0.00065 (+/- 0.000273)	0.0171
Single or multiple batch (single=1 multiple=2			5.6370 (+/- 3.2904)	0.0867
Single or multiple batch (both single and multiple =1.5 multiple only=2)			-5.1946 (+/- 2.8905)	0.0723
Number of harvests per year			2.6851 (+/- 1.1818)	0.0231
Was copper sulfate used for any use? (yes=1 no=0)			-5.9081 (+/- 3.0051)	0.0493
Maximum rescaled R-squared	0.4170		0.8252	

Given that the basic logistic regression equation regresses the explanatory variables against the natural logarithm of the ratio of the odds of success (log(probability of 1/probability of 0)) in this study the logistic regression model produces the natural logarithm of the probability of a farm having profits over $1,000 per acre divided by the probability of a farm having profits under $1,000 per acre. Therefore, in the regression models in table 3.27 above, continuous variables like aeration rate in the 2011 model can be examined by looking at the increase in the odds for a one unit change (effect of an increase of 1 hp/ac aeration on the odds of having farm profits over $1,000/acre). This effect is calculated by taking the exponent of the coefficient of the term. Therefore in the case of aeration rate:

Exp (0.7747) = 2.17

This means that holding all other factors constant the odds of a farm having profits above $1,000 per acre increase by 117% for every 1 horsepower/acre of additional aeration added.

The categorical variables in the models above can be handled in a similar fashion. Taking the exponent of the coefficient and subtracting 1 from the result gives the decimal percentage increase in the odds of having profits above $1,000 per acre for a change in category of the variable.

In the case of a variable with a negative coefficient the same holds true. For example from the 2011 model the variable "target stocking rate" has a coefficient of -0.00035 and could be interpreted in the following way:

Exp (-0.00035) = 0.99965

Meaning for every 1 unit of increase the odds of the farm in question having profitability of at least $1,000 per acre actually drop by 0.035%. Therefore, for every increase in stocking rate of 1,000 fish per acre the odds of that farm having profitability over $1,000 per acre drop by 35%. Table 3.28 shows the odds ratios (as calculated above) for all variables selected in the two models.

Table 3.28. Odds ratios for the variables included in the two selected logistic regressions.

2011 model	Odds ratio	2012 model	Odds ratio
Target stocking rate (fish/acre)	0.99965	Single or multiple batch (single=1 multiple=2	280.6196
Copper sulfate used only before harvest	0.3323	Single or multiple batch (both single and multiple =1.5 multiple only=2	0.0005546
Aeration rate (hp/ac)	2.1699	Number of harvests per year	14.6597
Feed fed (pounds/ac/yr)	1.00020102	Was copper sulfate used for any use? (yes=1 no=0)	0.00272
		Feed fed (pounds/ac/yr)	1.000650211

DISCUSSION:

The results present various ways of analyzing the data from the Best Management Practice survey, however the two common themes that seem to arise from these results is feeding higher protein feed and utilizing higher aeration rates. The literature strongly supports higher aeration rates being tied to higher production this study also shows that aeration rates are strongly tied to profit. Many farm managers are reluctant to add additional aeration to their ponds less because of the expense of buying the aeration equipment, and more due to the cost of operating the paddlewheels. However, this study clearly shows from the logistic modeling procedure above that increasing aeration rates has a strong effect on the likelihood that a farm will increase profits.

The other major variable of interest from the results of this study is that of protein level of the feed. There is great disagreement in the literature about the influence of protein level on growth factors in channel catfish. This disagreement is likely due to differences in the growing environment and feeding regimes in the different studies. This study being an industry wide management practices survey lacks precision like a controlled experiment has but the very broad industry wide approach in this case allows for results that span those individual in pond differences better than controlled studies can. By looking at the Alabama catfish industry as a whole it is more difficult to control the variation in the data set and the precision used to answer each question. However, factors like variations in natural productivity from pond to pond and feeding methods that vary from manager to manager all become part of the variance of the model. When a variable like protein content of the feed can be significant above the pond to pond and farm to farm differences it demonstrates its true importance.

This study does provide particular insight into several management practices. However, it is in the regression equations that have the power of prediction where the long term impact of this study probably lies. Having tools of prediction can be very powerful for farm managers. Using the production model, the logistic regression for profitability, or the equation predicting aeration's effect on production gives farm managers the power to know with a measure of certainty how a management decision will affect the long run profitability and viability of their farm. Being able to use the production equation, as the example above demonstrated, to show the effect on total farm production of changing from 28% protein feed to 32% protein feed (or as in the case of 2012 many farm managers decided to drop from 32% to 28% because of high feed prices) and then being able to create partial budgets for the predicted outcome of the change, as was done above, can give farm managers a way to begin to control the chaos in channel catfish production. Having a tool to predict production (and the power to budget the predicted outcome) allows farms to know with more certainty what their production from year to year will be. This is a giant step towards being able to sell fish on a contract basis to processing plants. Though there is push back from producers about contracting fish sales because of fear of losing their farm's autonomy, with time the Alabama catfish industry will likely move toward some form of contracting system which could greatly benefit the producers in the long run. Contracting is one way for producers to have assurance of being able to sell their fish to the processor and not having to hold them in on-farm inventory (and increase costs associated with producing that crop of fish as well as risk of losses from disease etc.).

The regression models developed above are powerful tools for farm managers towards the goal of increased efficiency, consistency and quality. Chapter 5 will continue the discussion of how to increase production efficiency, consistency, and quality comparing the BMPs from the literature to results from this study as well as chapters 2 and 4 in order to modify the existing BMPs or create new ones.

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Chapter 4. Pond Production Practices Causing Off-Flavor In The U.S. Catfish Industry: Linking Management To Product Quality

Abstract:

Off-flavor is one of the biggest problems in the U.S. catfish industry. Every year off-flavor cost the U.S. catfish industry between $15 and $23 million (Hanson, 2003). On the farm level when a pond is off-flavor it is not harvestable causing producers to hold fish risking increased mortalities and spending more on feed for every day that fish cannot be harvested. Processors also feel indirect economic effects of off-flavor. Despite the industries best efforts off-flavor fish occasionally reach the consumer. And probably more often than not that consumer will be lost to other alternative products after a bad off-flavor experience.

Many studies have looked at the particular chemical compounds that cause off-flavor and their sources, and have found that the most common causes of off-flavor are geosmin and 2-methylisoborneal (MIB).

This study takes a different approach pairing flavor check records from an Alabama processing plant with individual farm management practice surveys. The surveys are matched by farm with the frequency of on-flavor samples arriving at the processing plant and the management practices responsible for a greater frequency of on-flavor samples are identified. A generalized estimating equation model for predicting the

outcome of changes in certain management practices is developed and results show that increasing pond depth, alkalinity, chloride levels, and aeration rates can significantly increase the frequency of on-flavor fish.

Introduction:

Off-flavor is defined as the presence of objectionable flavors in the fishes' flesh, and is a significant problem for catfish producers because off-flavors can make fish unmarketable. Off-flavors can come from post-harvest problems such as bacterial spoilage or from pre-harvest factors (Tucker and van der Ploeg, 1999). This study will not address post-harvest off-flavor issues. Pre-harvest off-flavor problems come from either dietary sources or from chemicals in the water absorbed by the fish. The most common source of off-flavor problems in catfish (and the focus of this study is naturally occurring odorous compounds produced by microorganisms (Tucker and van der Ploeg, 1999). Off-flavors can be described in many ways such as; earthy, musty, rancid, woody, nutty, stale, moldy, metallic, painty, weedy, putrid, sewage, petroleum, and lagoon-like (Masser et al., 2005). These types of off-flavors have been documented in writing going back to at least the year 1550 (Tucker and van der Ploeg, 1999). Two specific chemical compounds have been identified to be the main source of catfish off-flavor, geosmin and 2-methylisoborneal (MIB). These compounds are produced by both blue-green algae and actinomycetes (a filamentous bacteria found both in the water column and in the bottom mud). The presence of these compounds even in minute concentrations (2-3 parts per billion) can produce off-flavor (Jensen 1997).

Many attempts have been made to reduce the concentrations of off-flavor causing cyanobacteria in catfish ponds. Research in Arkansas showed that stocking tilapia with catfish reduced the occurrence of off-flavor. However, there were problems obtaining tilapia fingerlings and controlling tilapia reproduction (Jensen 1997). Some aquaculture extension specialists recommend the use of threadfin shad and tilapia in tandem with copper sulfate and diuron treatments to continually crop the algae bloom (Jesse Chappell, personal communication, 2010). Giudice et al. (2004) showed that stocking threadfin shad with channel catfish resulted in higher density phytoplankton communities with more taxa and smaller organisms. The same study also determined from the interraker space of threadfin shad that adult threadfin could filter feed on plankton between 61 µm and 87 µm. However, in this study the percentage of the total algal population represented by blue green algae in ponds with threadfin shad and ponds without threadfin shad were not statistically different (Giudice et al. 2004). Massaut (1998) showed that the presence of gizzard shad in catfish ponds significantly reduced the blue green algae population (Massaut, 1998).

Also, research has been conducted on the manipulation of water quality parameters in order to control off-flavor. Giri and Boyd (2000) added calcium carbonate three times per week to catfish ponds and successfully reduced phytoplankton activity. This reduction in phytoplankton activity was hypothesized to be due to precipitation of soluble reactive phosphorus. However, though there was a reduction in phytoplankton activity the calcium carbonate treatment did not reduce cyanobacteria abundance (Giri and Boyd, 2000). In another study it was determined that the addition of calcium sulfate to catfish ponds decreased the concentrations of chlorophyll a which suggests less phytoplankton in ponds treated with gypsum (Seo and Boyd, 2001).

Though research has been accomplished at present the best means of controlling off-flavors comes from controlling the plankton bloom by periodic applications of copper sulfate. Tucker et al. (2001) showed that by applying weekly doses of 0.12 mg Cu/L in ponds when water temperatures were above 68°F incidence of off-flavor was reduced by 80% when compared to untreated control ponds under experimental conditions. As a follow up study in a commercial setting Schrader et al. applied weekly doses of the same concentration of copper sulfate to commercial ponds. The results showed significantly lower levels of MIB producing cyanobacterium in one of the farms. Copper sulfate treatment reduced the potential harvest delays from off-flavor by nearly half (Schrader et al. 2005).

Aside from eliminating the producers of off-flavor compounds, research has also been conducted to find ways of treating the fish or fillets post-harvest. If the fish are placed in clean water that is flushed at least two times per day the fish will eliminate the off-flavor causing compounds in 3-7 days depending on water temperature and concentration of the compounds in the flesh (Wellborn, N.D.). It is uncommon that farms have this type of holding facility, water, or time available to hold fish and wait for the off-flavor compounds to dissipate. Also, ongoing research at Auburn University shows promise in developing a wash solution to treat off-flavor fillets in order to remove or mask the off-flavor compounds.

Many studies have been conducted detailing the sources of flavor causing compounds in commercial catfish ponds; however, this study seeks to link the occurrence of off-flavor with specific management practices instead of specific sources. Pond systems are complicated and management variables are in constant flux therefore, instead of looking at specific management variables and how they affect the occurrence of undesirable flavors in catfish fillets this study looks at total farm management plans in an attempt to determine if some farm management plans are more successful in limiting the occurrence, duration, and strength of undesirable flavor episodes. Furthermore, though the most common method of understanding the problem of undesirable flavor in catfish is by examining ways to limit the occurrence of off-flavor episodes this study takes the opposite approach and analyzes farm management plans for their ability to maximize on-flavor occurrences, which is the goal of all flavor research after all. Therefore, it should be noted that though it is most common in the literature to examine this problem from an off-flavor basis all of the following analyses were conducted from the perspective of maximizing on-flavor incidence.

Hypotheses:

Ho1: Farms feeding greater than or equal to 30 pounds per acre per day for every horsepower per acre of aeration will have a lower frequency of on-flavor samples.

Ho2: Farms with aeration rates greater than or equal to 1 horsepower per acre-foot have a higher incidence of on-flavor samples.

Ho3: Farms applying either copper sulfate and/or diuron have a higher incidence of on-flavor samples.

Besides these stated hypotheses a farm level generalized estimating equation model was developed to predict the frequency of on-flavor samples. This model is the most significant result of this study giving farmers another tool for lowering the occurrence and impact of off-flavor.

Materials and Methods:

Catfish processing plants routinely check the flavor of ponds that are ready to harvest (or soon will be ready to harvest). Some processors require checking for off-flavor 2 weeks before harvest, again 3 days before harvest, and again on the day of harvest. Other processors require only that 3 flavor checks in a row show no off-flavor problems.

One Alabama catfish processor allowed access to their flavor check records for 2011 and 2012 representing a total of 20,223 flavor checks from 127 farms in Alabama, Mississippi, and Arkansas. Each check ranked the flavor of the fish from 0 to 5 with 0 being "on-flavor" and 5 being the strongest level of off-flavor. The off-flavors (levels 1-5) were also classified by type. This particular plant uses 5 off-flavor types, muddy, musty, blue green, sewer, and chemical.

These flavor records were then matched with the results from a comprehensive industry wide management practices survey that incorporated questions necessary to find the range of production practices utilized to produce catfish in Alabama. The results of the survey itself and the management implications not including off-flavor are detailed in chapter 3. The survey instrument was 70 questions and typically took about one half hour to complete.

Estimates of instrument validity and reliability were created using panel review (see appendix 4). The five members of the panel were asked to evaluate the instrument in terms of clarity and conciseness. On a scale of 1-5, 1 = low and 5 = high, the mean score for clarity was, m = 4.5 and the mean score for conciseness was m = 4.7. Reliability estimates were provided by using a Cronbach's Alpha technique. The resultant $\alpha = 0.72$ was determined to be sufficient for continuing the research project. This procedure is as described in Wiersma and Jurs, (2009).

The survey was sent to every catfish framer in Alabama which when the survey began was thought to be 95. Two weeks after the initial mailing, farms that had not replied received a reminder card in the mail. After another two weeks farms that still had not replied received a reminder letter with a second copy of the survey. This procedure follows the survey methodology established in Dillman (2007). After another three weeks had passed attempts were made to conduct the survey over the phone or in person with farms that still had not completed the survey.

At the end of the data collection period of the total 95 surveys sent out, 68 farms had participated (71.6% participation). Of those 68 surveys returned, 11 farms did not produce food size catfish to be sold to a processing plant in 2011 or 2012 making those farms ineligible for the study (these farms were mostly out of business or fee fishing operations). There were also 2 farms that were ineligible because of one being a new farm and one under a new manager that did not have data from the previous years. In the case of four farms from the original survey mailing list two of the farms were actually divisions of larger farms under the same manager therefore it was determined that the four farms were in actuality only 2 farms. These modifications to the original list of 95 farms results in a list of farms eligible for participation in the survey project numbering only 80. Of those 80 potential participants, 53 farms returned usable data (66.3%). Of those 53 farms, 20 had flavor check records with the processing plant in 2011 and/or 2012. Those 20 farms totaled 11,456 flavor checks in the two years.

The summary data below detailing industry wide off-flavor issues used all 20,223 flavor checks spanning farms from Alabama, Mississippi, and Arkansas. However, the results linking off-flavor to management practices use only the 11,456 flavor checks from the 20 Alabama farms in the survey project detailed in chapter 3.

As the flavor check data was obtained from real world processing plant records and the frequency of checks was not controlled by the researcher, there was high variation in sampling frequency between farms due to the number of ponds per farm as well as the farm manager's personal preference. Some managers wait several weeks before sending subsequent samples when a pond is strongly off-flavor others continue to send samples after only a few days. This variation causes an analysis problem which was solved by determining the frequency of on-flavor samples for each farm per month. This frequency was then divided by the total number of flavor checks conducted per month for each farm giving a ratio of on-flavor samples by farm per month. Then an arcsine square root transformation was performed on the ratio of on-flavor samples in order for the data to fit a normal distribution (no upper and lower limits as with the ratio). Then a farm specific generalized estimating equation (GEE) model with Gaussian response distribution and an autoregressive of order 1 (AR 1) working correlation structure was fit as described in Liang and Zeger (1986). For a more detailed description of statistical methods used see appendix 1.

Results:

Over the two year period (2011-2012) only 55.3% of all flavor checks were on-flavor. Also, of the flavor checks that were not on-flavor relatively few had low strengths of off-flavor (1 or 2). Of samples that were off-flavor, 83.5% of them were in strength categories 3, 4, and 5, with the most frequent type of off-flavor being "musty". Tables 4.1 and 4.2 below show a summary of the 20,223 flavor checks spanning 127 farms in Alabama, Mississippi, and Arkansas from 2011 and 2012.

Table 4.1 Frequency of off-flavor strengths from January 2011 through December 2012.

Strength	Frequency	Percent of total
0	11,187	55.3
1	164	0.8
2	1,328	6.6
3	4,523	22.4
4	1,650	8.2
5	1,355	6.7
Total	20,207	100

Note the total number of flavor checks shown in this table is less than the 20,223 stated above because some individual checks only recorded a type of off-flavor not the strength.

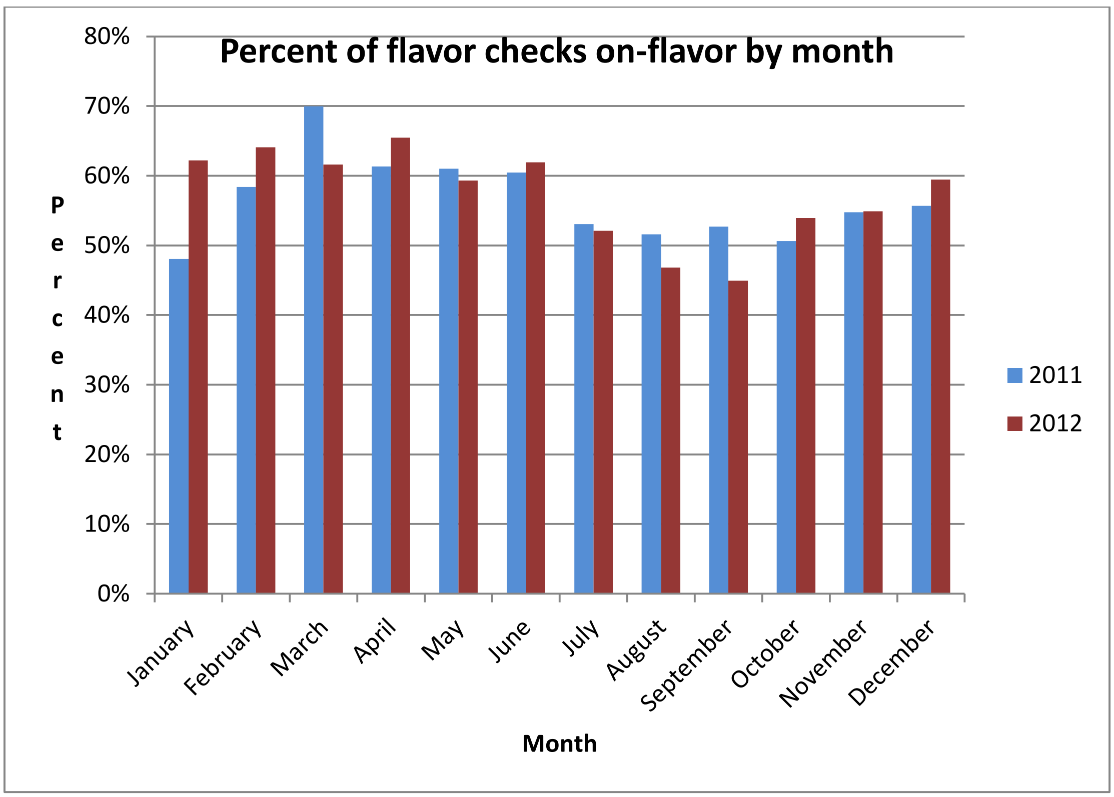
Table 4.2 Frequency of off-flavor types from January 2011 through December 2012.

Type of off-flavor	Frequency	Percent of total
Sewer	1,520	7.6
Blue green	554	2.8
Musty	5,444	27.2
Chemical	23	0.1
Muddy	1,287	6.4
Total	8,828	44.1

Note the percent of total column does not total 44.7 as table 4.1 indicates because some individual checks recorded a level of off-flavor but not a type.

Figure 4.1 illustrates the monthly trends in flavor samples and, as one would expect, the percent of samples "on-flavor" is lowest in the warmest months (July and August). The percent of on-flavor samples decline fairly sharply from June to July and rebounds slowly through the winter peaking in February, March, and April.

Figure 4.1. Monthly trend of flavor samples "on-flavor" for 2011 and 2012.



This decrease in on-flavor samples seems to begin with a spike in what the processing plant classes as "blue green" flavor which begins to peak in June and July then "musty" in July, August, September, and October. Figures 4.2 and 4.3 below illustrate the rise and fall of the off-flavor types on a yearly cycle.

Figure 4.2. Types of off-flavor by month for 2011.

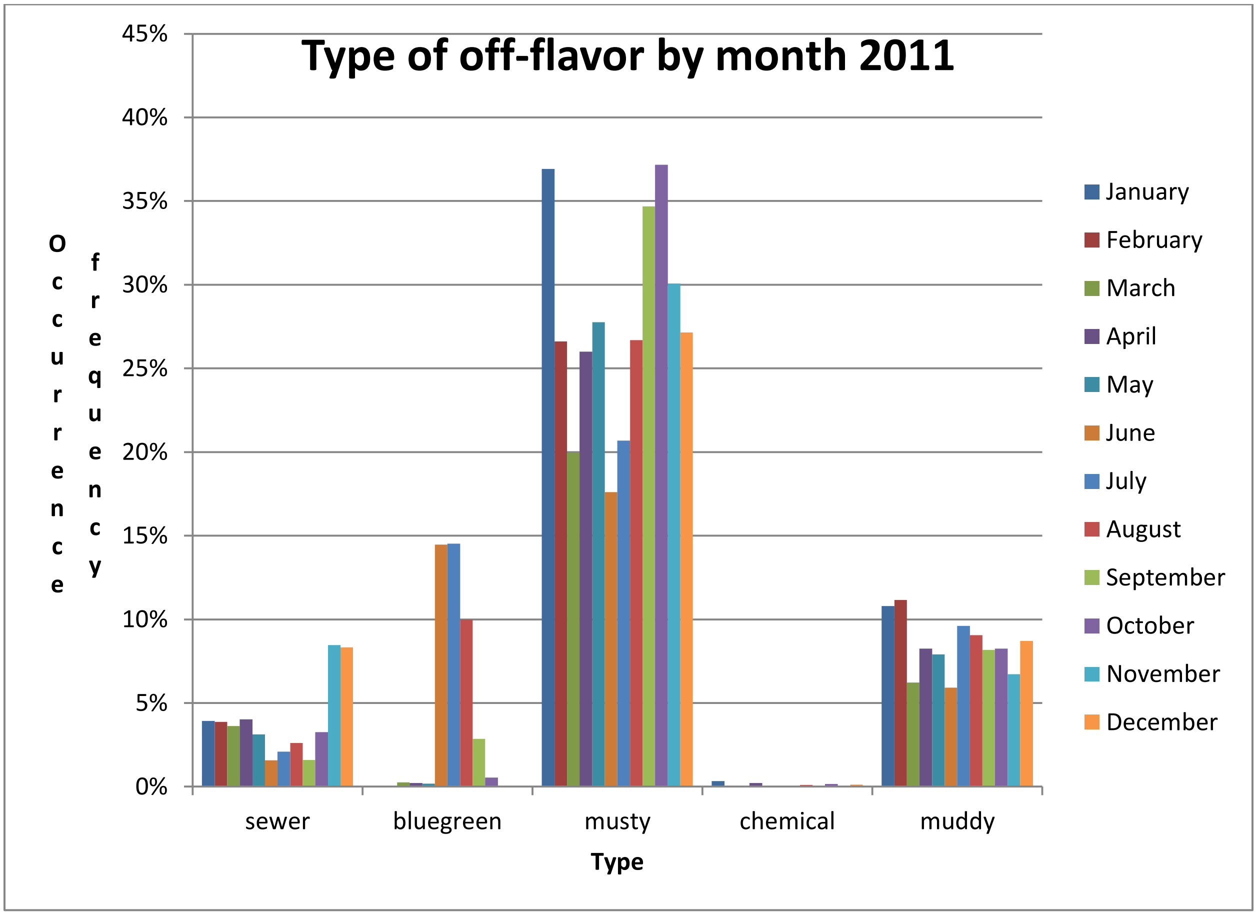
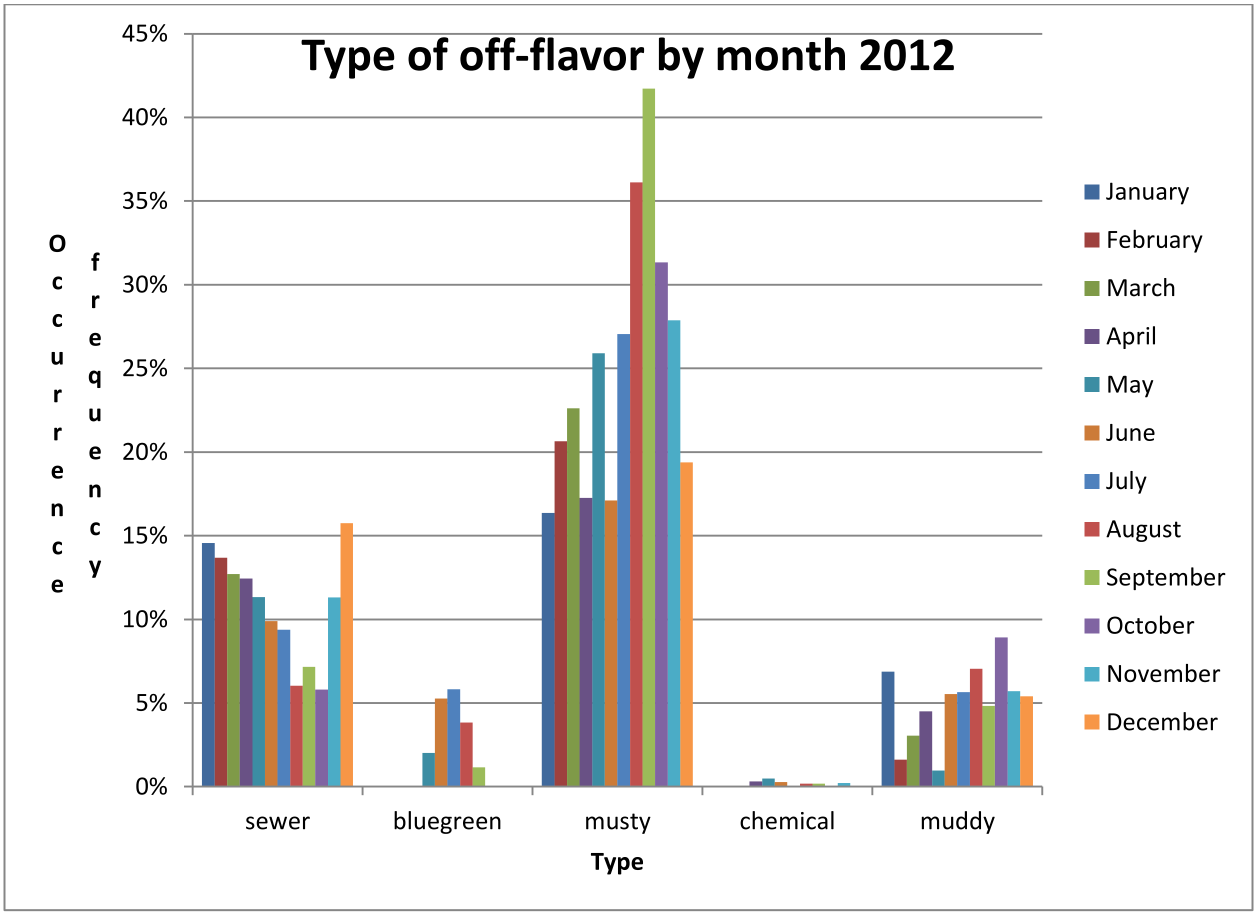


Figure 4.3. Types of off-flavor by month for 2012.



Having seen the scope and type of off-flavor issues that the industry as a whole is dealing with, the focus of the results will turn to management practices that can help reduce the occurrence of off-flavors in catfish ponds. As noted above the following hypotheses are tested using only a subset of the entire off-flavor data set summarized above. The following results come from 20 farms in Alabama that participated in the management practice survey detailed in chapter 3, and also had sent samples to the participating processing plant in 2011 or 2012. These 20 farms had 11,456 flavor checks done at this particular processing plant in 2011 and 2012.

Ho1: Farms feeding greater than or equal to 30 pounds per acre per day for every horsepower per acre of aeration will have a lower frequency of on-flavor samples.

In order to test Ho1 farms were divided into two groups. Group 1 represents those farms feeding greater than or equal to 30 pounds/acre/day/hp of aeration, and group 2 represents those farms feeding under 30 pounds/acre/day/hp of aeration. An ANOVA was then conducted comparing the mean frequency of on-flavor samples by group. Flavor checks were entered as the ratio of on-flavor samples to the total number of checks by farm by month. The means for groups 1 and 2 were 0.65 (N = 58) and 0.62 (N = 181), respectively. The slight difference in means between groups was not statistically significant ($p = 0.4347$). Therefore, Ho1 cannot be accepted. As confirmation that Ho1 should not be accepted in the generalized estimating equation model discussed below, aeration rate was included in the model (and statistically significant) however feeding rate (pounds/acre) was not included because it was found to not be statistically significant.

Ho2: Farms with aeration rates greater than or equal to 1 horsepower per acre foot have higher incidence of on-flavor samples.

Farms were divided into two groups those with aeration rates greater than or equal to 1 hp/ac-ft, and those aerating at lower rates. An ANOVA was conducted to examine the mean of the frequencies of on-flavor samples for the two groups. Data from 2011 and 2012 was pooled as the survey did not record a different aeration rate for 2011 and 2012. The ratio of on-flavor samples to total checks by farm by month was used as individual observations in the ANOVA procedure. It should be noted that only one farm with flavor check data reported aeration rates over 1 hp/ac-foot. However, even with the low N observed for the high aeration group the results were still statistically significant. The high aeration group had a mean on-flavor ratio of 0.831 (N = 18) and the low aeration group had a mean on-flavor ratio of 0.617 (N = 225) ($p = 0.0007$). Though there was only one farm in the high aeration group a ratio of on-flavor to total flavor samples was calculated monthly over the two year period. Therefore, there could be a maximum of 24 observations for the one farm. So, the concern of a single farm is not an issue because of repeated measures. This is confirmed by the generalized estimating equation explanatory model (see below). Therefore, given the ANOVA above (supported by the GEE model explained in table 4.1) Ho2 can be accepted. Farms with aeration rates at or above 1 hp/ac-ft have a higher incidence of the preferred on-flavor samples.

Ho3: Farms applying either copper sulfate and/or diuron have a higher incidence of on-flavor samples.

Farms were grouped into those using copper sulfate and/or diuron and those not using copper sulfate or diuron in order to conduct an ANOVA analysis using the ratio of on-flavor samples to total number of checks per month as observations. The data for 2011 and 2012 were analyzed separately as one farm used copper and diuron in 2011 and did not in 2012. The results of the ANOVA analyses for both 2011 and 2012 showed no significant difference in means between farms that did use copper or diuron (group 1) and those that did not (group 2). The means for 2011 and 2012 were as follows group 1 mean = 0.6198, 0.6248 group 2 mean = 0.6638, 0.6998 for 2011 and 2012, respectively. The associated p values were 0.6139 and 0.1574 for 2011 and 2012, respectively. Therefore, Ho3 cannot be accepted.

It is well established in the literature that using copper and diuron to control algae decreases the likelihood of off-flavor episodes. However, these data did not return significant results likely due to the variability of the survey data and small sample size paired with the extreme variation in flavor sampling frequency from farm to farm described above.

Explanatory model:

Aside from the stated hypotheses a model to explain the occurrence of off-flavor (or the likelihood of on-flavor samples) was constructed. As described in the materials and methods section above due to the variation in sampling frequency from farm to farm standard regression models and model selection procedures (like stepwise selection and BIC) are not appropriate. Therefore, the data were analyzed by farm on a monthly basis using the ratio of on-flavor samples to total checks for each farm per month as the predictor of flavor. This ratio was then transformed using the arcsin transformation. Then a farm specific generalized estimating equation (GEE) model with Gaussian response distribution and an autoregressive of order 1 (AR 1) working correlation structure was fit. Variables for this model had to be hand selected one by one adding or removing variables that were not significant, those which presented problems of missing data points, or correlation among explanatory variables. The selection was performed on the 2011 data and then the selected variables were used with both the 2011 data as well as the 2012 data. However, the 2012 data only returned significant results with one of the selected variables (aeration rate) therefore the following discussion will use the 2011 flavor check data for model development and prediction purposes. Table 4.3 below shows the results of the GEE model.

Table 4.3 Results of the GEE model forming an equation capable of predicting the outcome of a management change on the incidence ratio of on-flavor samples to total flavor checks.

Parameter	Estimate	S.E.	95% Confidence limit	p-value
Intercept	-0.0491	0.1917	-0.4249 to 0.3266	0.7977
Depth of ponds (D)	0.0739	0.0216	0.0316 to 0.1161	0.0006
Alkalinity (A)	0.0032	0.0012	0.0007 to 0.0056	0.0105
Chloride level (C)	0.0003	0.000	0.0002 to 0.0003	<0.0001
Aeration rate (hp/ac) (R)	0.0590	0.0102	0.0390 to 0.0791	<0.0001

The results from table 4.1 produce the following model predicting the percent of flavor checks that will be on-flavor.

$$P = 100 * \sin^2(-0.0491 + 0.0739 * D + 0.0032 * A + 0.0003 * C + 0.0590 * R) \qquad (4.1)$$

Where:
P = percent of checks that are on-flavor (number of on-flavor checks/total number of checks)
D = depth of ponds (feet)
A = alkalinity (ppm)
C = chloride level (ppm)
R = aeration rate (hp/ac)

Using this equation to predict the outcome of management changes is a powerful tool for producers. Using this type of model the SAS proc genmod procedure does not produce an R-squared value. However, the 95% confidence limits demonstrate the variation in the parameters. Though the confidence limits are fairly wide, all of the management variables included in the model are significant at the 0.05 level. Additionally, no lower confidence limit for any variable reaches zero or negative values.

In this type of analysis a negative sign on the coefficient would indicate a lowering of the on-flavor percentage; and the opposite for positive coefficient signs. Though there are other variables that undoubtedly influence the incidence of off-flavor (specifically use of copper sulfate and diuron) this model does provide insight into two fairly easily manipulated management variables that could have a significant effect on the incidence of off-flavor from a farm, specifically alkalinity and aeration rate.

Using the statewide averages from the BMP survey (Chapter 3) for each of the variables in equation 4.1 (D = 5.3, A = 114, C = 144, and R = 3.25) it is predicted that 65% of flavor checks will be on-flavor (which is actually 9% higher than the industry wide average). If a farm were operating with statewide averages for the management variables in equation 4.1 and increased aeration from 3.25 hp/ac to 6 hp/ac, 15% more of their flavor checks would be on-flavor (for a total of 80% on-flavor). Similarly if sodium bicarbonate were applied raising the alkalinity of the pond to 180 ppm (the maximum observed in the data set) the equation predicts that 19% more flavor checks would be on-flavor (for a total of 84% on-flavor). And if aeration rates were increased to 6 hp/ac and alkalinity increased to 180 ppm 29% more checks would be on-flavor (for a total of 94% on-flavor). It should be noted again that the 95% confidence limits for these parameters are fairly wide and there are other factors that come into play when looking at off-flavor episodes. However, even the lower confidence limits show improvement in on-flavor incidence with the above management changes.

The example above suggests increasing alkalinity to 180 ppm because that is the highest observed level in the data set. Though this equation has the power to predict within the observed range extrapolating outside of the observed range is not justifiable. Agricultural lime is the additive normally used in the U.S. catfish industry to raise alkalinity. However, agricultural lime normally does not dissolve in waters with alkalinities higher than 80-100 mg/L due to equilibrium concentrations of carbon dioxide Boyd, 2002). Therefore, in order to increase alkalinity to such high levels sodium bicarbonate is the preferred chemical additive. When sodium bicarbonate is dissolved in water 84 mg of sodium bicarbonate is equivalent to 50 mg of calcium carbonate. Therefore, to raise the alkalinity of a pond that is 10 surface acres with an average depth of 5 feet (61,674,450 liters of water) from the state average alkalinity of 114 mg/L to 180 mg/L, 15,076 pounds of sodium bicarbonate would be necessary (assuming little to no binding with the soil occurs which given the soil conditions of most catfish ponds in West Alabama is not an unreasonable assumption). The current sodium bicarbonate price is $1,342/ton plus $500 for shipping for a total of $1,842 per ton (SoapGoods website, 2013). So to raise the alkalinity of the pond described above would cost $13,885 (or $1,388.50 per surface acre). Therefore the cost is likely a limiting factor in raising the alkalinity to 180 ppm. However, the concept of higher alkalinity increasing the percent of on-flavor samples is a valid one, and each individual farm must decide what alkalinity level is economically feasible. For example increasing alkalinity by 30% above the state wide average (to 148 ppm) would cost $715.30/acre (using the calculations described above). If a farm were producing 10,000 pounds of catfish per acre (which is feasible especially in intensive production systems), raising the alkalinity of the pond described above would represent a $0.072/pound increase in production costs. However, it would also result in a predicted increase in 10% of flavor samples being on-flavor. This increase of 10% (from 65% to 75%) could be economically significant making the increased costs justifiable when combined with the economic benefits of single batch production. Also if a system of merit-based marketing were to be implemented processors may be willing to pay farms with high on-flavor percentages a premium for their fish which would help to off-set the cost of this management change (see Chapter 6 for a discussion of merit-based marketing). As noted above aeration is also an easily manipulated variable that can significantly increase on-flavor percentage, and the economic implications should be considered. Table 4.4 below shows the predicted impact on flavor of various management changes as well as comments on their real world feasibility.

Table 4.4 Predicted impact of management changes on flavor of catfish fillets.

Variable	AL average	Management change	Predicted effect	Comments
Pond depth (feet)	5.3	Increase by 1 foot	+ 7%	Difficult and costly to change except when conducting pond renovations for other purposes
Alkalinity (ppm)	114	Increase by 30% to 148	+ 10%	Potentially limited by cost, however merit-based marketing could provide producer/processor cost sharing incentives
Chloride (ppm)	144	Increase by 30% to 187	+ 1%	Very little change for the investment
Aeration rate (hp/acre)	3.25	Increase to 6	+ 15%	Cost effective means of manipulating on-flavor percentage
Total predicted on-flavor	65%	Cumulative effect of all changes	+ 28%	Cumulative effect resulting in an increased on-flavor percentage from 65% to 93%

Discussion:

As stated above over the two year period (2011-2012) only 55.3% of all flavor checks were on-flavor. Meaning that approximately half of the time that producers have fish ready for market they must wait to harvest them because of flavor issues. This is a huge strain on the industry in several ways. For producers it means longer times between harvests causing cash flow problems, increased risk of mortalities due to disease, increased feed expenses for holding fish a longer period of time, and lower FCRs as fish reach larger sizes and grow less efficiently.

Engle and Pounds found that for every 25% reduction in off-flavor incidence annual net returns of a given farm would increase by 1-3% (Engle and Pounds, 1993). Also, Engle et al. (1995) found that if a farm were to consider a purging system to eliminate off-flavor problems when considering the increased costs caused by off-flavor as well as inventory management problems and cash flow issues a purging system could cost as much as $0.11/pound of fish produced and still be economically feasible (Engle et al., 1995). Furthermore, Engle and Pounds (1993) also found multiple batch stocking returned much lower profits than single batch stocking systems.

The main reason that producers use multiple batch stocking is off-flavor problems. Given that both of these studies demonstrated significantly higher economic returns for reducing off-flavor at 1990's feed prices, in today's market where feed is much more costly holding fish longer would hurt farmer profits even more. Also, for processors, the frequency of off-flavor samples makes planning harvests to fill orders and keeping the processing plant running at optimal efficiencies difficult. When considering the cost to implement management changes in order to have a higher incidence of on-flavor fish these economic benefits of single batch production should offset a large portion of the cost of increased aeration as well as the addition of sodium bicarbonate to ponds. Furthermore, the merit-based marketing system discussed in Chapter 5 rewards premiums to farms producing fish with a narrow size range as would be possible in a single batch system (if off-flavor was not a problem) which would further off set the additional costs.

Equation 4.1 does not include all of the factors effecting off-flavor in catfish production. It is obvious from the literature that applications of aquatic herbicides (especially copper sulfate and diuron) can have a significant positive impact in lessening the frequency and duration of off-flavor episodes. However, due to the nature of the survey data, wording of the questions, and issues of correlation among variables copper sulfate and diuron use were not retained in the final Generalized Estimating Equation Model (GEE model). Though copper and diuron do have positive effects in controlling algae, and therefore off-flavor in fish, their being left out of the model does not make the model developed in this study any less powerful. Knowing that copper sulfate and diuron can help control off-flavor from the literature paired with the model developed in this study gives producers a very powerful management tool.

The GEE model developed above gives four variables that have the power to greatly increase the occurrence of on-flavor samples. The variable "pond depth" is one that is not easily changed, and the variable “chloride level” did not have a strong effect on the frequency of on-flavor samples. However, the variables “alkalinity” and “aeration rate” both had easily manipulated effects on the frequency of on-flavor samples. A farm manager can use the equation developed to predict how adding another paddlewheel aerator per pond would increase the likelihood of on-flavor samples. Also, though alkalinity is easily manipulated it has become uncommon in the West Alabama catfish industry because most of the remaining fish farms have alkalinities above 80 ppm. However, according to this data it could be very beneficial for producers to consider applying lime (or sodium bicarbonate) to raise their pond water alkalinities even higher to increase the percent of samples that are on-flavor so that harvests are not delayed as often whereby reducing the costs and risk to every crop of fish produced.

The model developed in this study is a powerful tool for farm managers to predict the effect of management changes to their on-flavor frequency. Increasing aeration rates and alkalinity levels can significantly increase the likelihood of keeping fish on-flavor as well as the benefits of higher aeration to increase production and profitability discussed in Chapter 3.

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Chapter 5. Discussion, Industry Implications, and A Road Map Forward

Introduction

The title of this dissertation “Best Management Practices for West Alabama Catfish Production: Creating Profitability Through Efficiency, Consistency, and Quality” describes the objective of chapter 5. This chapter will begin by comparing the existing BMPs from the literature reviewed (predominately in chapter 1) with the findings from the studies detailed in the previous chapters (2, 3, and 4) in order to update, revise, and/or confirm best management practices (BMPs) for growing catfish. It is more important now than ever that the U.S. farm raised catfish industry have a solid set of best management practices that detail the most efficient and economically viable ways of producing a consistently high quality product in order to compete with the many other options available to consumers.

After the discussion of best management practices in this chapter, a plan for marketing catfish on a merit-based pricing system is outlined in Chapter 6. The merit-based pricing model is a way of linking the BMPs to economics in order to help drive the industry forward toward higher product quality and better product consistency by providing an economically feasible (from the processing standpoint) means of rewarding producers that consistently grow a high quality product. The merit-based pricing system will also re- tool the current industry structure making farm management practices (BMPs) economically tied to producing what the consumer demands instead of looking for ways to sell what is produced.

Discussion:

A. Single versus multiple batch systems.

The first issue to address when considering the BMPs for growing catfish is that of production systems. The two basic production systems in place in catfish farming are single and multiple batch. In a single batch system only one year class of fish is produced in any single pond at a time, and in a multiple batch system fingerlings are under stocked one or more times per year and large fish are partially harvested by using a large mesh seine. This cycle continues for years without completely harvesting the pond resulting in a pond with many size classes present at any one time. Peer reviewed and extension literature agree that single batch systems are more efficient and more profitable (Engle and Pounds, 1993 and Tucker and van der Ploeg, 1999). However, because of off-flavor problems most producers use a multiple batch system so that there are harvestable size fish in most ponds at any time in order to maintain cash flow in the case of an off-flavor problem in one or more ponds. This practice may help with the cash flow problem but it causes many other issues and does not even begin to correct the root of the cash flow issue; off-flavor.

Use of multiple batch systems can create a wide size range of fish in most harvests. Size distribution at harvest is one of the biggest problems for processors. In order to efficiently run a processing plant management must know what quantity of each size category of fish they will receive and not have to deal with a wide range of size classes from each harvest. Furthermore, the size of fish harvested should be driven by consumer demand for certain size fillets not by what size range the seine crew happened to catch. Growing catfish in a multiple batch system immediately creates the need to market fish that are outside of the size range that consumers demand making the U.S. farm raised catfish inconsistent with consumer demand. Furthermore, the results from chapter 2 (yellow fillet) show that the more size classes in a pond at any one time the higher the occurrence of yellow fillet will likely be.

Therefore, multiple batch production of catfish hurts the producers economically from less efficient FCRs, likely lower survival, and from the processor view a wide size distribution and yellow pigmented fillets. This can affect the industry as a whole through lost market share due to the need to sell fillets either larger or smaller than most consumers demand. Also, the increased yellow pigment in fillets may result in consumer's refusal to buy U.S. farm raised catfish. Therefore, the solution to the on farm cash flow issues caused by off-flavor is not to use multiple batch production systems, it is to reduce the occurrence of off-flavor which will be discussed later in this chapter.

It should be noted here that though very little has been said to this point about intensive forms of production, especially the in pond raceway system (IPRS). By placing several IPRS production cells in a single pond such systems allow for inventory control, separation of size classes, and complete harvesting, giving the benefits of a single batch system with the cash flow benefits of a multiple batch system. Also, Brown et al. (2010) demonstrated production efficiency using the IPRS.

Given the benefits of single batch production systems explained earlier as well as the benefits outlined in this study, it is clear that catfish ponds should be operated using a single batch production system (or using some form of intensive production system (e.g. IPRS). Both separate size classes and allow complete harvests. The problems caused by off-flavor in single batch systems should be dealt with by controlling off-flavor not by switching production system. ***Therefore, the first BMP clarified by this study is that catfish should be produced using a single batch production system (or intensive production system like IPRS).*** It should be noted that the other management practices discussed in this chapter largely can be applied in similar ways to single or multiple batch systems even though it is the recommendation of this study that single batch production be used.

B. Feed protein level

The next management variable that the results of the above studies can significantly speak to is feed protein level. There are wide ranges of recommendations in the literature of what is the most appropriate protein level to feed pond raised catfish. Just examining total catfish production (not considering FCR, fillet yield, and profitability) usage recommendations from the literature range from 24% to 36% protein. The BMP survey study described in chapter 3 did not have any farms that reported consistently feeding any protein level other than 28% or 32% therefore no assumptions can be made about protein levels outside of this range. However, protein level was significantly linked to profitability (in the 2011 data, $p \leq 0.10$), and also one of the variables selected for the final production model. Therefore, when looking at statewide averages across farms in Alabama feeding 32% protein feed not only had a significant positive affect on production it also positively affected net farm returns. ***A second BMP clarified from this study is that 32% protein feed should be fed to increase production and profits.***

C. Winter feeding

Also, related to feeding practices in the literature one study recommends to not feed from December through February (Hatch et al. 1998a). Whereas, Bosworth (2012) found that feeding 2% of initial body weight twice per week through the winter months improved growth and fillet yield. Chapter 2 of this dissertation found that in order to significantly reduce the occurrence of yellow fillet fish should be left off feed before harvest as short of a time as possible. Therefore, if fish are to be harvested in winter or spring at least a once per week feeding regime should be maintained and when combined with the increased fillet yields found in the Bosworth study maintaining a twice weekly feeding regime throughout the winter is a best management practice. ***Therefore, the third BMP clarified in this study is in order to reduce yellow fillet and increase fillet yields maintain <u>at least</u> once per week feeding and preferably twice per week feeding (especially during warm weeks) throughout the winter.***

D. Alkalinity

The next best management practice that needs to be revised according to the data from this study is Alkalinity levels. Tucker and Hargreaves (2004) stated that alkalinity is typically considered to be adequate if it is above 20-30 mg/l. In the BMP survey it was found that Alabama's average alkalinity in catfish ponds is 114 ppm. When combined with the off-flavor data in Chapter 4, alkalinity was one of the variables included in the final equation for predicting the frequency of on-flavor samples. Higher alkalinities result in more frequent on-flavor samples. The information from Chapter 4 of this study does not show if there is an upper limit for the increased on-flavor percentage as affected by alkalinity rates (though the highest observed value in the Chapter 4 data was 180 ppm). However it does appear that higher alkalinities significantly increase the chances of keeping fish on-flavor. Also, Chapter 2 shows that alkalinity is negatively correlated with the occurrence of yellow fillet, meaning that the higher the alkalinity the less yellow fillet. Therefore not only do higher alkalinity levels lower the occurrence of off-flavor they also lower the occurrence of yellow fillet.

Given that the state average for alkalinity is 114 ppm and that higher alkalinity rates result in less off-flavor, ***the BMP for alkalinity should be modified toward maintaining alkalinity levels above 115 ppm.*** Furthermore, controlled studies should be done to examine the effects of high alkalinity (150-200 ppm) on the prevalence of off-flavor causing compounds. After controlled studies, this BMP could potentially change to even higher alkalinity rates.

E. Aeration

From this study aeration rates are another best management practice that needs to be updated especially in the extension literature. Older extension literature suggests 1-1.5 hp/ac (Jensen, 1997). Even more recent extension publications recommend a low level of aeration (2-2.5 hp/ac) (Masser et al., 2005). However in the best management practice study above, higher aeration rates significantly affected production and net returns. The current state average is 3.25 hp/ac. The results of the off-flavor study from chapter 4 show that higher aeration rates result in more flavor checks being on-flavor. One farm with extremely high aeration rates (9 hp/ac) even without a regular copper or diuron application program (which is considered to be the most effective and commonly practiced off-flavor control program) still achieved on-flavor samples 83.1% of the time as compared to the industry average of 55.3%.

Furthermore, though not included in the final regression model explaining yellow fillet aeration rates were significantly (negatively) correlated to the presence of yellow fillet. ***Given these strong ties to higher production, higher profits, less off-flavor, and less yellow fillet the more aggressive aeration rates of 6 hp/ac and above should be adopted as a best management practice.***

Table 5.1. Summary of BMPs from the literature and modifications or confirmations of those BMPs by the data in this study, as well as statewide averages showing compliance (or lack of compliance) to BMPs.

Management variable	State average value	BMP from the literature	Recommended modification to BMP from this study
Production system			
Single batch	9.6%	Single is more efficient and profitable	Single batch is by far the better system
Multiple batch	61.5% 28.8% use a combination of single and multiple	Multiple helps deal with the off-flavor problems	Multiple batch systems cause more problems than it solves
Stocking rate (fish/acre)	6,889	6000-7000	N/A
Size of fingerlings (inch)	6.2	6-9	N/A
Aeration (dissolved oxygen level)	3.25	4 ppm or more maintained by at least 3 hp/ac	At least 6 hp/ac if not more
Carbon dioxide	N/A	Less than 20 ppm, addressed with proper aeration and alkalinity	N/A
Ph	N/A	6 to 9.5, maintain proper alkalinity	N/A
Alkalinity (ppm)	114	At least 20-30 ppm possibly better to maintain 80 ppm	At least 115 ppm if not more
Hardness (ppm)	N/A	20 ppm or higher	N/A
Un-ionized ammonia	N/A	Less than 0.05 ppm	N/A
Nitrite	N/A	Less than 0.05 ppm	N/A

Table 5.1 Continued.

Management variable	State average value	BMP from the literature	Recommended modification to BMP from this study
Algae control		Copper or diuron applied weekly	Copper or diuron applied weekly
Copper sulfate usage	40% use regular low dose	0.12 mg Cu/L weekly application	Half maximum dose calculated as follows ((alk/100) X 2.7 X 0.5)
Diuron usage	55% use regular low dose 28% do not apply Cu or diuron on a regular basis	0.01 mg/L	N/A
Threadfin shad usage	70% with threadfin present in their ponds	Stock at a rate of approx. 700/acre	Threadfin shad increase yellow fillet. Use other filter feeders that will not be forage for catfish
Feed protein level			
2011		Unclear in literature Range 24%-36%	32%
28%	51%		
32%	49%		
2012			
28%	62%		
32%	38%		
Winter feeding	Not at all=15% >1X/week=0% 1X/week=40% 2X/month=17 % 1X/month=4% Other=25%	Disagreement in the literature ranging from no feed Dec.-Feb. to twice per week feeding throughout the winter	Feed at least once per week to reduce the incidence of yellow fillet in winter and spring Twice per week feeding has support in the literature
Days off feed before harvest	N/A	At least 1 day off feed	At least 1 day never more than 7

Using the best management practices from the literature from chapter 1, and modified in the discussion in this chapter as shown in table 5.1. The Alabama catfish industry can begin to produce catfish more efficiently, and profitably all the while producing a consistently high quality product. Using the prediction equations developed in the previous chapters farm managers can begin to predict the outcome of management changes.

The following chapter is an outline of a framework for selling catfish under a merit-based pricing system which would encourage producers, through price incentives, to make the management changes discussed above with the result of a product that the processors need and the consumers demand.

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Chapter 6: Merit-based Marketing: Incentive For Change

Abstract:

The goal of a merit-based pricing system is increased product quality and consistency as well as increased profitability for all levels of the industry meeting product quality goals. Yield grade or merit-based pricing can be defined simply as selling a product in a system where the price is based on the quality of the product. Selling agricultural products with the price tied to the quality of the product is not a new idea. In many livestock industries terminal sales of animals with prices based on carcass merit is commonly practiced. One of the best examples is that of the pork industry where merit-based pricing can be linked to large changes in meat quality over the last few decades.

In the U.S. Farm Raised Catfish industry there are many quality issues that could be addressed with a merit pricing system. Such a system would incentivize producers to begin to improve the quality of the product arriving at the processing plant, as well as give them financial means to make changes in their production practices. And a merit-based pricing system could increase the overall profitability of processors as well.

Chapter 6 develops an equation based model for implementing merit-based pricing in the U.S. catfish industry. The final equation for the merit-based marketing system being proposed is:

$$P_m = P_f \ [0 .75 \ (S_{yield} / A_{yield}) + 0.05 \ (S_{yellow} / A_{yellow}) + 0.6 \ (S_{red} / A_{red}) + 0.05 \ (S_{size} / A_{size}) + 1]$$

Where P_m is merit-based price, P_f is the average industry price, A is the average value for a given variable industry wide, and S is the difference from the average in a given sample.

Given this model as a starting point an industry stakeholder focus group with both producers and processors should be held to discuss and negotiate the details of the model for implementation. The multipliers are estimates that seem feasible; however without access to processor's private financial records it is difficult to put an exact value on each term. Furthermore, it is essential that any model that is to be implemented in the industry be discussed in an open and transparent way to promote producer and processor buy in.

The U.S. catfish industry is at a crossroads and now is the time to look toward the future and begin modifying our industry in ways that will improve product quality and consistency and improve profitability at all levels of the industry. It is clear from other livestock industries that merit-based price systems can be catalysts for change in product quality and it is the conclusion of this chapter that a merit-based price system can help the catfish industry be in a process of continual improvement in order to remain competitive in the world market.

Introduction:

As the United States catfish industry struggles to maintain a share of the global seafood market discussions of economics (feed prices and prices paid to producers for their fish) often assume a preeminent role in industry meetings. However, questions of quality and consistency are just as important considering that it is pointless to produce a fish that consumers do not want to buy. Selling fish on a yield grade basis also known as merit-based pricing addresses issues of economics as well as product quality and consistency. The goal of a merit-based pricing system is increased product quality and consistency as well as increased profitability for all levels of the industry that meet product quality goals. Yield grade or merit-based pricing can be defined simply as selling a product in a system where the price is based on the quality of the product. Selling agricultural products with the price tied to the quality of the product is not a new idea. In many livestock industries terminal sales of animals with prices based on carcass merit is commonly practiced. Carcass merit is defined by the cooperative extension service as: desirability of a carcass relative to quantity of muscle, fat, bone, and quality of lean tissue (Extension website, 2013).

In the U.S. Farm Raised Catfish industry there are many quality issues that could be addressed with a merit pricing system. A system of merit-based pricing would incentivize producers to begin to improve the quality of the product arriving at the processing plant. In order to begin considering the possibilities of a merit-based pricing system for the U.S. catfish industry one must first consider the current marketing situation in the industry. The U.S. catfish industry is comprised predominately of a system of independent growers that sell their fish to independent processors which in turn either sell fish through wholesalers or in some cases sell in more of a direct marketing system. There are very few situations of integration or contract buying currently in place in the industry. With growers mostly independent and detached from the final market the environment is such that growers can produce fish with little concern for product quality as long as processors are willing to buy their fish. The way that the catfish industry is currently structured there are a few price penalties assessed for exceptionally poor quality, for instance when red fillet is an issue those fillets are often removed from the processing line and the farmer docked in the total payment received proportional to the amount of fillets deemed to be unmarketable. Also, when fish are out of the size range desired by the processor producers receive a lower per pound price. This system only penalizes producers for exceptionally poor quality fish which only motivates producers to produce fish of minimum acceptable quality. A yield grade system would reward producers for exceptionally high quality fish giving an incentive for continuous improvement.

As mentioned above quality grading and selling animals based on those quality grades is not uncommon in other livestock industries in the United States. Most meat products are both inspected for wholesomeness and graded for quality by the USDA. While inspection by the USDA is required for most other meat products grading is not mandatory and must be paid for by processors or producers if that service is to be performed by the USDA's Agriculture Marketing Service. An example of a meat product that is commonly both inspected as well as graded by the USDA is beef. After carcasses are inspected and deemed wholesome they are then graded in two ways, both for quality and yield. The quality grade is based on tenderness, juiciness and flavor and the yield grade is based on the amount of usable lean meat on each carcass (USDA Food Safety Inspection Service website, 2013). The quality grades of beef are as follows; prime, choice, select, standard, commercial, utility, cutter, and canner. Besides these quality grades the carcasses are also ranked from 1 to 5 on a yield grade scale with 1 representing the highest ratio of lean meat to fat (USDA Food Safety Inspection Service website, 2013).

Poultry is graded for quality similarly to beef however the USDA does not put a yield grade on poultry. The quality grade goes from A to C. The grading is based on quality concerns such as the presence of defects for example bruises, discoloration, and lack of feathers as well as considerations in bone in products like no broken bones, and in whole bird and skin on products no tears in the skin, a covering of fat under the skin, and fully fleshed and meaty (USDA Food Safety Inspection Service website, 2013).

Pork, though not graded by the USDA for quality (USDA Food Safety Inspection Service website, 2013), is one of the best examples of selling a livestock product on a yield grade basis. Carcass merit pricing has been in place in the pork industry since at least the mid 1960's (Hayenga et al., 1985) though not all pork produced in the last five decades has been sold on a yield grade basis. In 1988 only 28% of all pork producers sold hogs under some form of merit pricing system however that number climbed to

78% only 9 years later (Brorsen et al., 1998). In just nine years an increase of 50% of producers having their economic futures tied to the quality of their product can have significant impact on an industry. According to the Daily Livestock Report though carcass leanness has been a factor in pricing systems for many years there existed no standardized way to report it to USDA before 2001. In the 1980's and 1990's packers tried to get hogs with more muscle and less fat. In those decades a "good hog" measured 48-49% total lean whereas at the beginning of 2012 market hogs averaged more than 55% lean (CME Group, 2012). As producers responded to the incentives to raise leaner hogs it became evident that a hog that was too lean lacked some of the meat quality characteristics that consumers find desirable. In response packers changed the incentive structure and not only focused on leanness but also meat quality and they began to limit premiums for very high lean carcasses. Producers responded by paying more attention to muscle quality and the pace of hogs getting leaner actually slowed down as increased focus was put on meat quality along with leanness (CME Group, 2012). This example from the pork industry clearly demonstrates how producers can and will respond to incentives to producing the product that the market demands and that those incentives can even be modified over time to keep the consumers pleased with the product.

It is clear that selling livestock products on a merit-based system can have positive influence on the quality of the product being produced. However, there are at times push back from marketing plans that include merit-based pricing especially where penalties are assessed to producers that do not produce at or above minimum quality standards. Brorsen et al. (1998) suggest that Kahneman and Tversky's prospect theory applies to producer's reaction to some merit-based pricing systems in that the disutility of giving something up is about twice as great as the utility of gaining it. The idea here is that in a system where both penalties and incentives are applied based on product quality producers will be afraid of losing the base price that they have in the form of penalties and that fear can potentially outweigh the hope of gaining extra price incentives. As this discussion of the possibility of yield grade pricing for catfish continues this concept should be considered. Even though the discussion that follows will focus on a merit price system that includes penalties as well as incentives one must keep in mind that in order to gain producer buy in a modified system may be necessary with only incentives for better quality. This however may put undue burden on the processors when fish arrive at the plant and do not meet the base quality standards. Processors would be passing part of the profit for high quality fish back to the producers but carrying all of the losses from poor quality fish. Therefore, in an attempt to develop a plan that is fair and equitable to both producers and processors a merit-based system that involves both price incentives and penalties seems the most appropriate.

A Model for Merit-based Marketing in the U.S. catfish industry:

In the United States catfish industry there are several factors that could be used in a merit-based pricing system. Yield, fillet color, and size distribution of fish at harvest are a few of the immediate issues that could see positive change if a merit-based pricing system was to be initiated.

Yield:

Dress-out yield is the most obvious component that should be incorporated into a merit-based pricing system. Wide variations in carcass yield can have significant effects on the profitability of a processing plant. Data from one Alabama processing plant show that in 2011 and 2012 the biggest farms selling to them achieved an average carcass yield of about 60.4%. With the highest yield from a single farm reaching 63.41% and the lowest yield reported from a single farm being 55.30% (this data was reported in monthly and quarterly averages). This particular plant, if processing near capacity, can conservatively process 150,000 pounds (live weight) of fish per day. If that plant were to process 5 days per week and 4.3 weeks per month that would result in 3,225,000 pounds of fish processed per month. If those fish all yielded 55.3% that would produce 1,783,425 pounds of marketable fish compared to 1,947,900 pounds if the fish averaged 60.4% (as they did in the data provided) and 2,044,972.5 pounds at the highest reported yield of 63.41%. That is a difference of 97,072.5 pounds between the highest yield and the average, a difference of 261,547.5 between the highest yield and the lowest yield with the difference between the average and the lowest yield reported being 164,475 marketable pounds processed in this hypothetical processing month. If the processor is selling fish for $3.08 per pound, which was the average price for fish marketed in 2012 (National Agricultural Statistics Service Catfish Processing Report), the difference between the highest yielding fish and the lowest yielding fish would represent a difference of $805,566.63 per month for that processor. It is obvious that the yield of the fish coming into the plant has huge economic impact on the processing plant. Fish with below average yields hurt the processor's bottom line and fish yielding above average have the opposite effect. These costs and benefits could be partially passed along to the producers in the form of price incentives for fish yielding above average and penalties for fish yielding below average(please see the discussion of economics below).

Fillet Quality:

Of the several potential issues that could be addressed under the category "Fillet Quality" the most important and likely the most practical to measure and quantify with current technology is that of fillet color. Red fillet an issue predominately caused by handling stress during harvest and transport as well as oxygen and carbon dioxide stress and is already an example of a quality variable where exceptionally poor quality fish receive a penalty. There, however, is no system in place for incentives for exceptionally high quality fish. The other main color issue is that of yellow fillet which is caused by the build-up of carotenoid pigments in the fillets (see yellow fillet chapter). Red fillet affects both the esthetic value as well as the flavor of the fillet whereas yellow fillet affects only the visual component of quality and consumer appeal. Quantifying the economic importance of controlling both red and yellow fillet is difficult without access to processing plant's sales records which are not readily available however, anecdotally some 200 outlets of a major chain supermarket stopped buying U.S. catfish because of the high occurrence of yellow fillet. Therefore, if producers were incentivized to lower the occurrence of yellow and red fillet old markets that have been lost could potentially be regained as well as having the potential to enter new markets with a higher quality product.

Size distribution:

Size distribution of the fish harvested is another important factor to consider when looking at merit-based pricing systems. When fish are either too small or two large the fillets are outside of the size range that consumers demand. Also, processing equipment is set for specific tolerances in size and fish outside of those tolerances slow down the processing plant. Currently processors want fish between 1.5 and 3 pounds. As stated above a penalty is currently assed for fish that are too large. Therefore the penalty aspect of merit-based pricing is already in place for size of fish but the incentive side is not. In a merit-based system a sample of fish could be taken from each pond and the percent that fall into a pre-determined size range could be used for assessing penalties or adding incentives.

Several other factors could be incorporated into a model for marketing fish in a merit-based system for instance; the incidence of off-flavor fish on a farm wide basis. It is important for processors to know what fish are available and be able to plan harvests accordingly to keep the plant running at optimum efficiency. Having farms that consistently have fewer problems with off-flavor allows for better planning of harvests. Also, fillet texture is another factor that could fit into a model for merit-based marketing. Anecdotally fish from some farms have much less firm meat than other farms. It has also been suggested that factors such as quality of roads on the farm could even be worked into a model because processors send hauling trucks to the farm and better roads would decrease maintenance costs on those hauling trucks. However, though these factors could be useful in the future at this point in the development of the industry it seems more important to focus on a few factors that can quickly improve the quality and consistency of the product being produced as well as the profitability of all levels of the catfish industry. With that in mind the discussion that follows focuses on a merit-based marketing system with the factors of yield, fillet color, and size distribution as factors because these variables seem to be some of the most useful and practical to implement grading procedures and an incentive structure which would reward those producers producing high quality fish and provide a reason for producers to continually be improving their production practices and genetics resulting in an industry continually seeking ways to improve and stay competitive in the world market.

In order to develop a model for selling fish in a merit-based marketing regime a workshop would have to be conducted bringing together a focus group of catfish producers and processors so that all aspects of the model could be understood and agreed on by all stakeholders. Not only would this help insure equitable facilitation of a merit base marketing system it would also help encourage buy in from all the players in the industry. Two models for developing a merit-based system are outlined in the following discussion and could serve as a starting point for negotiations in that focus group.

The first model for a merit-based marketing system and probably the least complex model that the catfish industry could adopt is something similar to the grading system used in beef. At the processing plant fish could be graded on certain characteristics (yield, color, size distribution). And premiums or penalties could be assessed by class. For example if 97-100% of the fish harvested where within the desired size range that could be considered grade A for the factor of size distribution and 1% (for example) of the market price could be added as a premium. If 90-96% were in the desired size range that could be a grade B harvest which might not receive any premium but no penalty either. If 80-89% were in the desired range that might be considered a grade C harvest and receive a 1% of the market price penalty (for example), with each lower class receiving a larger penalty. Similarly for color if 96-100% of the fish sampled have no issues of red or yellow fillet then they could be considered grade A for the factor of color and a 1% incentive could be added. Grade B could be 85-95% on color and no premium but no penalty assessed, grade C might be 75-84% and receive a 1% penalty. And yield could be treated in a similar fashion. These ranges and percentages of market price used as premiums or penalties are only examples of what these categories might look like. Without more access to processor financial records to document real world losses from fish out of size range or off-color it is not possible to set exact premiums or grade class ranges only to show what the system might look like. To decide what the actual premium or penalty for each class described above processors would have to come up with an average price per pound lost because of fish being out of the preferred size range or off-color (including potential markets lost from these factors) and then split the cost/risk with the producers in a percent of the total change.

This class model though easy to understand could actually be difficult to implement, as setting the divisions between classes could be a hotly debated issue with processors only wanting to give premiums for exceptionally high quality fish making the grade that receives no premium and those below it to contain the majority of the fish marketed which would in turn make large changes in management practice necessary before even small premiums would be paid. On the other side producers would want the grade receiving premiums to contain a higher percentage of the fish harvested making processors pay premiums for what in reality are average quality fish. Also, this system would not pay a premium for increasing quality for instance in the case of yield once a producer has fish just barely in the highest class there is no incentive for continual improvement. Since continual improvement is the goal of a merit-based marketing system though a system based on classes would be easy to understand it would not fulfill the goal of continuous improvement as well as a system that rewards improvements on a continuum. For that a model needs to be developed that is more equation based.

A possible basic equation for this second and preferable type of model might look like the following equation:

$$P_m = Y + C + W + P_f \tag{5.1}$$

Where P_m is the merit-based price including any premiums or penalties based on merit of the carcass, Y is a price factor based on the carcass yield of fish, C is the price factor based on color of the fillet, W is a price factor based on the size distribution of fish, and P_f is the average industry wide pond bank price for fish (note any penalty assessed should be entered into the equation as a negative). Each of these factors provide a premium or penalty based on a particular batch of fish being above or below industry averages and would add to (or in the case of a penalty decrease from) the average pond bank price being paid for fish industry wide to produce a new price based on the quality of the product. Hatch et al. (1998b) developed an equation for premiums to be paid for higher yielding fish that serves nicely as a basis for a potential equation to find Y in equation 1 above.

$$R = S\,(P_f / D) \tag{5.2}$$

Where R represents the largest premium that processors would be willing to pay for increased yields in fish (considering that market price plus R would cause processor's raw product cost on a dressed weight basis to remain constant with varying dress out yields), S is the change in yield (difference in industry average yield and particular farmer yield) ($0 \le S \le 1$), P_f is the industry wide farm price, and D is the average industry wide yield ($0 \le D \le 1$). This equation works very nicely for calculating the maximum premium that processors would be willing to pay for a given increase in yield above industry average yield at a given industry wide farm price.

Though many details would need to be fine-tuned by the processor/producer focus group one can assume that processors would not pass on all of the revenue from increased yields to producers in the form of premiums. Therefore, for the sake of model development if we work through a hypothetical example given the hypothetical processor described above that per month processes 3,225,000 pounds of live fish with an average yield of 60.4%. And if we assume an average market price paid to producers of $0.90 per pound (though this is well below the average for the last two years it is higher than the market price at the writing of this discussion, therefore a reasonable estimate for this hypothetical situation). Using the equation from Hatch et al (1998b) for a 1% increase in yield the maximum premium a processor could pay and keep their costs the same would be $0.0149 per pound. Processors would likely incur an additional expense of hiring at least one full time employee to grade each load of fish, if they do not have automated equipment in place as some do. Additionally, processors would almost certainly like to profit some for the extra trouble of grading fish and calculating premiums. Therefore, one might assume that processors would only pay 75% of the maximum premium (R). For this hypothetical processor retaining 25% of the increased revenue would represent $12,013.12 per month. Subtracting $3,500 per month for an additional employee's salary and benefits would leave the processor $8,513.13 per month or $102,157.50 per year in additional profits for each 1% increase in carcass yield. It should also be noted that processors would also be saving money under this system for fish that do not reach the average yield as penalties in per pound price would be assessed.

In this scenario 75% of the maximum premium is paid back to the producers. If we were to take a hypothetical farm of 100 acres producing 10,000 pounds per acre per year for a total yearly production of 1,000,000 pounds that 75% of R that this farm could receive for each 1% increase in yield would represent a difference of $11,175 per year. If, for example this particular farm were to attempt to increase their yields by changing to stocking hybrid versus channel catfish. Bosworth (2012) reported that hybrid catfish had a 3.2% higher carcass yield than did channel catfish. Similarly, Bosworth et al. (2004) reported an average of 3.325% higher carcass yield for hybrid catfish when compared to two different strains of channel catfish. Therefore, if this hypothetical 100 acre farm could achieve a 3.3% increase in carcass yield by switching to hybrid catfish the premium based on this change in yield would represent an increase in yearly revenue of $36,877.50. In 2012 six inch hybrid fingerlings cost about $0.066 more than channel catfish fingerlings ($0.162 and 0.096 respectively). If this 100 acre farm stocked 6,750 fish per acre that difference in price would represent an increase of $44,550 in stocking expense. Therefore, the premium paid by the processor would cover all but $7,672.50 of the difference of stocking hybrid fingerlings. When the additional benefits possible with hybrids such as faster growth, better feed conversion ratios, and better survivals (Li et al., 2004) are considered the difference of $7,672.50 is almost certainly more than paid for in these other benefits. Though the processor premium does not completely cover the cost of the management change it would likely be sufficient to encourage farm managers to consider changes in their management scheme.

Returning to equation 5.1 above ($P_m = Y + C + W + P_f$) and using the equation from the Hatch publication along with the multiplier for the portion of the maximum premium that processors might pass along to producers from the hypothetical example we now have a value for Y = 0.75 R. Therefore,

$$Y = 0.75 * S_{yield} (P_f / D_{yield}) \qquad (5.3)$$

The other factors in equation 5.1, Color (C) and size distribution (W) do not fit as neatly into the equation developed by Hatch et al. (1998b) because the assumption used for the Hatch equation is that yield directly effects price of the final product that the processor sells. In the variables of color and size distribution some fish that are off color or out of the desired size range are still marketable. Therefore, processor input would be needed to find the real world revenue losses associated with these quality problems. However keeping that in mind possibly Hatch's equation could be modified with a much lower multiplier than was used for yield to figure in the fact that though undesirable, off color fish and fish out of the desired size range are often still usable. Therefore processors would not pay nearly as high of a percentage if Hatch's equation were to be modified and applied in these situations. But to get the exact multiplier processor input would be necessary to find the maximum premium that they would be willing to pay to farms that have very uniform and correctly sized fish as well as fish that are on color. Therefore, it can be argued that the basic equation still serves only needing the percentage of the premium that processors are willing to pay worked out. For instance for the color variable (C) a possible premium equation could look like:

$$C = [0.05 * S_{yellow} (P_f / A_{yellow})] + [0.6 * S_{red} (P_f / A_{red})] \quad (5.4)$$

Note in equation 5.4, A was substituted for the term named D in Hatch's equation because D referred to average dress out yield and in this more generalized equation A will be used to represent "average" for the particular variable in question, and should be entered as a decimal percentage (as in the case of yield) or as a decimal percentage of frequency of occurrence as in yellow and red fillet. S will continue to represent the change in the observed sample above or below industry averages, also entered as a decimal. This change in variable nomenclature will be used for the remainder of this discussion.

Across the industry 14.5% of fillets exhibit yellow pigmentation (making A_{yellow} = 0.855) (data from the yellow fillet survey discussed in Chapter 2). If we estimate 2.5% of fillets are unusable because of red fillet (making A_{red} = 0.975) we can calculate the premium to be paid to a hypothetical farm with 4.5% occurrence of yellow fillet and 0% red fillet and, still assuming a market price (P_f) of $.90 per pound. This would give a premium for lack of yellow fillets of $0.0053 per pound and a premium for lack of red fillets of $0.0138 for a total color premium of $0.0191 for on color fillets. Again it must be remembered that these numbers are hypothetical and processors would have to use their private records to determine the amount of real world loss due to red and yellow fillet (including market loss because of strong preferences by the customer base). But the factors used above seem like a reasonable starting point because serious issues of red fillet make the fillet unusable whereas yellow fillet is not sellable in some markets but other buyers don't mind, especially those buyers that use the fillet in breaded products which justifies the larger premium for lack of red fillet.

Again the same equation can be modified for size distribution in a similar way and like yellow fillet should pay a small portion of the possible premium because fish that are out of the size range are still usable though not as profitable to the processor. Therefore if A_{size} were to equal to the average percentage of fish industry wide that are in the desired size range. Then S_{size} would be equal to the difference from the industry average in the current harvest, giving the equation:

$$W = 0.05 * S_{size} (P_f / A_{size}) \quad (5.5)$$

Again to determine the factor 0.05 information on processor revenue and losses on fish out of the desired size range would be necessary however 0.05 would give a small premium that could be useful to both producers and processors, and therefore 0.05 seems like an appropriate place to begin discussions in a focus group.

Returning to Equation 5.1 ($P_m = Y + C + W + P_f$) we can now substitute the equations developed above resulting in the following expanded form of the equation:

$$P_m = 0.75 * S_{yield} (P_f / A_{yield}) + 0.05 * S_{yellow} (P_f / A_{yellow}) + 0.6 * S_{red} (P_f / A_{red}) + 0.05 * S_{size} (P_f / A_{size}) + P_f \quad (5.6)$$

This gives us a working equation of:

$$P_m = P_f\,[0.75\,(S_{yield} / A_{yield}) + 0.05\,(S_{yellow} / A_{yellow}) + 0.6\,(S_{red} / A_{red}) + 0.05\,(S_{size} / A_{size}) + 1] \qquad (5.7)$$

This working form of equation 5.7 allows for easy modification of the multipliers as more information becomes available from processors on real world profits and losses it also easily facilitates addition of terms based on other quality variables that the industry may determine to be important. For instance the yield term could be split into a term for fillet yield and one for nugget yield and fish with a larger fillet and smaller nugget could be incentivized. Or, for instance variables like fat content of the fillet could be added into the equation if the industry were to decide it to be an important factor for marketing catfish as a low calorie healthy product or for palatability proposes.

If variables in the future are developed that do not work well using the model shown by equation 5.7 a hybrid system using equation 5.7 as a basis could be developed and terms for factors graded by class, as discussed above, could be added to the equation by simply inputting the premium calculated in the class system as a variable in equation 7.

Discussion

This model should serve as an example of what a merit-based marketing system price model might look like and as a basis for discussion by industry stakeholders. Each factor would have to be analyzed and scrutinized by both producers and processors in order to develop a model that serves both producers and processors as well as providing the necessary incentive for continuous improvement in the industry. The focus group approach mentioned above would be very important in the U.S. catfish industry so that the process of determining the premiums and penalties would be as transparent as possible because trust between producers and processors would be one of the biggest obstacles to implementing a merit-based marketing system.

Many producers would likely be reluctant to participate in a system with penalties for subpar fish however such penalties are important so that the burden of poor quality is shared by both the processor and the producer. If premiums for exceptionally high quality fish are given then penalties for subpar fish should be part of the equation as well. The industry could develop in such a way where some processors adopt a merit-based price system and others do not, giving producers a choice as to if they will adopt these ideas. However, if the pork industry is an example the proper merit-based pricing system will attract producers and facilitate change in the industry.

Change in product quality is possible through changes in producer management practices which become economically feasible through premium prices paid for producing premium products. Producers would need to individually conduct economic analyses for their particular farm for each potential way to improve their product quality similar to the example calculated above using hybrid catfish to increase yield. Developing prediction equations for each factor in a merit base marketing model, as was done in chapter 2 predicting the level of yellow pigment in fillets, would give producers a means of calculating the anticipated effect of proposed management changes. Furthermore, a merit-based marketing system could provide incentive and financial means for producers to adopt new technologies like in pond raceways that allow for greater inventory control which is beneficial for controlling size distribution at harvest. Other management changes that could result from incentives for higher quality products include but are not limited to; feeding strategies, frequent application of copper sulfate, higher aeration rates, and improved harvesting techniques (like fish pumps). Overarching all of these quality factors is the question of genetics of the fish being raised. In many other livestock industries genetic improvement has been a major driving force in producing a quality product more efficiently and needs to be considered strongly by every catfish producer. For each management change economic analyses are important for each farm's decision making process. Also, these economic analyses are important for establishing a fair and equitable merit-based marketing system.

Though the details must be worked through by industry stakeholders it is clear from looking at the example left by other livestock industries that merit-based marketing can change the U.S. farm raised catfish industry and help keep it remain competitive in the world market. The prediction equations established in chapters 2, 3, and 4 of this dissertation are a powerful tool for farmers to begin to use to make management decisions with an informed prediction of the outcome. Using the methods described in chapters 2, 3, and 4 of this dissertation prediction models can be developed for many of the potential factors that could be included in a merit-based marketing system. Linking producers and processors and their overall profitability directly to consumer demand is essential in keeping the U.S. farm raised catfish industry viable long into the future.

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Appendix 1. Statistical procedures

ANOVA is a procedure that tests for differences between groups showing if there is a statistically significant difference between mean values of several groups. However, the ANOVA procedure does not show which groups are different just that there are differences.

Tukey-Kramer procedure is a follow up procedure to the ANOVA procedure that is useful for all pairwise comparisons. The Tukey-Kramer procedure shows which groups have significantly different mean values from other groups.

Forward selection: Forward selection is a procedure used to develop regression models selecting only the variables with F-values with corresponding p-values of a specified level. The procedure begins with only the intercept term and progressively adds independent variables starting with the variable with the lowest p-value, and continues to add independent variables until there are none with p-values below the specified alpha level. The resulting list of variables selected becomes the regression model. Once a variable is added to the model it cannot be removed (Beal paper SA01_05).

Backward elimination is similar to forward selection except in the backward elimination procedure the model begins with all the independent variables included in the model and successively eliminates those with the highest p-values until only those with p-values below the specified alpha value are left in the model. Once a variable is removed from the model it cannot be added (Beal paper SA01_05).

Stepwise regression is similar to the forward selection procedure in that each variable is added to the model one at a time based on having an F statistic p-value less than the specified alpha level. However the difference between the forward selection model and the stepwise regression model is that after each variable is added to the model and before another variable is added the procedure re-evaluates all the variables included in the model and removes any that have a non-significant F statistic p-value. The procedure continues until all independent variables with significant p-values at the specified alpha level are included in the model and all those with non-significant p-values are removed from the model (Beal paper SA01_05).

AIC (Akaike's Information Criteria) is a comparison between a particular regression model and the "true model." The equation used for calculating the AIC is

$AIC=n[\ln(SSE/n)]+2P$

Where n is the number of observations, SSE is the sum of squared errors, and P is the number of parameters included in the model. Therefore, AIC is made up of a lack of fit term (the first part of the equation) and a penalty term (the second part of the equation). As the number of parameters included in the model increases the lack of fit term decreases but the penalty term increases.

Conversely, as variables are dropped from the model the lack of fit term increases and the penalty term decreases. The model with the lowest AIC value is considered to be the best model and closest to the "true" model (Beal paper SA01_05).

BIC (Sawa's Bayesian Information Criteria) is similar to AIC except that the penalty term for including more parameters in the model is much more complex including not only the number of parameters (k) in the model but also the number of observations (n), the sum of squared errors (SSE), and the pure error variance fitting the whole model (σ).

$BIC=n[\ln(SSE/n)]+[(2(k+2)n(\sigma 2)/SSE]-[(2n2\ \sigma 4)/SSE]$

This added complexity allows for the error term also to be weighted for changes in the fit of the model. But the basic idea of one term being a lack of fit term which decreases as more variables are added to the model and the other being a penalty term which increases as more variables are added to the model is the same as AIC. However, BIC does give more weight to the fit statistics like SSE by incorporating them into the penalty term as well (Beal paper S1-157).

Clustering procedures are designed to group data based on similarity. For the purposes of this study the SAS code FASTCLUS was used to group the data. FASTCLUS finds disjoint clusters as opposed to hierarchical clusters like CLUSTER analysis.

Disjoint clusters are more appropriate for this study because they allow objects to be in only one and only one cluster.

Logistic regressions: The logistic modeling procedure is not as straight forward as a simple regression model because it uses for its response variable an odds ratio. In this application the logistic model calculates the log of the odds of a farm being profitable above a certain breaking point. Then the model selection methods described above can be utilized.

Generalized Estimating Equation (GEE) Model: The GEE model allows a regression model to be developed on data like the off-flavor samples in chapter 4 because it creates a model based on success and total tries. In the case of the off-flavor data the response variable was actually a ratio of the successful flavor tests divided by the total flavor tests per farm per month. The GEE model also allows for repeated measures as in Chapter 4.

Appendix 2. Yellow fillet survey instrument

Protocol to Determine Cause and Steps to Correct Yellow Coloration in Catfish Fillets (Auburn University)

The objective of this data gathering is to correlate catfish production practices with processed fillet coloration, specifically yellow coloration. Regression analysis using processor and producer information will allow us to determine the significant factors contributing to yellow coloration that will lead us toward developing best management practices to obtain non-yellow fillets. Field trials will follow using best management practices to eliminate yellow coloration in fillets. The more accurate the information, the greater the value of this data is to our analysis.

Processor Information Needs

1. Processor Name ____

2. Harvest Date____

3. Catfish Producer Name____

4. Pond Identification for harvested pond_____________________________________

5. Percentage of fish that fall into each color range for the Identified Producer and specific Pond Identified in questions 3. and 4. above:

- Percent of fish that are white ____% Fillet Sizes _______________________ Quantity? ________ lbs
- Percent of fish that are yellow ____% Fillet Sizes _______________________ Quantity? ________ lbs
- Percent of fish that are red ____% Fillet Sizes _______________________ Quantity? ________ lbs
- Percent of fish that are pink ____% Fillet Sizes _______________________ Quantity? ________ lbs

OR if the above is not possible, then the percentage of good, i.e., useable, and "yellow fillets"

6. Have you had a recurring problem with yellow fillets from this producer? _______________yes or no

7. Have you had a recurring problem with red fillets from this producer? ____________yes or no

8. Have you had a recurring problem with "off-flavor" fish from this producer? ____________yes or no

Producer Information Needs

These questions must be asked of the specific producer and for the specific pond that was harvested for which processed fish data is provided above. If more than one pond from a producer supplied fish to the processor on any day, the following questions need to be asked for each pond.

Management of This Pond

1. How much total feed (and feed per acre) have you put into this pond in the last 12 months?

______ pounds _______ pounds per acre?

- What was the last feeding date before harvest? ____

- What is your average feeding rate during the summer growing season? ________ lb/acre/day

- Who do you purchase your feed from?____

- If you purchase feed from more than one source, supply the names of feed suppliers for:

- the last 2 months? Name(s) ______________________________

- 2 – 6 months earlier? Name(s) ____________________________

2. Do you stock or have other than catfish in this pond? __ yes ___ no

- Gizzard shad? __________ yes or no

- Threadfin shad? _________ yes or no

- Fathead minnows? _______yes or no

- Other fish?_________ yes or no, please list name(s) ____________________________________

2a. Have you had shad or other supplemental fish (not catfish) die-offs in the last 30 days? ____Yes or No

3. Have you used copper sulfate in this pond to manage plankton? _______yes or no

- If yes, when was your last application? ____

- Is the form a liquid or crystal copper sulfate? ____

- How much, in pounds or liquid, was put into the pond during the last two months? ____

4. Have you used diuron in this pond?______________________ yes or no

- If yes, when was your last application? ____

- How much was put into the pond during the last two months? _______________________

5. What other chemicals have you used in this pond during the last two months?

- Item: __________________________________ Quantity applied? _______________________

- Item: __________________________________ Quantity applied? _______________________

- Item: __________________________________ Quantity applied? _______________________

- Item: __________________________________ Quantity applied? _______________________

- Item: __________________________________ Quantity applied? _______________________

6. Do you use an automated Dissolved Oxygen (DO) measuring device in this pond? ________ yes or no

- If yes, what is your DO level set at to turn on your aerator(s)? ___________ ppm

- How long do you or the automated monitoring devise retain DO information for this pond? ____

6a. If you do not use an automated Dissolved Oxygen measuring device, what is the minimum D.O. level you try to keep in this pond? ___________________ ppm

Information for This Pond

7. What type of catfish do you raise in this pond?

- Channel Catfish? ___________ yes or no

- Hybrid Catfish? ____________ yes or no

- Both? _____________________ yes or no

8. Who do you buy your fingerlings from? Provide name and city/state _____________________

- What fingerling size do you try to obtain? ___________________

9. What is your catfish stocking rate? ____

10. How many batches of catfish were in this pond before harvest? ______________________________

11. What is this pond's surface area? ______________ acres

- What is this pond's water volume? __________ acre-feet

- What is this pond's average depth? __________________ feet

- What is this pond's maximum depth? _____________ feet

12. How much horsepower of fixed (electric) aeration do you have for this pond? _____________HP

  - What has been the history of aeration in this pond for the last 4 months, that is, has the aeration been "normal", "above normal", or "below normal"? _____________________

13. What were the following water quality parameters for this pond?

  - Alkalinity level? __________________________ ppm

  - Hardness? ________________________________ppm

  - pH? _____________________________________

  - Salinity? _________________________________ ppm

14. Have you seen a noticeable change in algal bloom in this pond during the last 2 months? _____ y or n

  - What about during the summer of 2009? ______________________ yes or no

15. Is this pond a watershed pond or a levee pond? ______________________________

  - What is your water source for filling this pond? ___________________ watershed, well, stream

  - Are there beef cattle or livestock on the watershed of this pond? ________________

16. Have you noticed a more than normal amounts of :

- Snails around the edge of this pond during the last 2 months? _____________ yes or no
- Filamentous algae? ____________ yes or no
- Blue-green mats? __________ yes or no
- Other things you have noticed particular to this pond:
- In the last 2 months? ____
- In the last 6 months?____

17. How long has it been since this pond was last filled with water? _______________________________

- Was the pond renovated before the last re-filling? _________________________ yes or no
- How old is this pond? _______________ years

Production and Harvest

18. How many harvests have you had in this pond during the last year (including this harvest)?__________

- During which months did each harvest occur? ____

19. Is the number of harvests this pond has had in the last year "on-track" or "behind track"?
____

20. Have the fish in this pond been called "off-flavor" during the last 6 months? ___________ yes or no
When, i.e., what month? _______________________________

21. Has there been any recent disease incidence in this pond during the last 6 months? ________ yes or no

If yes, please provide disease information below?

- Disease?______________ Date?_______ Losses (lb)? ________ Treated? _____ If treated, with what? _________
- Disease?______________ Date?_______ Losses (lb)? ________ Treated? _____ If treated, with what? _________
- Disease?______________ Date?_______ Losses (lb)? ________ Treated? _____ If treated, with what? _________
- Disease?______________ Date?_______ Losses (lb)? ________ Treated? _____ If treated, with what? _________
- Disease?______________ Date?_______ Losses (lb)? ________ Treated? _____ If treated, with what? _________

22. Has there been a recent time when oxygen levels declined below 1.5 ppm in the last 60 days? _______________ Number of times? _______ When? ______________________________

23. Has there been a recent time when carbon dioxide levels have been above 25 ppm in the last 60 days? _______________ Number of times? _______ When? ___________________________

24. Has this pond had instances of "red" fillets during the past 30 days? ________ yes, no, or don't know

- If yes, when? __________________

25. Has this pond had instances of "yellow" fillets during the last 30 days? ________ yes, no, or don't know

- If yes, when? __________________

Appendix 3. BMP Producer Survey

(NOTE: DO NOT AGREE TO PARTICIPATE UNLESS AN IRB APPROVAL STAMP WITH CURRENT DATES HAS BEEN APPLIED TO THIS DOCUMENT.)

INFORMATION LETTER
For a Research Study entitled:

Best Management Practices For West Alabama Catfish Production: creating profitability through efficiency and quality.

You are invited to participate in a research study to determine the most profitable and efficient production methods for the Alabama catfish industry. The study is being conducted by Corey Courtwright under the direction of Dr. Terry Hanson in the Auburn University Department of Fisheries and Allied Aquacultures. You were selected as a possible participant because you produce food size catfish and are age 19 or older. This study consists of a survey that should take about 30 minutes to fill out. All information you provide will remain confidential. Information from this survey will be published and disseminated in extension workshops and publications as well as professional publications and meetings but will be anonymous in all forms of publication and dissemination. Information from this study will benefit the U.S. farm raised catfish producers (and especially the Alabama catfish producers) by helping to determine the most profitable and efficient ways of growing catfish today and making that information available to all of you through the Alabama Cooperative Extension Service. We hope you will participate in this study however, if you change your mind about participating, you can withdraw at any time during the study. Your participation is completely voluntary. If you choose to withdraw, your data can be withdrawn as long as it is identifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, the Department of Fisheries and Allied Aquacultures. If you have questions about your rights as a research participant, you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board by phone (334)-844-5966 or e-mail at hsubjec@auburn.edu or IRBChair@auburn.edu. HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE IF YOU WANT TO PARTICIPATE IN THIS RESEARCH PROJECT. IF YOU DECIDE TO PARTICIPATE, THE DATA YOU PROVIDE WILL SERVE AS YOUR AGREEMENT TO DO SO. THIS LETTER IS YOURS TO KEEP. If you have questions about this study, please contact Corey Courtwright at 334-444-5566 (cac0039@tigermail.auburn.edu) or Dr. Terry Hanson at 334-844-4786.

Thank you very much for your help,

Sincerely,

Corey Courtwright

The Auburn University Institutional Review Board has approved this document for use from 2/1/13 to 1/31/16
Protocol # 13-014 EX 1302

Dear catfish producer,

Thank you for taking the time to complete this very important industry survey. As we all know our industry is at a cross roads right now. The goal of this survey is to analyze our current ways of growing fish in order to determine which are the most efficient and profitable so that best management practices can be established. The data collected from this survey will be compiled from everyone participating and we will distribute that information in publications as well as through meetings and workshops in order to help all of you make your farm the most profitable that it can be in these tough times. Your information will be kept anonymous and only averages, trends, or completely anonymous data will be published. Please answer each question completely, however if you are uncomfortable answering a particular question do not feel obligated to do so. Your participation is very important for U.S. catfish producers if we are to stay as efficient and competitive as possible. If you have any questions feel free to call or email me at the address below. I really appreciate your time in helping with this effort!

Thank you very much,

BEST MANAGEMENT PRACTICE SURVEY

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AUBURN UNIVERSITY

AFBI
Aquaculture & Fisheries Business Institute

Please answer each question. If you are not sure of an answer please make your best guess.

1. **Did your farm produce food size catfish to be sold to a processing plant in 2011 or 2012? (circle one)**

   Yes

   No (If No please select one of the following explain)
   [ ] only produce fingerlings
   [ ] fee fishing business
   [ ] out of business
   [ ] other ___________

   If "yes" (produce food size catfish) please continue with the survey. If "no" please return the survey without completing the rest so that we will be able to count you as having participated.

2. **What is your age?**

   [ ] 18-24
   [ ] 25-34
   [ ] 35-44
   [ ] 45-54
   [ ] 55-64
   [ ] 65 and up

3. **What is your gender?**

   [ ] Male
   [ ] Female

4. **What is your role on the farm?**

   [ ] owner/operator
   [ ] owner not actively managing
   [ ] manager

5. Is the majority of the income for your family (or corporation) generated by producing catfish?

[ ] Yes
[ ] No

6. How many years experience do you have growing catfish?

______________________years

7. What county is your farm located in? (If multiple counties please list each county).

____

Please fill in the boxes below for 2011 and 2012.

		2011	2012
8.	Number of water acres actively farmed		
9.	Number of ponds in production		
10.	Average depth of ponds		
11.	Number of acres taken out of production		
12.	Total pounds of fish sold for the entire year		
13.	Total pounds of fish ready for sale but you were unable to find a buyer?		
14.	Total amount of feed fed on the whole farm for the entire year		
15.	Target stocking rate (Number of fish per acre)		
16.	Size fingerlings typically used for stocking?		
17.	Do you purchase size graded fingerlings? (circle one for both years)	Yes No	Yes No
18.	Were you able to get the quantity of fingerlings you needed when you needed them? (circle one for both years)	Yes No	Yes No

19. Do you use single batch or multiple batch production systems, or both?

[ ] Single
[ ] Multiple
[ ] Both

20. If you use a multiple batch system how many batches do you attempt to maintain in the pond at any one time?

[ ] 1
[ ] 2
[ ] 3
[ ] 4
[ ] more

21. How many times per year is each pond stocked?

2011	2012
[ ] 1	[ ] 1
[ ] 2	[ ] 2
[ ] 3	[ ] 3
[ ] other______	[ ] other ______

22. In 2011 and 2012 did your operation use channel catfish, hybrids, or both?

2011	2012
[ ] Channel	[ ] Channel
[ ] Hybrid	[ ] Hybrid
[ ] Both	[ ] Both

23. Did your farm use any vaccinated fingerlings in 2011 or 2012?

2011	2012
[ ] yes	[ ] yes
[ ] no	[ ] no

24. Do your ponds have any other fish growing with your catfish (shad etc.)?

[ ] yes
[ ] no (If no, please go to question 26)

25. If yes, please check all that apply.

[ ] Gizzard shad	[ ] Threadfin shad
[ ] Bluegill	[ ] Fathead minnows
[ ] Crappie	[ ] Grass carp
[ ] Bighead carp	[ ] Silver carp
[ ] Common carp	[ ] Other ________________________________(please list)

26. On average how many times per year was each pond harvested?

2011	2012
[ ] 1	[ ] 1
[ ] 2	[ ] 2
[ ] 3	[ ] 3
[ ] 4	[ ] 4
[ ] 5	[ ] 5
[ ] 6	[ ] 6
[ ] other______________ (please specify)	[ ] other ________ (please specify)

27. Did you notice a change between 2011 and 2012 in the size of fish harvested?

Yes No If "yes" please explain____________

28. Pond water source (check all that apply)

[ ] well
[ ] surface runoff
[ ] stream/river
[ ] other, please explain___________________________

29. What method is used to determine the amount of feed to be fed on a daily basis during the peak grow-out season? (check all that apply)

[ ] use sight feeding until the fish appear full
[ ] estimate feed amounts needed based on fish size, number, and water temperature
[ ] base feeding on historical records from the same pond
[ ] other please explain, ______________________________

30. Is there an amount of feed that you consider to be the maximum amount that you feed per day and do not go over in the summer (circle yes or no for each year)?

2011	YES	NO
2012	YES	NO

31. If there was a maximum amount of feed allowed to be fed to each pond in the summer what was that amount? (pounds per acre per day) If no maximum write none.

2011_________________________pounds/acre/day
2012_________________________pounds/acre/day

32. **Which feed mill did you buy your feed from in 2011 and 2012?**
    2011________________________________
    2012________________________________

33. **What percent protein feed do you use? (check one)**

2011	2012
[ ] 28%	[ ] 28%
[ ] 32%	[ ] 32%
[ ] 35%	[ ] 35%
[ ] other _____%	[ ] other ______%

34. **What percent protein feed would you prefer to use if all the levels were available to you?**

    _______________________%

35. **In the winter do you feed…**

    [ ] not at all
    [ ] every day but low amounts
    [ ] every other day
    [ ] once per week
    [ ] twice per month
    [ ] once per month
    [ ] other, please explain________________

36. **Did you change management strategy between 2011 and 2012 in either of the following areas? If so what changes did you make?**

Feeding frequency	yes	no	If "yes" what change?_________________
Protein level used	yes	no	If "yes" what change?_________________

37. **Did you use copper sulfate? (circle one)**

2011	2012
Yes	Yes
No	No (if "no" in both 2011 and 2012 skip to question 42.)

38. **For which of the following purposes do you use copper sulfate? (check all that apply)**

2011	**2012**	
[ ]	[ ]	Regular low dose application in order to thin algae populations
[ ]	[ ]	Treatment of disease
[ ]	[ ]	Snail control
[ ]	[ ]	Only before harvest to kill algae with the result of getting fish on-flavor
[ ]	[ ]	Other, please explain ____

39. How many pounds of copper (or gallons of liquid) do you apply on average PER WATER ACRE PER MONTH during the peak growing season?

2011________________________(please specify pounds or gallons)
2012________________________(please specify pounds or gallons)

40. If you use crystal copper sulfate what application method do you use?

[ ] Broadcast the crystals over the pond surface
[ ] Mix with pond water and apply as a liquid
[ ] Suspend a bag of crystal in front of aerators or other mixing device
[ ] Other, please explain _______________________________

41. On average how many times in the course of a month would copper sulfate be applied to any given pond during the peak growing season?

2011	2012
[ ] Only at harvest	[ ] Only at harvest
[ ] 0	[ ] 0
[ ] 1	[ ] 1
[ ] 2	[ ] 2
[ ] 3	[ ] 3
[ ] 4	[ ] 4
[ ] more often	[ ] more often

42. Did you use diuron? (circle one)

2011	2012
[ ] Yes	[ ] Yes
[ ] No	[ ] No (if “no” in both years skip to question 46.)

43. For which of the following purposes do you use diuron? (check all that apply)

[ ] Regular application in order to thin algae populations
[ ] only before harvest to kill algae with the result of getting fish on-flavor
[ ] Other, please explain _______________________________________

44. How many ounces of diuron did you apply on average PER WATER ACRE PER MONTH during the peak growing season?

2011________________________ounces
2012________________________ounces

45. **How many times in the course of a month do you apply diuron to a given pond during the peak growing season on average?**

2011	2012
[ ] Only at harvest	[ ] Only at harvest
[ ] 0	[ ] 0
[ ] 1	[ ] 1
[ ] 2	[ ] 2
[ ] 3	[ ] 3
[ ] 4	[ ] 4
[ ] more often	[ ] more often

46. **What other chemicals are used on a regular basis in your ponds?**

[ ] salt
[ ] lime
[ ] potassium permanganate
[ ] alum
[ ] formalin
[ ] other (please specify) ___________________________________

47. **During the peak summer growing season please indicate how often you test each of the following water quality parameters by checking the appropriate box**

	Multiple times per day	Daily	Weekly	Twice per month	Once per month	Once per year	Only when there is a problem	Never	Other (please explain)
Oxygen									
Ammonia									
Nitrite									
Nitrate									
Hardness									
Alkalinity									
Salinity									
CO_2									

48. **When water quality is checked who performs the test? Please check the appropriate box for each of the following water quality tests. If the tests are conducted by two or more groups please indicate that by checking multiple boxes.**

	Yourself (or on farm labor)	Use the services of the Fish Farming Center	Private Consultant	Other (Please explain)
Oxygen				
Ammonia				
Nitrite				
Nitrate				
Hardness				
Alkalinity				
Salinity				
CO_2				

49. **What is the average alkalinity in your ponds?**

________________ppm

50. **What is the chloride level in your ponds?**

_________________ppm

51. **Have you changed how you use copper sulfate, diuron, or other chemicals from 2011 to 2012? If so how?**

	Yes	No	If yes how?
Copper sulfate			
Diuron			
Salt			
Lime			
Potassium permanganate			
Alum			
Other			

52. **How many horsepower of fixed electric paddlewheels do you typically have per water acre (do not include emergency tractor aerators)?**

___________________________hp

53. **Is pond volume (that is pond surface area multiplied by average pond depth) considered when planning aeration horsepower for each pond?**

[ ] Yes
[ ] No

54. **At what dissolved oxygen level (in ppm) do you begin aerating your ponds?**

____________________________ppm

55. **Do you use an automated oxygen monitoring system on your farm?**

[ ] yes
[ ] no (if no skip next question)

56. **If you use an oxygen monitoring system how many of your ponds have this system?**

_______________________number of ponds

57. **On average, in July, how many hours per night did the aerators in your ponds run?**

2011________________________hours
2012________________________hours

58. **Approximately how many hours of emergency tractor aeration were necessary for your entire farm in 2011 and 2012 (number of tractors multiplied by hours per tractor)?**

2011_________________________hours
2012_________________________hours

59. **Have you changed anything about how you aerate from 2011 to 2012? If so what has been changed (please note if the change was an increase or decrease from 2011 to 2012)?**

Number of fixed paddlewheels_______________________________
Number of tractors____
Other____

60. Which of these diseases resulted in the loss of more than 20% of the fish of ANY pond on your farm in 2011 or 2012? Check all that apply.

	2011	2012
Columnaris		
Aeromonas		
ESC (hole in the head)		
Ich		
Proliferative Gill Disease (hamburger gill)		
Anemia (no blood)		
Winter kill		
Trematodes		
Other, what?		

61. When you have a disease problem what is your typical response?

[ ] notify the fish center or get help from them in any way
[ ] use a private consultant and/or diagnostic services
[ ] consult directly with a veterinarian
[ ] get information from a neighbor/friend that has dealt with the same disease
[ ] use your own experience and knowledge in dealing with the disease

62. How many managers are there on your farm (including owner/operators and family)?

___________full time
___________part time

63. How many laborers are there on your farm (including family)?

___________full time
___________part time

64. Did you make any changes in the number or type of equipment you use between 2011 and 2012? If yes, what changes did you make?

65. For each of the following subjects where do you get most of your information? (Please check one source of information per subject)

	Neighbors and Friends	Alabama Cooperative Extension	Feed Mills	Fish Processors	The Catfish Institute	Alabama Producers Associations	Other, Please Explain
Technical Production Information							
Disease Treatment							
Feeding Strategies							
Fish Prices							
Feed Prices							
Industry Issues							

66. In which of the following ways have you used the Alabama Cooperative Extension Service in the last year? For example at the Fish Farming Center. Check one or more.

[ ] Attended workshops
[ ] Talked with Extension personnel
[ ] Visit by Extension personnel
[ ] Read Extension publications
[ ] Rarely use Extension service

67. What technological advance would have the biggest impact in making your farm more profitable? (Pick 3 of the following)

[ ] more aeration
[ ] computerized feed monitoring
[ ] computerized oxygen monitoring
[ ] more intense production systems (ex. Raceways or split pond system)
[ ] more vaccines against disease
[ ] better genetic strains of fish
[ ] higher quality feed
[ ] industry wide best management practices for efficient production
[ ] other (what) __________________

68. **When faced with a choice to implement a new technology on your farm do you <u>first</u> consider the…**

[ ] cost of the change
[ ] comparison of the cost and benefit from the change
[ ] potential benefit from the change
[ ] the amount of risk that will be removed or added to producing a crop of fish?
[ ] Other, please explain ________________________

69. **How much time usually passes after a new technology is introduced before you seriously consider buying the new device?**

[ ] I always try to buy the newest and latest version of technology.
[ ] I like for a new technology to be on the market for at least a year before I buy it.
[ ] I wait until a technology is considered a tried and tested standby before I buy it.
[ ] Other, please explain______________________

70. **Do you try new ideas such as conducting research on your farm based on ideas you have or have heard from others?**

[ ] Yes
[ ] No

Appendix 4. Survey validation panel scores raw data.

Panel members:

Dr. John Jensen Professor emeritus Auburn University (reviewer 3)

Dr. Luke Roy- post doctoral research fellow III Auburn University (Fish Farming Center) (reviewer 4)

Dr. Julie Bebak- Private fisheries/aquaculture consultant (reviewer 2)

Bill Hemstreet (MS) -Fish disease specialist Auburn University (Fish Farming Center) (reviewer 5)

Greg Whitis (MS)-Aquaculture extension agent Alabama Cooperative Extension System (reviewer 1)

Reviewer	Question	Clarity	Conciseness
1	1	4	3
1	2	5	5
1	3	5	5
1	4	5	5
1	5	5	5
1	6	5	5
1	7	5	5
1	8	5	5
1	9	5	5
1	10	5	5
1	11	5	5
1	12	3	3
1	13	3	3
1	14	5	5
1	15	5	5
1	16	5	5
1	17	3	3
1	18	5	5
1	19	5	5
1	20	5	5
1	21	3	3
1	22	5	5
1	23	5	5
1	24	5	5

Reviewer	Question	Clarity	Conciseness
1	25	5	5
1	26	5	5
1	27	5	5
1	28	5	5
1	29	4	4
1	30	5	5
1	31	5	5
1	32	5	5
1	33	5	5
1	34	5	5
1	35	5	5
1	36	5	5
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1	39	2	2
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1	44	2	2
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1	47	5	5
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1	59	5	5
1	60	5	5
1	61	5	5
1	62	5	5
1	63	5	5
1	64	5	5
1	65	4	4
1	66	5	5

Reviewer	Question	Clarity	Conciseness
1	67	5	5
1	68	5	5
1	69	5	5
1	70	5	5
2	1	3	4
2	2	5	5
2	3	5	5
2	4	3	5
2	5	4	5
2	6	5	5
2	7	5	5
2	8	5	5
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2	12	3	5
2	13	5	5
2	14	3	5
2	15	4	5
2	16	2	5
2	17	4	4
2	18	5	3
2	19	2	5
2	20	3	5
2	21	3	5
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2	23	4	5
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2	26	3	5
2	27	3	5
2	28	3	3
2	29	4	5
2	30	4	5
2	31	4	4
2	32	2	5
2	33	2	5
2	34	5	5
2	35	2	5
2	36	5	5
2	37	5	5
2	38	4	5

Reviewer	Question	Clarity	Conciseness
2	39	2	5
2	40	2	5
2	41	4	5
2	42	5	5
2	43	4	5
2	44	4	5
2	45	4	5
2	46	3	5
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3	3	5	5
3	4	5	5
3	5	2	5
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3	7	5	5
3	8	5	5
3	9	5	5
3	10	4	5

Reviewer	Question	Clarity	Conciseness
3	11	3	5
3	12	3	5
3	13	5	5
3	14	5	5
3	15	5	5
3	16	5	5
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3	51	5	5
3	52	5	5

Reviewer	Question	Clarity	Conciseness
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4	21	4	3
4	22	5	5
4	23	5	5
4	24	5	5

Reviewer	Question	Clarity	Conciseness
4	25	5	5
4	26	5	5
4	27	5	5
4	28	5	5
4	29	5	5
4	30	4	5
4	31	5	5
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4	59	5	5
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4	62	5	5
4	63	5	5
4	64	2	2
4	65	5	5
4	66	5	5

Reviewer	Question	Clarity	Conciseness
4	67	5	5
4	68	5	5
4	69	4	3
4	70	5	5
5	1	5	5
5	2	5	5
5	3	5	5
5	4	5	5
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5	32	4	4
5	33	5	5
5	34	5	5
5	35	3	3
5	36	4	4
5	37	5	5
5	38	4	4

Reviewer	Question	Clarity	Conciseness
5	39	4	4
5	40	5	5
5	41	4	4
5	42	5	5
5	43	5	5
5	44	4	4
5	45	5	5
5	46	5	5
5	47	5	2
5	48	5	2
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5	50	5	5
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5	58	3	3
5	59	4	4
5	60	4	4
5	61	4	4
5	62	5	5
5	63	5	5
5	64	2	2
5	65	3	3
5	66	3	4
5	67	4	4
5	68	4	3
5	69	3	3
5	70	5	5
Average		4.5	4.7